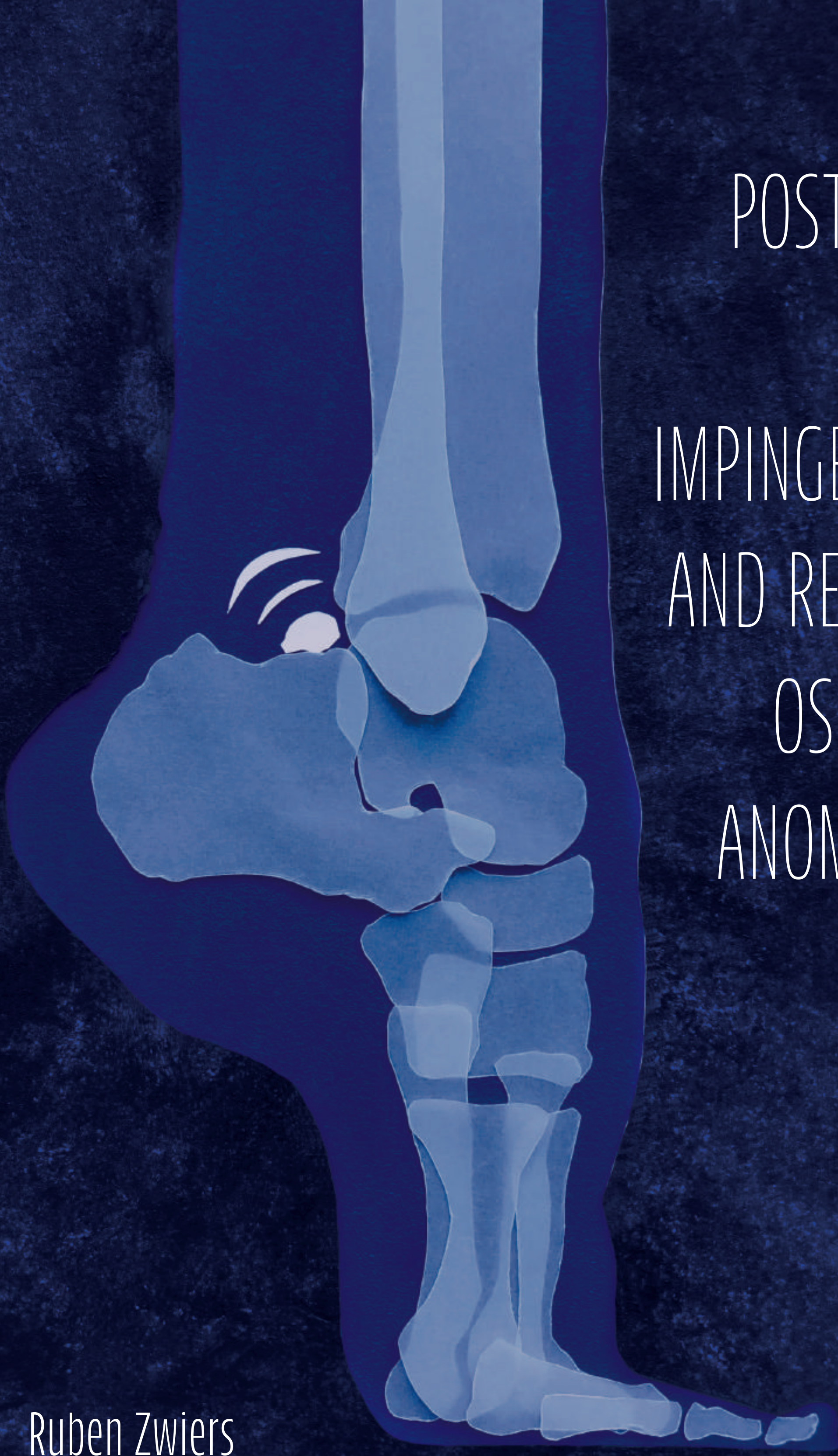
POSTERIOR ANKLE IMPINGEMENT AND RELATED OSSEOUS ANOMALIES



Ruben Zwiers

Posterior Ankle Impingement and Related Osseous Anomalies

Ruben Zwiers

Colofon
Cover design: Esther Scheide, proefschriftomslag.nl
Layout and printing: Optima Grafische Communicatie, Rotterdam, The Netherlands
ISBN: 978-94-6361-571-6

The publication of this thesis was kindly supported by:
Amsterdam UMC, department of Orthopaedic Surgery
Anna Fonds
Nederlandse Orthopaedische Vereniging
Nederlandse Vereniging voor Arthroscopie
Implantcast
Bauerfeind
Push braces
Podobrace
Chipsoft
Leuk Orthopedie

POSTERIOR ANKLE IMPINGEMENT AND RELATED OSSEOUS ANOMALIES

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. ir. K.I.J. Maex
ten overstaan van een door het College voor Promoties ingestelde commissie,
in het openbaar te verdedigen in de Agnietenkapel
op maandag 13 september 2021, te 14.00 uur

door

Ruben Zwiers
geboren te Purmerend

PROMOTIECOMMISSIE

Promotores:

Prof. dr. C.N. van Dijk	AMC - Universiteit van Amsterdam
Dr. ir. L. Blankevoort	AMC - Universiteit van Amsterdam

Overige leden:

Prof. dr. M. Maas	AMC - Universiteit van Amsterdam
Prof. dr. R.J. Oostra	AMC - Universiteit van Amsterdam
Prof. dr. C. Lucas	AMC - Universiteit van Amsterdam
Prof. dr. M.P.J. van den Bekerom	Vrije Universiteit Amsterdam
Prof. dr. S.K. Bulstra	Rijksuniversiteit Groningen

Faculteit der Geneeskunde

TABLE OF CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Ankle injuries are common, especially in people involved in sports activities.[1-4] Physical activity has evident health benefits, however, since the number of people that are involved in sports has raised over the last decades, the amount of sports-related injuries has significantly increased.[5 6] In the Netherlands in 2018, ankle injuries that needed medical treatment were the second most common sports-related injuries after shoulder injuries. [7] Two-third of the sport-related injuries has an acute onset, the most common acute ankle injury is a simple ankle sprain accounting for 6% of all sports-related Emergency Department visits.[7] The number of non-acute ankle injuries, for example overuse injuries or injuries as result of post-traumatic changes, is increasing.[5] In this thesis will be focused on posterior ankle impingement, an uncommon and less well-known condition characterized posterior ankle pain in a physical active population.

Posterior ankle impingement

Posterior ankle impingement is a condition characterized by pain in the hindfoot during plantar flexion. During plantar flexion structures posterior to the talus become entrapped between the distal tibia and calcaneus. This condition can be chronic, due to repetitive plantar flexion movements or acute, after a hyper plantarflexion trauma. The condition is therefore often seen in the active population where activities require repetitive plantar flexion, for example in athletes and dancers, predominantly soccer players and ballet dancers. [8-11]

Figure 1. Posterior ankle impingement is frequently seen in dancers and athletes with repetitive plantar flexion movements, like ballet dancers.

Anatomy of the ankle

The ankle joint complex consists of four separate joints: the talocrural joint (also named tibiotalar or ankle joint), the subtalar joint (also named talocalcaneal joint), the distal or inferior tibiofibular joint, and the transverse-tarsal joint (also named Chopart's or talonavicular and calcaneocuboid joints). The distal tibiofibular joint is part of the mortise formed by the distal tibia, including the medial malleolus, and the distal fibula, being the lateral malleolus. This is not a synovial articulating joint but a fibrous joint that has providing stability as its main role. The talocrural joint forms the articulation between the ankle mortise and the talus. The main movements in the talocrural joint are dorsal and plantar flexion. The subtalar joint is formed by the talus and calcaneus and allows inversion and eversion of the ankle. [12 13]

Figure 2. Lateral radiographic view of the ankle in neutral position and plantar flexion.

The stability of these ankle joints is ascertained by several ligaments. These ligaments could be divided in three groups: lateral collateral ligaments (anterior talofibular ligament, calcanofibular ligament and posterior talofibular ligament), medial collateral ligament (also known as deltoid ligament consisting of a bundle of ligaments) and the syndesmotic ligaments (anteroinferior tibiofibular ligament, posteroinferior tibiofibular ligament and the interosseous ligament). [14]

The talus plays a key role in all ankle movements. However, no tendons are attached to the talus. Ligaments and contact forces keep the talus in place.[15] More than 60 percent of the talar surface is covered by cartilage.[12] The talus has three components: a head, which articulates with the navicular bone, a body, the main part that articulates with the tibia and calcaneus, connected to each other by the talar neck. The talar body is cuboidally shaped and has a curved trochlear surface, with at both sides a facet for the lateral and medial malleolus. The body has a lateral and a posterior process. The posterior process has two tubercles, posteromedial and posterolateral. These two tubercles form a central groove for the flexor hallucis longus tendon. The tubercles vary in size and shape, however the lateral tubercle is generally larger.[9 12 16]

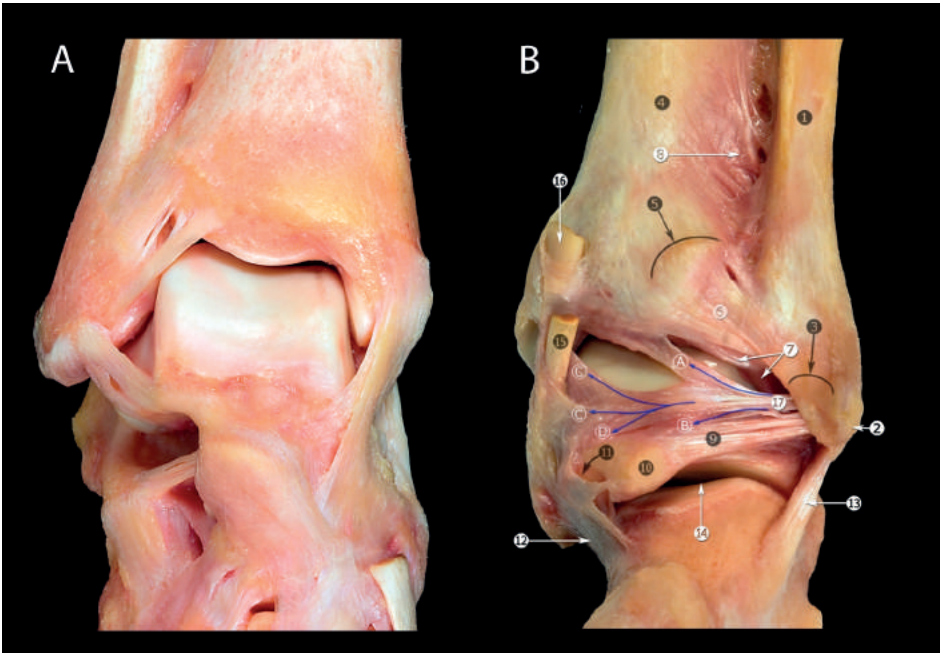


Figure 3. A. Anterior view of the ankle joint. B. Posterior view of the anatomic dissection of the ankle ligaments showing the posterior intermalleolar ligament with its relation to the surrounding anatomy. 1 fibula; 2 tip of the fibula; 3 peroneal groove of the fibula; 4 tibia; 5 posterior tubercle of the tibia; 6 superficial component of the posterior tibiofibular ligament; 7 deep component of the posterior tibiofibular ligament or transverse ligament; 8 interosseous membrane; 9 posterior talofibular ligament; 10 lateral talar process; 11 tunnel for flexor hallucis longus tendon; 12 flexor hallucis longus retinaculum; 13 calcaneofibular ligament; 14 subtalar joint; 15 flexor digitorum longus tendon (cut); 16 tibialis posterior tendon (cut); 17 posterior intermalleolar ligament: A Tibial insertion (tibial slip in arthroscopic view). B Talar insertion (lateral talar process). C Tibial malleolar insertion through the septum between the flexor digitorum longus and posterior tibial tendons. D Talar insertion (medial talar process) through the joint capsule. Reproduced with permission from: Anatomy of the ankle ligaments: a pictorial essay. Pau Golano et al. Knee Surg Sports Traumatol Arthrosc (2010) 18:557–569.

The medial tubercle forms the insertion place for the talocalcaneal ligament and the superficial and deep posterior tibiotalar ligaments (part of the deltoid ligament or medial collateral ligament). The posterior talofibular, posterior talocalcaneal and fibulotalocalcaneal ligaments insert on the lateral tubercle. [14,17,18] The retinaculum of the flexor halluces longus tendon runs from the medial to lateral tubercle.[14,18] The lateral tubercle is thought to be developed by a secondary ossification center. When during ossification this part is not fused with the rest of the posterior talar process, this accessory osseous structure is named an os trigonum.

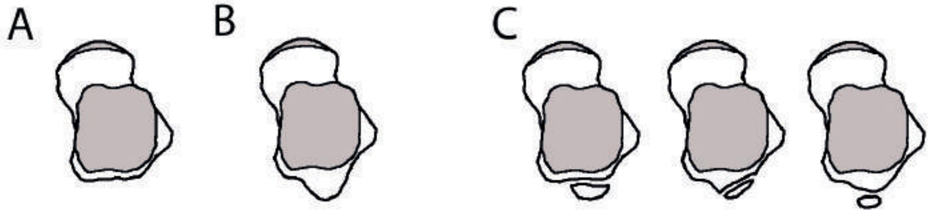


Figure 4. Schematic axial view of the talus. A. Small lateral tubercle of the posterior talar process. B. Hypertrophic lateral tubercle of the posterior talar process (Stieda's process). C Os trigonum.

Anatomical structures associated with posterior ankle impingement

Several anatomical structures are associated with posterior ankle impingement. Broadly they can be divided in osseous and soft tissue. [8 9 19 20] The most common osseous causes reported are located at the posterolateral tubercle, with the os trigonum as most frequently mentioned, followed by the enlarged posterolateral tubercle (or Stieda's process) and posterolateral tubercle fracture (Shepherds fracture).[21] Other bony causes could be posterior downsloping of the tibia, a prominence of the calcaneus, osteophytes or a loose body. Regarding soft tissue structures, the posterior ankle capsule of the ankle joint, synovitis and scar tissue are described to be involved. In addition, the posterior intermalleolar ligament is thought to play a role. [21 22]

Since the flexor hallucis longus tendon runs between the posterior tubercles, a bony prominence like an enlarged lateral tubercle or an os trigonum, is likely to interfere with the tendon. In addition, hypertrophy or a low-riding muscle belly can cause tenosynovitis when the musculotendinous junction is repetitively pulled into the narrow tunnel.[23] FHL tendon pathology is therefore highly associated with posterior impingement. [24-26] When the cause of pain is located at the posteromedial tubercle, like a fracture (the Cedell fracture), the pain is experienced more posteromedially. [19 27]

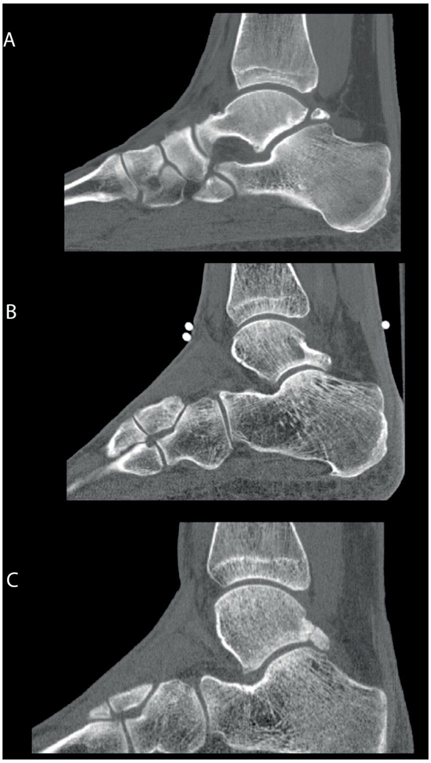


Figure 5. Sagittal CT images of the ankle. A. Os trigonum. B. Hypertrophic lateral tubercle of the posterior talar process (Stieda's process). C. Fracture of the lateral tubercle of the posterior talar process (Shepherd's fracture).

The os trigonum

Rosenmuller was in 1804 the first to identify a small ossicle located posterior to the posterolateral talar tubercle.[28] The term os intermedium tarsi was initially used for this ossicle. Gruber in 1864 named it the talus secundarius.[29] The German anatomist Karl von Bardeleben was the first who used the term os trigonum in 1885.[30]

There was a lot of discussion on the formation of the os trigonum. Von Bardeleben believed the os trigonum was a separate part that had to fuse with the rest of the talus. Shepherd thought the os trigonum was the result of an avulsion of one of the posterolateral ligaments, since he found the ligament attached to the ossicle during dissections.[31] Although he later had to correct himself, following Bennet[32], he stated it was a separate ossicle instead of a nonunited fracture.[33-35] Gruber, Stieda and Turner agreed that the os trigonum was a part of the talus that during development had to fuse with the rest of the talar bone.[16 29 36] Bennett mentioned after he found a patient with a complete separated ossicle and one that was partly separated that the os trigonum has not failed to fuse but was actually slowly separating from de talus.[32] However, currently the secondary ossification center is assumed to be the main reason for the presence of an os trigonum.[9 37] First reports of a symptomatic fractured os trigonum was published by Meisenbach[38], followed by a few others. [39-41] McDougall was in 1955 the first who described a relation between the os trigonum and posterior ankle pain as a result of impingement.[9]

Prevalence of the os trigonum

How often an os trigonum occurs is uncertain. There is a large variation in the reported estimated prevalence of the os trigonum. Burman and Lapidus found an os trigonum in half of the ankles [42], where Mann and Owsley reported a prevalence of only 1.7% [43]. In the largest radiological study on accessory bones around the ankle Tsuruta et al. detected an os trigonum in 12.7% of the 3460 studied ankles.[44] However, a wide variety of prevalence have been described until now. [45-49] Probably patient selection, the detection tool used and also definition play a role in the large variation.

Related Pathology

There are several other pathologies that could cause pain in the posterior ankle region. By thorough physical examination disorders of the Achilles' tendon insertion, like insertional tendinopathy or retrocalcaneal bursitis, should be excluded. Posterior ankle pain can also be caused by an intraarticular problem, like a posteriorly located osteochondral defect. [50-54] As stated before, flexor hallucis longus tendinopathy is strongly associated with posterior ankle impingement because of its close anatomical location to the talus.[24 25]

In addition, there are also less common osseous pathologies associated with bony impingement, like the talus bipartitus, the posteromedial tubercle fracture and the talus secundarius, which should be recognized as cause of posterior ankle pain.

Talus Bipartitus

Talus bipartitus, also referred to as 'talus bipartita', 'talus partitus' or 'frontal split of the talus', is a rare bony anomaly of the talus.[55 56] It is defined as two non-fused talar fragments, with the posterior fragment located at the level of the posterior talar process. Strehle in his dissertation on talar anomalies described the first case in 1928 [57]. The prevalence of the talus bipartitus is unknown, and only a few case reports and small case series were published. Little is known about its etiology, clinical manifestations, treatment and outcome.[58-62]

Posteromedial tubercle fracture or Cedell Fracture

The Cedell fracture is a fracture of the posteromedial tubercle of the posterior talar process. In 1974 Cedell described four cases of this type of fracture after a dorsiflexion-pronation trauma.[27] However, there is not much literature on the etiology and treatment. Probably these fractures are often missed and diagnosed as simple sprain, leading to prolonged pain complaints. Ebraheim and colleagues described an altered radiographic projection to better visualize the posteromedial aspect of the talus that showed to be beneficial in the diagnosis of these type of fractures. [63 64] Only case reports and small case series have been published on posteromedial tubercle fractures. [65-68]

Talus Secundarius

The talus secundarius is one of the rarest accessory ossicles of the foot and ankle. [44] It is located at the lateral process of the talus, and may cause lateral ankle pain. Only a few cases are hitherto described. [69-72] The talus secundarius should not be confused with the os trigonum, since the ossicle posterior to the posterior talar process was called talus secundarius before. [29 73]

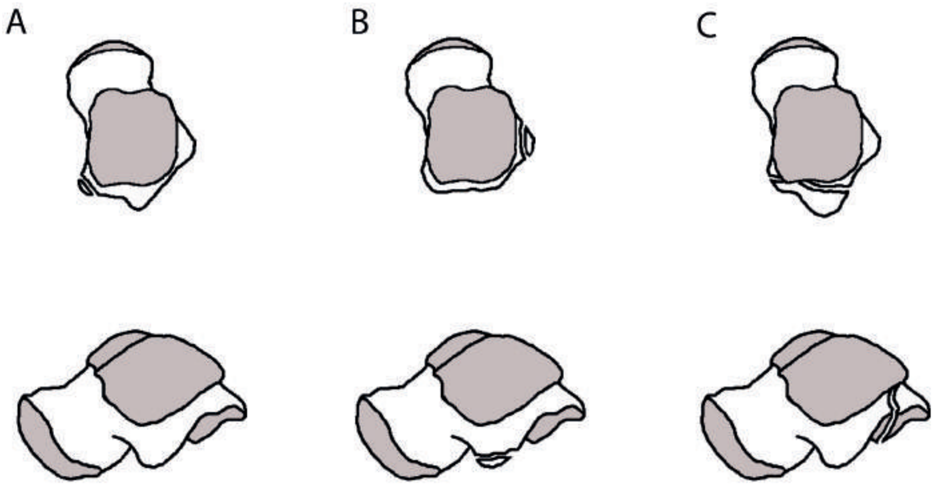


Figure 6. Schematic image of osseous anomalies of the talus. A. Fracture of the posteromedial tubercle (Cedell fracture) B. Talus secundarius. C. Talus bipartitus.

Hypothesis on the development of the talus and accessory bones

In his work in 1972 Cihák summarized the studies on the ontogenesis of the tarsal bones.[74] Gegenbaur was the first to introduce a theory of basic elements in each extremity as precursors for definitive tarsalia.[75] Since then there were many adaptions of the theory of development of the tarsal bones.[76-79] The 'canonical' elements are the tibiale, fibulare, intermedium and the centralia I -IV.[75] According to all embryological studies in mammals there seems consensus that the talus is developed out of the fusion of the tibiale (the corpus tali), the intermedium (posterior process) and the centrale I (at the location of the future lateral process). [80 81] During further development the centrale I is reduced and is replaced by an expansion and chondrification of the main talar body. [74]

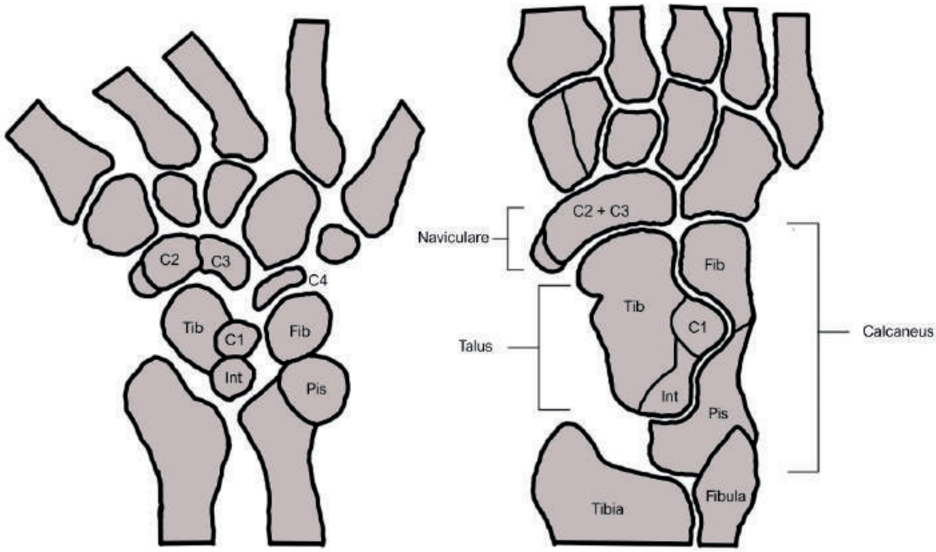


Figure 7. Schematic image of the 'canonical' elements during the embryological development of the tarsal bones, according to Cihák[74].

Cihák concluded that accessory bones are the result of remnants of elements that develop during the ontogenesis of the talus. The os trigonum and talus bipartitus are probably the result of failure of fusion during ossification of the talus. Furthermore, it is hypothesized that accessory bones near the lateral tubercle of the talus are the results of rudiments of the centralia. The talus secundarius could be the result of the remnants of centrale III that is not incorporated in the navicular bone. [74]

The development of the tarsal bones follows the process of chondrification and ossification in a definite sequence. All 'canonical' elements start as mesodermal condensations, and are visible at the 5th week. Generally, these elements have started chondrification in the 7th week. From that moment first ossification begins with the distal phalanx. The ossification of the talus starts in the third trimester. [82]

The secondary ossification center at the posterolateral aspect of the talus appears around 8 years in girls and 11 years in boys. Fusion occurs at mean age of 10 years in girls and 13 years in boys.[82-84]

Incidence of posterior ankle impingement

Posterior ankle impingement is uncommon in the non-athlete population. However there is a paucity of data on the incidence of posterior impingement. McBryde found in runners 18% of all impingement-type ankle injuries to be posterior ankle impingement.[85] Ribbans et al reported posterior ankle impingement to be the most common cause of missing a training or match due to foot and ankle problems in cricket players.[86] Albisetti et al. found in a group of 186 ballet dancers followed for a one year period an incidence of 6.5%. [87]

In contrast, in an 11 year follow-up study of 27 elite football teams by Walden et al., only 25 cases of posterior ankle impingement were reported accounting for 2.5% of all ankle injuries. This means an incidence of 0.024 injuries per 1000 player hours. In 16 of the 25 cases the dominant leg was involved. [88]

Patient presentation and physical examination

Patients present with posteriorly localized pain, typically during plantar flexion. There is pain on palpation of the posterolateral side of the talus. Diagnosis is made by the hyper plantarflexion test, which is pathognomonic. The examiner brings the ankle from neutral position into maximal plantar flexion, with a quick movement. The test is positive when the patients encounters a recognizable pain at the posterior side of the ankle. By bringing the foot in exorotation and eversion the examiner can cause more pressure on the posterolateral aspect of the talus to provoke the pain. [8]

When the test is not clear an infiltration with a local anesthetic can be performed. If the plantar flexion test is negative after infiltration the diagnosis is made.

To test the involvement of the FHL tendon, the ankle can be placed in dorsiflexion with flexion of the hallux. When the patient experience recognizable pain the FHL tendon is involved.

Diagnostic imaging

Standard diagnostic work-up consists of conventional radiographs with additional computer tomography (CT) or magnetic resonance imaging (MRI).[89] Historically, a standard lateral radiograph is the primary diagnostic tool in patients with posterior ankle complaints. However, due to overprojection of the posterior aspect of the talus, the posterior process is difficult to assess and an os trigonum is easily not distinguished.[90-93] Therefore a lateral view with the foot in 25 degrees of exorotation was developed, the posterior impingement view (PIM-view). In a prospective study this view appeared to be superior to the standard lateral view in detecting an os trigonum.[94] Although additional three-dimensional imaging modalities have their advantages, with better assessment of the osseous structures (CT scan) and soft tissue or visualization of bone marrow patterns (MRI). They also have their counter sides in terms of higher costs and longer duration.[64 94 95] These disadvantages have decreased over the last years and the availability of advanced imaging modalities has increased. The role of these diagnostic tools will increase, however conventional modalities will still have a place in the diagnostic work up of patients with posterior ankle impingement.

Treatment

Initial treatment of posterior ankle impingement is nonsurgical, and generally consist of rest or activity adjustment, technique modification, orthotics or shoe modification, physical therapy, NSAIDs or corticosteroid injections. Although always recommended, the use of nonsurgical treatment is not supported by evidence. The literature on nonsurgical treatment is scarce, only a few reports of the use of corticosteroid injections were published. [87 96]

The first report on surgical treatment of a patient with posterior ankle impingement was from Howse in 1982. He described a case of a classic ballet dancer with a posterior ankle block resulting in limited plantain flexion. He used a medial approach to remove the obstructing bone.[97] Quirk described an alternative lateral approach.[98] After these first publications several followed on open surgical removal of impediments, using either a lateral or medial approach. [10 26 87 99-105]

Burman was in 1931 the first to attempt arthroscopy of the ankle joint in a cadaveric model.[106] Since then, due to development of more appropriate instrumentation, the ankle joint and its surrounding extra-articular tissue became more accessible. In 1972 Watanabe reported the first clinical series of anterior ankle arthroscopies.[107] Thereafter, the indications for ankle arthroscopy extended to the posterior ankle and hindfoot. Marumoto and Ferkel described and advocated in 1997 [108] the use of a posterolateral portal, as described by Parisien and Vangsness[109], in conjunction with standard anterior arthroscopy. They presented a series of eleven patients in which a symptomatic os trigonum was removed.[108]

In 2000, Van Dijk et al. introduced a 2-portal hindfoot endoscopy technique that provided access to the hindfoot, including the posterior ankle and subtalar joints. [110] With this technique both intra- and extra-articular structures of the hindfoot, including the os trigonum and flexor hallucis longus (FHL) tendon can be addressed. [110-113]

Although good results for open surgery were described [99 100], endoscopic techniques generally have the advantages of minimal pain postoperatively, lower infection rates and a shorter rehabilitation period. [113-115] There is however no data on long term outcome and recurrence rate. Based on the available literature no conclusions can be made on whether open or endoscopic surgery for posterior ankle impingement is superior.

AIM AND THESIS OUTLINE

Following from the above, there are several unanswered questions. One of these is that the prevalence of the os trigonum is uncertain. Large differences in prevalence are described, varying from 1.7 to 12.7%. The presence of an os trigonum usually is an asymptomatic condition, however, historically strongly associated with posterior ankle impingement. A traumatic event and repetitive plantar flexion are thought to be main cause of symptoms, but it is unknown whether anatomical characteristics of the os trigonum like size and shape play a role.

Regarding diagnostic imaging, it is known that the standard lateral view has limited diagnostic value. The role of advanced diagnostics like CT and MRI is increasing, since they have clear additional diagnostic value and the availability increases. However there is still room for conventional imaging. As an alternative to the lateral radiograph, the PIM-view was developed to improve the diagnostic value and showed better diagnostic properties. The projection angle of 25 degrees was pragmatically chosen and it is unclear whether this is the most optimal view for detecting bony impediments.

There are several case series on surgical treatment of posterior impingement. Generally, good clinical outcomes are reported for endoscopic treatment, however literature on the long term outcome of surgical treatment and the recurrence rate is lacking. Also, there is still debate on surgical technique. Based on the available literature no firm conclusions can be made on which type of surgical treatment is superior.

Little is known about related osseous pathologies like talus bipartitus, Cedell fracture and talus secundarius. Literature is scarce and consist only of case reports and small case series.

Hence, the following research questions were postulated:

What is the prevalence of the os trigonum in an asymptomatic population?
What are the anatomical differences between symptomatic and non-symptomatic ossa trigona?
What are the optimal radiographic views to detect an os trigonum or hypertrophic posterior talar process in patients with posterior ankle pain?
What are the long-term outcomes after endoscopic treatment?
What is the recurrence-rate after endoscopic treatment?
Which factors are associated with long-term outcome?

Is endoscopic surgery for posterior ankle impingement superior to open surgery in terms of functional outcome, return to full activity, patient satisfaction and complication rate?
What is known about related osseous pathologies, like the talus bipartitus, talus secundarius and the posteromedial tubercle (Cedell) fracture? Could an endoscopic technique be used as an alternative for open surgery?

This thesis aims to answer the aforementioned research questions to provide more insight in the epidemiologic and geometric characteristics of the os trigonum, the role of conventional radiographs, and surgical treatment of posterior ankle impingement and the long term outcomes. In addition, related osseous pathologies will be addressed, as well as new insights on their treatment.

Part I - The os trigonum

In this section is focused on the prevalence and the anatomical characteristics of the os trigonum. In chapter 2 the prevalence of the os trigonum in an asymptomatic population will be determined by analyzing CT scans of the ankle. In chapter 3 the differences between symptomatic and asymptomatic ossa trigona will be studied. Aim is to identify geometric characteristics associated with symptoms to provide more insight in which ossa trigona are more likely to become symptomatic. In this study CT-based 3D models of symptomatic and asymptomatic ankles will be compared.

Part II - Conventional imaging

In chapter 4 different projection angles will systematically be compared using digitally reconstructed radiographs (DRR) and assessed by a large group of observers to identify the optimal radiographic view for detecting osseous impediments.

Part III - Surgical treatment

In this part the focus is on outcome of surgical treatment of posterior ankle impingement. In chapter 5 the long term outcome of patients that underwent endoscopic treatment are studied. In a retrospective case series the patient satisfaction and recurrence rate will be determined. In addition, factors associated with outcome will be identified. In chapter 6 the available literature on surgical treatment are systematically reviewed. A meta-analysis is performed to compare the open approaches with endoscopic techniques, in terms of functional outcome, patient satisfaction, return to activity and complication rates.

Part IV – Related and osseous hindfoot pathologies

In this section three rare diagnosis are discussed that are related to osseous posterior ankle impingement. First, the literature will be reviewed for cases of talus bipartitus. Three cases treated by an endoscopic technique are described. Second, a systematic review is performed about cases of a fracture of the posteromedial tubercle of the talus, often referred to as the Cedell fracture. Results of a series of patients treated endoscopically in our institution will be described. Lastly, a case of a symptomatic os talus secundarius is reported.

LITERATURE

1. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. Journal of athletic training 2007;42(2):311.
2. Orchard J, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997–2000. British journal of sports medicine 2002;36(1):39-44.
3. Roos KG, Wasserman EB, Dalton SL, et al. Epidemiology of 3825 injuries sustained in six seasons of National Collegiate Athletic Association men's and women's soccer (2009/2010–2014/2015). British journal of sports medicine 2017;51(13):1029-34.
4. Rejeb A, Johnson A, Horobeanu C, et al. EPIDEMIOLOGY OF SPORTS INJURIES AMONG HIGHLY TRAINED YOUTH MULTISPORT ATHLETES. British Journal of Sports Medicine 2017;51(4):377-78.
5. Paavola M, Kannus P, Järvinen M. Epidemiology of tendon problems in sport. Tendon Injuries: Springer 2005:32-39.
6. Occurrence and epidemiology of sports injuries in Finland. Annales chirurgiae et gynaecologiae; 1991.
7. VeiligheidNL. Sportblessures in Nederland. 2018
8. van Dijk CN. Anterior and posterior ankle impingement. Foot Ankle Clin 2006;11(3):663-83.
9. McDougall A. The os trigonum. J Bone Joint Surg Br 1955;37-b(2):257-65. [published Online First: 1955/05/01]
10. Brodsky AE, Khalil MA. Talar compression syndrome. Am J Sports Med 1986;14(6):472-76.
11. Hedrick MR, McBryde AM. Posterior ankle impingement. Foot & ankle international 1994;15(1):2-8.
12. Kelikian AS, Sarrafian SK. Sarrafian's anatomy of the foot and ankle: descriptive, topographic, functional: Lippincott Williams & Wilkins 2011.
13. Brockett CL, Chapman GJ. Biomechanics of the ankle. Orthopaedics and trauma 2016;30(3):232-38.
14. Golano P, Vega J, de Leeuw PA, et al. Anatomy of the ankle ligaments: a pictorial essay. Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA 2016;24(4):944-56. doi: 10.1007/s00167-016-4059-4 [published Online First: 2016/04/08]
15. Leardini A, O'Connor JJ, Giannini S. Biomechanics of the natural, arthritic, and replaced human ankle joint. Journal of foot and ankle research 2014;7(1):8.
16. Stieda CHL. Ueber secundare fusswurzelknochen. Arch Physiol Wissensch Med 1869:108-11.
17. Golano P, Vega J, Perez-Carro L, et al. Ankle anatomy for the arthroscopist. Part I: The portals. Foot Ankle Clin 2006;11(2):253-73, v. doi: S1083-7515(06)00024-6 [pii];10.1016/j.fcl.2006.03.005 [doi]
18. Golano P, Vega J, Perez-Carro L, et al. Ankle anatomy for the arthroscopist. Part II: Role of the ankle ligaments in soft tissue impingement. Foot Ankle Clin 2006;11(2):275-2vi. doi: S1083-7515(06)00022-2 [pii];10.1016/j.fcl.2006.03.003 [doi]
19. Liu SH, Mirzayan R. Posteromedial ankle impingement. Arthroscopy: The Journal of Arthroscopic & Related Surgery 1993;9(6):709-11.
20. Guhl JF SJ. Soft-tissue pathology. In: JF G, ed. Foot and ankle arthroscopy, 2nd edn. New Jersey: Slack Incorporated 1993.

21. Ribbans WJ, Ribbans HA, Cruickshank JA, et al. The management of posterior ankle impingement syndrome in sport: a review. Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons 2015;21(1):1-10. doi: 10.1016/j.fas.2014.08.006 [published Online First: 2015/02/16]
22. Pereira H, Batista J, Sousa D, et al. Posterior Impingement and Os Trigonum. Sports Injuries of the Foot and Ankle: Springer 2019:191-206.
23. van Dijk CN. Flexor Hallucis Longus Release. Ankle Arthroscopy: Springer 2014:265-73.
24. Hamilton WG. Stenosing tenosynovitis of the flexor hallucis longus tendon and posterior impingement upon the os trigonum in ballet dancers. Foot Ankle 1982;3(2):74-80.
25. Hamilton WG. Tendonitis about the ankle joint in classical ballet dancers. Am J Sports Med 1977;5(2):84-88.
26. Hamilton WG, Geppert MJ, Thompson FM. Pain in the posterior aspect of the ankle in dancers. Differential diagnosis and operative treatment. J Bone Joint Surg Am 1996;78(10):1491-500.
27. Cedell CA. Rupture of the posterior talotibial ligament with the avulsion of a bone fragment from the talus. Acta Orthop Scand 1974;45(3):454-61. [published Online First: 1974/01/01]
28. Rosenmuller J. De mon nullis musculorum corpus humani varietatibus. Leipzig 1804;8
29. Gruber W. Vorläufige mittheilung über die secundären fusswurzelknochen des menschen. Archiv für Anatomie Physiologie Wissenschaftliche Medizin 1864;31:286-90.
30. Bardeleben K. Das intermedium tarsi beim menschen und saugethieren. J Anat Physiol 1885;19:509.
31. Shepherd FJ. A hitherto undescribed fracture of the astralagus. The Journal of anatomy and physiology 1882;17(April):79-81.
32. Bennett E. Ossicle occasionally found on the posterior border of the astragalus. J Anat Physiol 1886;21(Pt 1):59.
33. Thompson IM. FJ Shepherd as anatomist. Canadian Medical Association Journal 1938;39(3):287.
34. Visotsky JL, Benson LS. Eponyms in orthopaedics. The Journal of bone and joint surgery American volume 2001;83-A Suppl 2 Pt 2:123-27.
35. Wiegerinck JI, Somford MP, Hoornenborg D, et al. Eponyms of the Kager triangle. JBJS 2012;94(10):e67.
36. Turner W. A secondary astragalus in the human foot. Journal of anatomy and physiology 1882;17(Pt 1):82.
37. Grogan DP, Walling AK, Ogden JA. Anatomy of the os trigonum. J Pediatr Orthop 1990;10(5):618-22.
38. Meisenbach R. Fracture of os trigonum: report of two cases. Journal of the American Medical Association 1927;89(3):199-200.
39. Milch H. Fracture of Processus Posticus Tali. Med Rec Ann 1941;154:90-92.
40. Hauser EDW. Diseases of the foot. WB Saunders, Philadelphia 1939:172-75.
41. DuVries H. Surgery of the foot, ed. 2, St. Louis: C V Mosby Co 1965:517-18.
42. Burman M, Lapidus PW. The functional disturbances caused by the inconstant bones and sesamoids of the foot. Archives of Surgery 1931;22(6):936-75.
43. Mann RW, Owsley DW. Os trigonum. Variation of a common accessory ossicle of the talus. J Am Podiatr Med Assoc 1990;80(10):536-39.

44. Tsuruta T, Shiokawa Y, Kato A, et al. [Radiological study of the accessory skeletal elements in the foot and ankle (author's transl)]. Nihon Seikeigeka Gakkai zasshi 1981;55(4):357-70. [published Online First: 1981/04/01]
45. Thompson A. Report of the committee of collective investigation of the Anatomical Society of Great Britain and Ireland for the year 1889-1890. J Anat 1891;25:89-101.
46. Pfitzner W. Beiträge zur Kenntniss der Missbildungen des menschlichen Extremitätenskelets. In: Schwalbe, ed. Morph Arb. Jena1896:245 - 528.
47. Sewell RS. A study of the astragalus. J Anat Physiol. 1904;38(pt 3):233.
48. Cilli F, Akçaoğlu M. [The incidence of accessory bones of the foot and their clinical significance]. Acta orthopaedica et traumatologica turcica 2004;39(3):243-46.
49. Coskun N, Yuksel M, Cevener M, et al. Incidence of accessory ossicles and sesamoid bones in the feet: a radiographic study of the Turkish subjects. Surg Radiol Anat 2009;31(1):19-24. doi: 10.1007/s00276-008-0383-9 [doi]
50. Singh R, Rohilla R, Siwach RC, et al. Diagnostic significance of radiologic measurements in posterior heel pain. Foot (Edinb) 2008;18(2):91-98. doi: S0958-2592(08)00007-2 [pii];10.1016/j.foot.2008.01.005 [doi]
51. Theobald P, Bydder G, Dent C, et al. The functional anatomy of Kager's fat pad in relation to retrocalcaneal problems and other hindfoot disorders. J Anat 2006;208(1):91-97. doi: JOA510 [pii];10.1111/j.1469-7580.2006.00510.x [doi]
52. Tsai I, Motamedi D, Chow K, et al. Overuse syndromes in the ankle and hindfoot. American Journal of Roentgenology 2012;198(5 SUPPL. 1)
53. van Dijk CN, van Sterkenburg MN, Wiegerinck JI, et al. Terminology for Achilles tendon related disorders. Knee Surg Sports Traumatol Arthrosc 2011 doi: 10.1007/s00167-010-1374-z [doi]
54. Van Wyngarden TM. The painful foot, Part II: Common rearfoot deformities. Am Fam Physician 1997;55(6):2207-12.
55. Schreiber A, Differding P, Zollinger H. Talus partitus. A case report. Journal of Bone & Joint Surgery, British Volume 1985;67(3):430-31.
56. Blauth W, Harten K, Kirgis A. [Frontal talus cleft--talus bipartitus]. Zeitschrift fur Orthopadie und ihre Grenzgebiete 1986;125(3):302-07.
57. Strehle E. Über Abnormitäten im Bereich der Tarsalknochen und ihre klinische Bedeutung: mit besonderer Berücksichtigung eines selbst beobachteten Falles einer Talusmißbildung: Oberreuter 1928.
58. De Oliveira Junior AS, Mendes AAM, Saito GH, et al. Bipartite Talus: Arthroscopic Resection-Case Report. Techniques in Foot and Ankle Surgery 2018;17(3):e5-e8. doi: http://dx.doi.org/10.1097/BTF.0000000000000178
59. Mann HA, Myerson MS. Treatment of posterior ankle pain by excision of a bipartite talar fragment. J Bone Joint Surg Br 2010;92(7):954-7. doi: 10.1302/0301-620X.92B7.23465
60. Rose B, Southgate C, Louette L. Bipartite talus: a case series and algorithm for treatment. Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons 2013;19(2):96-102. doi: 10.1016/j.fas.2012.11.011 [published Online First: 2013/04/04]
61. Thiel E, Feibel J, Chorey N, et al. Bipartite talus: a case report. Foot & ankle international 2010;31(6):552-55.
62. Weinstein SL, Bonfiglio M. Unusual accessory (bipartite) talus simulating fracture. A case report. J Bone Joint Surg Am 1975;57(8):1161-63.

63. Ebraheim NA, Karkare N, Gehling DJ, et al. Use of a 30-degree external rotation view for posteromedial tubercle fractures of the talus. Journal of orthopaedic trauma 2007;21(8):579-82. doi: 10.1097/BOT.0b013e31804ea0d9 [published Online First: 2007/09/07]
64. Ebraheim NA, Patil V, Frisch NC, et al. Diagnosis of medial tubercle fractures of the talar posterior process using oblique views. Injury 2007;38(11):1313-17. doi: http://dx.doi.org/10.1016/j.injury.2007.04.025
65. Banks AS, Caldarella D. Fractures of the posteromedial process of the talus. J Am Podiatr Med Assoc 1994;84(2):66-70. doi: 10.7547/87507315-84-2-66 [published Online First: 1994/02/01]
66. Cohen AP, Conroy JL, Giannoudis PV, et al. Impingement fracture of the postero-medial process of the talus--a case report. Acta Orthop Scand 2000;71(6):642-4. doi: 10.1080/000164700317362325 [published Online First: 2001/01/06]
67. Ebraheim NA, Padanilam TG, Wong FY. Posteromedial process fractures of the talus. Foot and Ankle International 1995;16(11):734-39.
68. Kim DH, Berkowitz MJ, Pressman DN. Avulsion fractures of the medial tubercle of the posterior process of the talus. Foot and Ankle International 2003;24(2):172-75.
69. Hahn J. Surgical excision of an os talus secundarius: a case report. The Journal of foot surgery 1977;17(3):129-31.
70. Oliveira F, Serrano P, Faísca J, et al. Symptomatic os talus secundarius: a case report. European Orthopaedics and Traumatology 2012;3(4):261-62.
71. Schluter A. [Two cases of talus secundarius in adolescents.]. Archiv fur orthopadische und Unfall-Chirurgie 1952;45(6):624-28.
72. Viana S, Fernandes J, Mendonca J, et al. Painful os talus secundarius: A case report and imaging findings. Foot & ankle international 2007;28(5):624-25.
73. Ecker ML, Ritter MA, Jacobs BS. The symptomatic os trigonum. JAMA (Chicago, Ill) 1967;201(11):1157-60.
74. Čihák R. Ontogenesis and Homologies of Human Carpal and Tarsal Components. Onto-genesis of the Skeleton and Intrinsic Muscles of the Human Hand and Foot: Springer 1972:12-59.
75. Gegenbaur C. Untersuchung zur vergleichenden Anatomie der Wirbeltiere. I. Carpus und Tarsus Leipzig, Germany: Engelmann 1864
76. Baur G. Zur Morphologie des Tarsus der Säugethiere. 1885.
77. Bardeleben K. Das Os intermedium tarsi der Saugethiere. Zool Anz 1883;6:278-80.
78. Leboucq HLF. Sur la morphologie de carpe et du tarse1886.
79. Stieda J. Talus und das os trigonum bardelebens beim Menschen. Anat anz 1889;4:305-15.
80. Holmgren N. An embryological analysis of the mammalian carpus and its bearing upon the question of the origin of the tetrapod limb. Acta Zoologica 1952;33(1-2):1-115.
81. Steiner H. Der Aufbau des Säugetier-Carpus und-Tarsus nach neueren embryologischen Untersuchungen. Rev Suisse Zool 1942;49(13):217-23.
82. O'Rahilly R, Gardner E, Gray DJ. The Skeletal Development of the Foot. Clinical Ortho-paedics and Related Research® 1960;16:7-14.
83. Hoerr NL, Pyle SI, Francis CC. Radiographic Atlas of Skeletal Development of the Foot and Ankle; A Standard of Reference. Springfield, Illinois: Charles C Thomas 1962.
84. Francis CC. The appearance of centers of ossification from 6 to 15 years. American journal of physical anthropology 1940;27(1):127-38. doi: 10.1002/ajpa.1330270132

85. McBryde AM. Disorders of the ankle and foot. In: Brana WA, and Kalenak, A. (eds.), ed. Clinical Sports Medicine. Philadelphia: W.B. Saunders 1991:466-89.
86. Ribbans WJ, Natarajan R, Alavala S. Pediatric foot fractures. Clin Orthop Relat Res 2005(432):107-15. doi: 00003086-200503000-00014 [pii]
87. Albisetti W, Ometti M, Pascale V, et al. Clinical evaluation and treatment of posterior impingement in dancers. American journal of physical medicine & rehabilitation 2009;88(5):349-54.
88. Walden M, Hagglund M, Ekstrand J. Time-trends and circumstances surrounding ankle injuries in men's professional football: an 11-year follow-up of the UEFA Champions League injury study. British journal of sports medicine 2013;47(12):748-53. doi: 10.1136/bjsports-2013-092223 [published Online First: 2013/07/03]
89. Hayashi D, Roemer FW, D'Hooghe P, et al. Posterior ankle impingement in athletes: Pathogenesis, imaging features and differential diagnoses. European journal of radiology 2015;84(11):2231-41. doi: http://dx.doi.org/10.1016/j.ejrad.2015.07.017
90. Keene JS, Lange RH. Diagnostic dilemmas in foot and ankle injuries. JAMA 1986;256(2):247-51.
91. Karasick D, Schweitzer ME. The os trigonum syndrome: Imaging features. American Journal of Roentgenology 1996;166(1):125-29.
92. Blake RL, Lallas PJ, Ferguson H. The os trigonum syndrome. A literature review. J Am Podiatr Med Assoc 1992;82(3):154-61.
93. Holland T. On rarer ossifications seen during X-ray examinations. Archives of Radiology and Electrotherapy 1921;26(4):105-18.
94. Wiegerinck JI, Vroemen JC, van Dongen TH, et al. The posterior impingement view: an alternative conventional projection to detect bony posterior ankle impingement. Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association 2014;30(10):1311-6. doi: 10.1016/j.arthro.2014.05.006 [published Online First: 2014/07/16]
95. Tol JL, Verhagen RA, Krips R, et al. The anterior ankle impingement syndrome: diagnostic value of oblique radiographs. Foot & ankle international 2004;25(2):63-68.
96. Robinson P, Bollen SR. Posterior ankle impingement in professional soccer players: effectiveness of sonographically guided therapy. American Journal of Roentgenology 2006;187(1):W53-W58.
97. Howse AJ. Posterior block of the ankle joint in dancers. Foot Ankle 1982;3(2):81-84.
98. Quirk R. Talar compression syndrome in dancers. Foot & ankle 1982;3(2):65-68.
99. Wredmark T, Carlstedt CA, Bauer H, et al. Os trigonum syndrome: a clinical entity in ballet dancers. Foot & ankle 1991;11(6):404-06.
100. Abramowitz Y, Wollstein R, Barzilay Y, et al. Outcome of resection of a symptomatic os trigonum. J Bone Joint Surg Am 2003;85-A(6):1051-57.
101. Jourdel F, Tourne Y, Saragaglia D. [Posterior ankle impingement syndrome: a retrospective study in 21 cases treated surgically]. Revue de chirurgie orthopedique et reparatrice de l'appareil moteur 2005;91(3):239-47. [published Online First: 2005/06/25]
102. Marotta JJ, Micheli LJ. Os trigonum impingement in dancers. Am J Sports Med 1992;20(5):533-36.
103. Rietveld A, Haitjema S. Posterior Ankle Impingement Syndrome and M. Flexor Hallucis Longus Tendinopathy in Dancers Results of Open Surgery. Journal of dance medicine & sci-

ence : official publication of the International Association for Dance Medicine & Science 2018;22(1):3-10. doi: 10.12678/1089-313x.22.1.3 [published Online First: 2018/03/08]

104. Coetzee JC, Seybold JD, Moser BR, et al. Management of Posterior Impingement in the Ankle in Athletes and Dancers. Foot & ankle international 2015;36(8):988-94. doi: 10.1177/1071100715595504 [published Online First: 2015/07/15]

105. Heyer JH, Dai AZ, Rose DJ. Excision of Os Trigonum in Dancers via an Open Posteromedial Approach. JBJS essential surgical techniques 2018;8(4):e31. doi: 10.2106/jbjs.st.18.00015 [published Online First: 2019/02/19]

106. Burman MS. Arthroscopy of direct visualization of joints. An experimental cadaver study. J Bone Joint Surg Am 1931;13:669-95.

107. Watanabe M. Selfoc-Arthroscope (Watanabe no. 24 arthroscope). Monograph. Tokyo: Teishin Hospital 1972

108. Marumoto JM, Ferkel RD. Arthroscopic excision of the os trigonum: a new technique with preliminary clinical results. Foot & ankle international 1997;18(12):777-84.

109. Parisien JS, Vangsness T. Arthroscopy of the subtalar joint: an experimental approach. Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association 1985;1(1):53-7. doi: 10.1016/s0749-8063(85)80079-7 [published Online First: 1985/01/01]

110. van Dijk CN, Scholten PE, Krips R. A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association 2000;16(8):871-76.

111. van Dijk CN. Hindfoot endoscopy. Foot Ankle Clin 2006;11(2):391-414, vii.

112. van Dijk CN. Hindfoot endoscopy for posterior ankle pain. Instr Course Lect 2006:545-54.

113. van Dijk CN, de Leeuw PA, Scholten PE. Hindfoot endoscopy for posterior ankle impingement. Surgical technique. J Bone Joint Surg Am 2009;91 Suppl 2:287-98. doi: 91/Supplement_2/287 [pii];10.2106/JBJS.I.00445 [doi]

114. Zengerink M, van Dijk CN. Complications in ankle arthroscopy. Knee Surgery, Sports Traumatology, Arthroscopy 2012;20(8):1420-31.

115. Wiegerinck JI, Kok AC, van Dijk CN. Surgical Treatment of Chronic Retrocalcaneal Bursitis: A Systematic Review. Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association 2012

CHAPTER 2

PREVALENCE OF OS TRIGONUM ON CT IMAGING

R. Zwiers
T.P.A. Baltes
K.T.M. Opdam
J.I. Wiegerinck
C.N. van Dijk

Foot Ankle Int 2018

ABSTRACT

Background

The os trigonum is known as one of the main causes of posterior ankle impingement. In the literature, a wide variation of occurrence has been reported.

Methods

All foot and/or ankle computed tomography (CT) scans made between January 2012 and December 2013 were reviewed. CT images were assessed, blinded for patient characteristics, for the presence of an os trigonum, size of the os trigonum, and type of os trigonum. In addition, the shape of the lateral tubercle of the posterior talar process was assessed.

Results

A total of 628 patients (1256 ankles) were included. In 32.5% of the patients of the cohort an os trigonum was present. In 14.3% of these patients it was present bilaterally. In a subgroup of patients without posterior ankle impingement the prevalence was 30.3%. Of the nonaffected ankles, an os trigonum was present in 23.7%. Patients with posterior ankle impingement were more likely to have an os trigonum (adjusted odds ratio [OR] 1.86). Caribbean/ Surinamese origin was associated with a lower rate of occurrence of the os trigonum (adjusted OR 0.43). In the ankles without an os trigonum, an enlarged lateral tubercle of the posterior talar process was found in 34.9% and 36.5% of the ankles.

Conclusion

This study showed that the os trigonum is a common accessory bone. With a prevalence of 30.3% in a population of patients with CT imaging of both ankles and 23.7% of the nonaffected ankles, the os trigonum is more common than previously reported. Patients with posterior ankle impingement complaints had a higher prevalence of an os trigonum. In one-third of the patients without an os trigonum, there was an enlarged lateral tubercle of the posterior talar process.

INTRODUCTION

Posterior ankle impingement is a condition characterized by posterior ankle pain in plantar flexion. It is caused by overuse, repetitive plantarflexion, or a traumatic event, often in combination with congenital anatomic anomalies.[1] These include the presence of an os trigonum, a prominent lateral tubercle of the posterior talar process (Stieda's process) or prominent posterior downward sloping of the tibia.[2]

The os trigonum is known as one of the most common causes of posterior ankle impingement. It is a separate ossicle located posterior to the lateral tubercle of the posterior process of the talus, lateral to the groove of the flexor hallucis longus. When fused to the talar body it creates an enlarged lateral tubercle of the posterior talar process. During plantar flexion, the os trigonum or enlarged lateral tubercle and surrounding soft tissue become impinged between the posterior distal surface of the tibia and the superior surface of the calcaneus.

In 1804, Rosenmuller was the first to describe a small ossicle posterior to the lateral tubercle of the posterior talar process. [3] In 1885, Bardeleben used the term os trigonum for the ossicle, previously referred to as os intermedium tarsi.[4] The relationship between posterior ankle pain and the radiological findings of an os trigonum was first described by McDougall.[5] However, since the first descriptions of the os trigonum, there has been no consensus about its prevalence.

A wide variation of occurrence (1.7% - 12.7%) has been reported.[6-15] (Table 1) It is also not clear whether an os trigonum occurs more often unilaterally or bilaterally. Furthermore, until now, no literature on the prevalence of an enlarged posterior talar process has been published.

Table 1. Overview of prevalence reported in the literature.

Study	Year	Type	N=		Prevalence (%)
Thompson[6]	1891	Dissections	438	tali	2.7
Pfitzer[7]	1896	Dissections	841	tali	6.1
Stieda[16]	1889	Dissections	305	tali	5.9
Sewell[9]	1904	Dissections	1006	tali	10.9
Burmann[10]	1931	Radiograph	1000	tali	6.4
Grant[11]	1962	Dissections	558	tali	7.7
Tsuruta[12]	1981	Radiograph	3460	tali	12.7
Mann[13]	1990	Dissections	300	tali	1.7
Cilli[14]	2005	Radiograph	464	tali	4.3
Coskun[15]	2009	Radiograph	984	patients	2.3

The aim of this study was to elucidate the prevalence of the os trigonum and hypertrophic posterior talar process. Based on our experience, we hypothesized that an os trigonum is more common than previously reported.

MATERIALS AND METHODS

Subjects

All foot and/or ankle computed tomography (CT) scans made between January 2012 and December 2013 in the Academic Medical Center in Amsterdam were reviewed. All CT scans with axial slices of both ankles were included. According to the local radiology protocol for ankle CT scans, axial slices of both ankles were obtained. Only of the affected ankle coronal and sagittal slices were reconstructed. The CT scans of patients who underwent hindfoot surgery prior to the CT scan were excluded. In addition, patients with extensive deformation of the ankle joint (i.e. as a result of rheumatoid arthritis or congenital deformations) were excluded. In cases where patients had multiple CT scans during this period, the first scan was included in this study.

Demographic data, symptoms, indication for CT scan, and affected or symptomatic side were obtained from the medical records. Ethnicity was classified according to country of birth or the country of birth of the patient's parents.[17] Regarding origin, Dutch/European, Caribbean/Surinamese/African, Moroccan/North African, Turkish, Indian/Central Asian, Southeast Asian, Middle Eastern, and South American were distinguished. In total, 628 patients (1256 ankles) were included. Of these patients, 55.9% were male. The median age was 32 years, and a large majority was of Dutch/European origin. The reason for the CT scan in 84 of the cases was suspected posterior ankle pathology. Of the 1256 ankles, 665 were symptomatic ankles. The remaining 591 ankles were nonaffected. (Table 2)

Table 2. Patient characteristics. CT, computed tomography; IQR, interquartile range.

Population characteristics		
Number of subjects	Patients	628
	Ankles	1256
Sex	Male	55. 9% (n= 351)
	Female	44. 1% (n= 277)
Ethnicity/origin	Dutch/European	84. 4% (n= 530)
	Caribbean/ Surinam/ African	9. 2% (n= 58)
	North African/ Moroccan	2. 1% (n=13)
	Indian/Hindu	1. 3% (n= 8)

Table 2. Patient characteristics. CT, computed tomography; IQR, interquartile range. (continued)

Population characteristics		
	Turkish	1. 1% (n= 7)
	Southeast Asian	0. 6% (n= 4)
	South American	0. 5% (n= 3)
	Middle East	0. 8% (n= 5)
Age		Median 32.0 (IQR 22-48)
	<20	22. 1% (n= 139)
	21- 30	24. 2% (n= 152)
	31- 40	15. 6% (n= 98)
	41- 50	16. 4% (n= 103)
	51- 60	12. 4% (n= 78)
	>60	9. 2% (n= 58)
Department	Orthopedic Surgery	68. 3% (n= 429)
	Traumatology	15. 4% (n= 97)
	Emergency Unit	6. 7% (n= 42)
	Pediatric Department	4. 3% (n= 27)
	General Surgery	2. 1% (n= 13)
	Miscellaneous	3. 2% (n= 20)
Reason for CT scan	Trauma/fracture	27. 0% (n= 169)
	Foot/midfoot/bone deformity	22. 8% (n=143)
	Osteochondral defect	16. 3% (n=102)
	Osteoarthritis	10. 2% (n=64)
	Miscellaneous	23. 6% (n=148)
Affected ankle	Right	49. 5% (n=311)
	Left	44. 6% (n=280)
	Both	5. 9% (n=37)
Posterior ankle impingement complaints	With complaints	13. 4% (n= 84)
	Without complaints	86. 6% (n= 544)

CT images were assessed, blinded for patient characteristics, for the presence of an os trigonum, size of the os trigonum, and type of os trigonum. In addition, the shape of the lateral tubercle of the posterior talar process was assessed. Presence of an os trigonum was defined as a nonunited ossicle located posterior to the lateral tubercle of the posterior talar process. Regarding the size of the os trigonum, three groups were distinguished based on largest size measured in the axial plane: smaller than 0.5 cm, between 0.5 and 1 cm, and larger than 1 cm. Three types of os trigonum were distinguished: (A) os trigonum with intact lateral tubercle, (B) os trigonum as part of the lateral tubercle, and (C) os trigonum without lateral tubercle. (Figure 1) Size of shape of the lateral tubercle was assessed according to the classification by Sarrafian and Kelikian.[18] We defined type III and IV as an enlarged lateral talar process. (Figure 2)

All images were assessed independently by two observers. In case of disagreement, a third observer was consulted. For assessment of the lateral tubercle and type of os trigonum, the interobserver reliability was assessed.

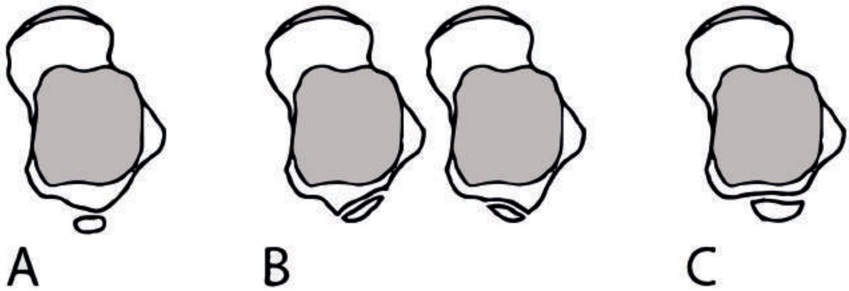


Figure 1. Different types of os trigonum. A. Os trigonum with intact lateral tubercle. B. Os trigonum as part of the lateral tubercle. C. Os trigonum without lateral tubercle.

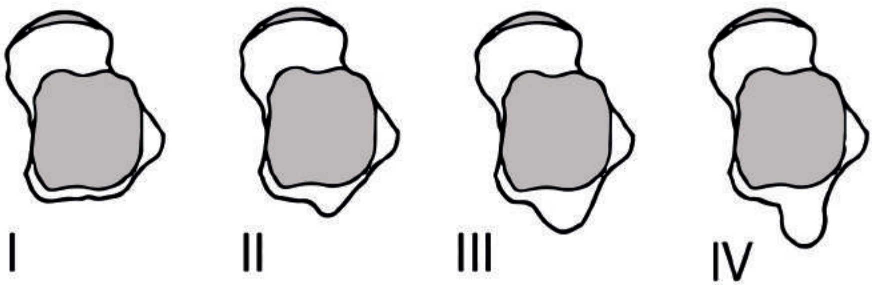


Figure 2. Different shapes of the lateral tubercle of the posterior talar process. Four types were distinguished according to the classification by Saraffian and Kelikian.[18]

Statistical Analysis

Descriptive data were presented as frequencies (percentages) for categorical data and as mean (standard deviation) or median (interquartile range) for continuous variables, depending on the distribution. Interobserver reliability was assessed using Cohen's unweighted κ for dichotomous and nominal data and Cohen's weighted κ for ordinal data. To describe the association between sex, age, and ethnicity and the presence of os trigonum, we used a multivariable logistic regression. Associations were reported in adjusted odds ratios (ORs). Data were collected and entered in a SPSS database (SPSS Inc., an IBM Company, Chicago, IL), and statistical analyses were performed using RStudio version 0.98.1103 (RStudio, Boston, MA) and R version 3.1.3 (The R Foundation, Vienna, Austria).

RESULTS

In 32.5% of the mixed cohort (both symptomatic and asymptomatic), an os trigonum was present. In 14.3% of these patients it was present bilaterally. In a subgroup of patients without posterior impingement complaints an os trigonum was detected in 30.3%. Of the nonaffected ankles, in 23.7% an os trigonum was present. (Table 3)

The most common type of os trigonum was type B (κ = 0.77), and 57% of the ossa trigona were between 0.5 and 1.5 cm. In the ankles without an os trigonum, an enlarged lateral tubercle of the posterior talar process was found in 34.9 and 36.5% of the ankles (κ = 0.60). (Table 4)

Table 3. Prevalence of os trigonum presented as percentage.

		Os trigonum present	Os trigonum not present	Unilateral	Bilateral	Nonaffected ankles	Affected ankles
Total		32. 5% (n= 204)	67. 5% (n= 424)	18. 2% (n= 114)	14. 3% (n= 90)	23. 2% (n=137)	23. 7% (n=140)
	Without posterior ankle complaints	30. 3% (n= 165)	69. 7% (n= 379)	16. 4% (n= 89)	14. 0% (n= 76)	23. 1% (n=18)	21. 6% (n=111)
	With posterior ankle compliants	46. 4% (n= 39)	53. 6% (n= 45)	29. 8% (n= 25)	16. 7 (n= 14)	23. 2% (n=119)	37. 2% (n=29)
Side	Right	23. 6% (n= 148)	76. 4% (n= 480)				
	Left	23. 2% (n=146)	76. 8% (n= 482)				
Sex	Male	33. 3% (n= 117)	66. 7% (n= 234)	19. 9% (n= 70)	13. 4% (n= 47)	22. 6% (n=73)	24. 5% (n=79)
	Female	31. 4% (n= 87)	68. 6% (n= 190)	15. 9% (n= 44)	15. 5% (n= 43)	23. 9% (n=64)	22. 7% (n=61)
Ethnicity	European	34. 3% (n= 182)	65. 7% (n= 348)	18. 9% (n= 100)	15. 5% (n= 82)	24. 7% (n=124)	25. 4% (n=128)
	Caribbean/ Surinamese/ African	19. 0% (n= 11)	81. 0% (n= 47)	13. 8% (n= 8)	5. 2% (n= 3)	11. 3% (n=6)	11. 3% (n=8)
	North African/ Moroccan	38. 5% (n= 5)	61. 5% (n= 8)	23. 1% (n= 3)	15. 4% (n= 2)	25. 0% (n=3)	25. 0% (n=3)

Ethnicity, age, and presence of posterior ankle complaints were associated with the presence of an os trigonum. Caribbean/Surinamese/African origin was associated with a lower rate of occurrence of an os trigonum (adjusted OR, 0.43; 95% confidence interval [CI], 0.21-0.86). In younger patients, an os trigonum was more commonly detected. Furthermore, patients with posterior ankle impingement were more likely to have an os trigonum (adjusted OR, 1.86; 95% CI, 1.15-3.00). (Table 5)

Table 4. Prevalence of type and size of os trigonum and lateral tubercle of posterior talar process. Interobserver reliability reported as Cohen's kappa.

	Type	κ
Type of Os Trigonum	A - 19.6% - 18.2% B - 50.3% - 46.8% C – 30.1% - 35.1%	0. 77
Size of os Trigonum	I – 23.5% II – 57.7% III – 18.8%	
Percentage of enlarged Lateral tubercle posterior talar process	34. 9% - 36.5%	0. 60

Table 5. Factors associated with prevalence of an os trigonum.

	Adjusted Odds Ratio	Confidence Interval	p-value
Ethnicity: Caribbean/ Surinamese/ African	0. 43	0. 21-0.86	p< 0.05
Age	0. 98	0. 97-0.99	p< 0.05
Posterior Impingement complaints	1. 86	1. 15-3.00	p< 0.05

DISCUSSION

The most important finding of this study was that in a population of patients without posterior impingement complaints, with a prevalence of 30.3%, the os trigonum was more common than previously reported. In a subgroup of nonaffected ankles, an os trigonum was present in 23.7% of the ankles. Patients with posterior ankle impingement complaints were more likely to have an os trigonum. In addition, we found that patients with Afro-Caribbean/Surinamese/ African origin were less likely to have an os trigonum. No sex-related differences were observed. Of the patients without an os trigonum, in approximately one-third, an enlarged posterior talar process was present.

The frequency of occurrence found in this study is considerably higher in comparison with previous literature. One of the reasons could be that in this study, CT scans were used, whereas other studies often used conventional radiographs, which are known to have lower sensitivity for detecting an os trigonum. Mann and Owsley presented an explanation for the variation in the prevalence reported in literature.[13] The first hypothesis was the use of nondiscriminating terminology, as some authors also classified partially separated or even an enlarged posterior process as an os trigonum, were others did not. However, this makes the high prevalence in this study even more remarkable. Burman and Lapidus reported an occurrence of 50%, but only 6% of them were truly separated, indicating a true os trigonum.[10] Another explanation could be the difference in origin of the investigated populations. For example, Mann and Owsley did not find any os trigonum in a cohort of Native Americans and Inuits.[13] In this study, a difference in prevalence between populations was found; patients with a Caribbean/Surinamese/African origin had a lower frequency of occurrence. Last, the age distribution could be a cause for differences in reported prevalence, since in children, the fusion of the secondary ossification center with the talus has not yet occurred.

In a small study on ballet dancers, a prevalence of 30% was reported.[19] It was hypothesized that in these patients, due to the ballet activities at a young age, the os trigonum failed to fuse resulting in a relative high prevalence. With the results of the current study it is questionable whether this prevalence is actually higher than in the general population.

Although occasionally mentioned as the most common cause of posterior ankle impingement, little knowledge on the occurrence of enlarged posterior talar process is available.[20] The aforementioned study on ballet dancers reported a hypertrophic posterior process in 4 of 23 dancers. We found an enlarged process in approximately one-third of the population. When we combine the prevalence of the os trigonum and enlarged process, a similar frequency to that reported by Burman and Lapidus is found.[10] It should be stated, however, that there is no clear definition of an enlarged posterior talar process.

This study has several limitations. One of them is that we only assessed the axial CT images. On these axial images, the presence of an os trigonum is easy to detect, but assessment of the posterior talar process and other anatomical variants is more difficult. Therefore, assessment of prominent posterior downward sloping of the tibia could not be included in this study. In addition, the classification we used for defining an enlarged posterior talar process was arbitrary, but was supported by a “moderate” interobserver reliability. We were not able to include information on the activity level of the patients. This could have been an interesting addition, since, as mentioned before, it is hypothesized that physical activity at an early age might prevent fusion of the secondary ossification center. The classification of ethnicity that we used has limitations, since we used only the country of birth. For example, the Surinamese population consisted of different ethnic groups, Afro-Caribbean Surinamese and South Asian Surinamese. We were not able to distinguish between these groups, and hence the ethnicity related differences should be interpreted with caution.

To gain more insight into the role of anatomic variations in the development of posterior ankle complaints, three-dimensional assessment and comparison of the anatomy should be performed. Future studies should focus on the anatomical difference between patients with and without posterior impingement.

CONCLUSION

This study showed that an os trigonum is a common accessory bone, with a prevalence of 30.3% in a population of patients without posterior impingement complaints and 23.7% of the nonaffected ankles, more common than previously reported. Patients with posterior ankle impingement complaints had an os trigonum more commonly. In one third of the patients without an os trigonum, there was an enlarged lateral tubercle of the posterior talar process.

LITERATURE

1. van Dijk CN. Anterior and posterior ankle impingement. *Foot Ankle Clin* 2006;11(3):663-83.
2. Hedrick MR, McBryde AM. Posterior ankle impingement. *Foot & ankle international* 1994;15(1):2-8.
3. Rosenmuller J. De mon nullis musculorum corpus humani varietatibus. *Leipzig* 1804;8
4. Bardeleben K. Das intermedium tarsi beim menschen und saugethieren. *J Anat Physiol* 1885;19:509.
5. McDougall A. The os trigonum. *J Bone Joint Surg Br* 1955;37-b(2):257-65. [published Online First: 1955/05/01]
6. Thompson A. Report of the committee of collective investigation of the Anatomical Society of Great Britain and Ireland for the year 1889-1890. *J Anat* 1891;25:89-101.
7. Pfitzner W. Beiträge zur Kenntniss der Missbildungen des menschlichen Extremitätenskelets. In: Schwalbe, ed. Morph Arb. Jena1896:245 - 528.
8. Stieda CHL. Ueber secundare fusswurzelknochen. *Arch Physiol Wissensch Med* 1869:108-11.
9. Sewell RS. A study of the astragalus. *Journal of anatomy and physiology* 1904;38(Pt 3):233.
10. Burman M, Lapidus PW. The functional disturbances caused by the inconstant bones and sesamoids of the foot. *Archives of Surgery* 1931;22(6):936-75.
11. Agur AM, Dalley AF. Grant's atlas of anatomy: Lippincott Williams & Wilkins 2013:475.
12. Tsuruta T, Shiokawa Y, Kato A, et al. [Radiological study of the accessory skeletal elements in the foot and ankle (author's transl)]. *Nihon Seikeigeka Gakkai zasshi* 1981;55(4):357-70. [published Online First: 1981/04/01]
13. Mann RW, Owsley DW. Os trigonum. Variation of a common accessory ossicle of the talus. *J Am Podiatr Med Assoc* 1990;80(10):536-39.
14. Cilli F, Akçaoğlu M. [The incidence of accessory bones of the foot and their clinical significance]. *Acta orthopaedica et traumatologica turcica* 2004;39(3):243-46.
15. Coskun N, Yuksel M, Cevener M, et al. Incidence of accessory ossicles and sesamoid bones in the feet: a radiographic study of the Turkish subjects. *Surg Radiol Anat* 2009;31(1):19-24. doi: 10.1007/s00276-008-0383-9 [doi]
16. Stieda J. Talus und das os trigonum bardelebens beim Menschen. *Anat anz* 1889;4:305-15.
17. Stronks K, Snijder MB, Peters RJG, et al. Unravelling the impact of ethnicity on health in Europe: the HELIUS study. *BMC Public Health* 2013;13:402-02. doi: 10.1186/1471-2458-13-402
18. Kelikian AS, Sarrafian SK. Sarrafian's anatomy of the foot and ankle: descriptive, topographic, functional. Philadelphia: Lippincott Williams & Wilkins 2011:40-199.
19. Peace KA, Hillier JC, Hulme A, et al. MRI features of posterior ankle impingement syndrome in ballet dancers: a review of 25 cases. *Clinical radiology* 2004;59(11):1025-33. doi: 10.1016/j.crad.2004.02.010 [published Online First: 2004/10/19]
20. Hess G. Ankle impingement syndromes: a review of etiology and related implications. *Foot & ankle specialist* 2011;4(5):290.

CHAPTER 3

GEOMETRICAL CHARACTERISTICS OF THE SYMPTOMATIC AND NON-SYMPTOMATIC OSSA TRIGONA

R. Zwiers
B. Görgec
C.N. van Dijk
L. Blankevoort

Foot Ankle Surg 2020

ABSTRACT

Background

Posterior ankle impingement is strongly associated with the presence of an os trigonum, however, most patients with an os trigonum will never develop symptoms. It is hypothesized that the os trigonum is larger in the symptomatic ankle than in the non-symptomatic ankle, the distance between os trigonum and tibia is smaller and there are more degenerative changes in ankles with symptoms of posterior impingement. In this study the geometrical characteristics of the ipsilateral and contralateral os trigonum are compared in patients with a bilateral os trigonum and unilateral posterior impingement symptoms.

Methods

Patients with a bilateral os trigonum and unilateral posterior impingement complaints were included. Comparison between the symptomatic and asymptomatic ankles was done within each patient. From the CT-scan of each ankle, the tibia, fibula, calcaneus, talus and os trigonum were segmented and a geometric model was created. Based on these bone models, the volume of the os trigonum and talus, the size of the os trigonum, the distance between os trigonum and surrounding bones (talus, calcaneus, fibula and tibia) were calculated. In addition, the CT images were assessed for the type of os trigonum, the presence of cysts, irregular synchondrosis, calcifications and whether the os trigonum consisted of more than one fragment.

Results

A total of 22 patients were included in this study. In seventeen of the 22 patients, the symptomatic os trigonum was larger in comparison with the non-symptomatic side in terms of length (median Δ 2.4 mm, 8.9 versus 10.6 mm) and relative volume (median Δ 0.09%, 0.30 versus 0.45% of talar volume). Distances between the ossa trigona and surrounding bones were not statistically significantly different between both sides. Calcifications were more frequently found around the os trigonum in the symptomatic side (10 versus 3/22).

Conclusions

The findings in this study support the hypothesis that symptomatic ossa trigona are larger in comparison with asymptomatic ossa trigona. Calcifications around the os trigonum were found more frequently in symptomatic than in non-symptomatic ossa trigona.

INTRODUCTION

Posterior ankle impingement is strongly associated with the presence of an os trigonum. Historically, the condition was referred to as os trigonum syndrome.[1 2] Although an os trigonum can become symptomatic, most patients with an os trigonum will never develop symptoms.[3]

The prevalence of an os trigonum is approximately 30% in an asymptomatic population. In a population of patients with posterior ankle impingement the prevalence is remarkably higher, about 46%.[4] Often the os trigonum is only present unilaterally. We noticed that both size and shape are different between both ankles in patients with a bilateral os trigonum. Literature describing the geometrical characteristics like size and shape of the os trigonum in relation to the presence of symptoms is lacking. Furthermore, it is not clear where the pain in patients with posterior ankle impingement originates from and what role the anatomical characteristics play. It is known that posterior ankle impingement is frequently associated with tendinopathy of the flexor hallucis longus tendon, and the relation with the size of the os trigonum has been studied.[5] We postulate that pain in absence of FHL tendinopathy is probably caused by impingement of soft tissue between the os trigonum and the posterior aspect of the distal tibia. Another cause can be micro-movement between the ossicle and the talus. Degenerative changes between calcaneus and os trigonum can also be a source of pain.

To achieve a better understanding of the role of the anatomical characteristics of the os trigonum in the etiology of posterior ankle impingement complaints, in this study the geometrical characteristics of the ossa trigona in patients with a bilateral os trigonum in which only one side is symptomatic will be compared. We hypothesize that the ossa trigona are larger in the symptomatic ankles than in the non-symptomatic ankles. Secondary, the distance between os trigonum and tibia is smaller in the symptomatic ankles and degenerative changes are more present in ankles with symptoms of posterior impingement.

METHODS

Subjects

All ankle CT scans manufactured between January 2004 and December 2011 of patients who were treated for posterior ankle impingement in the Academic Medical Centre in Amsterdam were assessed for the presence of ossa trigona. All patient records of the patients with bilateral ossa trigona were screened.

Patients with a bilateral os trigonum and unilateral posterior impingement complaints were included in this study. Patients with a history of bilateral complaints or patients who subsequently developed complaints on the contralateral side (7–14 years follow-up) were excluded. Only patients without a history of trauma were included. Athletes with a dominant leg that is used for kicking a ball were excluded. For this reason we excluded all soccer, rugby and American football players, since in these sports most players have a dominant leg.

All CT scans were made according to the local high resolution ankle CT protocol (axial slices of both ankles with an increment of 0.3 mm and a thickness of 0.6 mm, and coronal and sagittal reconstructions of 1 mm) with the patients in the supine position and the ankle in neutral position. Of all included patients the original DICOM files were extracted.

Demographic characteristics were extracted from patient records. Diagnosis was made by an experienced orthopedic surgeon, based on history taking and thorough physical examination. Other causes for posterior ankle pain were ruled out by additional diagnostic imaging, i.e. radiographs, and MRI.

Study design

This study had a case-control design. The comparison between the symptomatic and non-symptomatic ankle was done within each patient. Of each ankle the volume of the os trigonum and talus, the size of the os trigonum in three directions by using an ellipsoid approximation and the distance between os trigonum and surrounding bones (talus, calcaneus, fibula and tibia) were calculated. In addition, the CT images were assessed for the type of os trigonum (Figure 1), the presence of signs of degenerative changes like cysts, irregular synchondrosis, calcifications and whether the os trigonum consisted of more than one fragment.

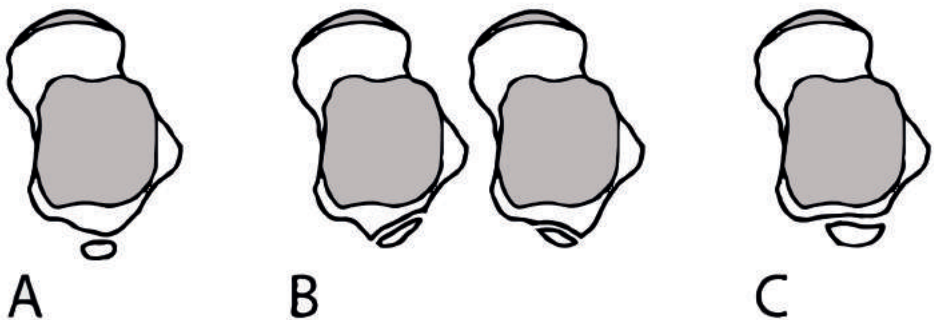


Figure 1. Types of os trigonum. A.Os trigonum completely separated from lateral tubercle B. Os trigonum consist of part of lateral tubercle. C. Os trigonum consists of complete lateral tubercle.

CT segmentation and data processing

DICOM files were loaded in the Seg3D segmentation software (version 2.2.1).[6] Computer segmentation of the talus, os trigonum, calcaneus, distal tibia and distal fibula of each ankle was performed in a standardized manner. Segmentation data were acquired with a voxel size of 0.3 by 0.3 by 0.3 mm. In each bone up to 5 points were manually selected, then using the 'neighborhood connected' tool the bone was filled. Thereafter using the 'smooth dilate-erode' tool (2 pixels) the irregularities were solved. The coordinates of the surface data points were exported for further processing.

Data processing was performed using custom-made software based on Matlab (R2013B version 8.2.0.701, The Mathworks, Natick, Massachusetts, USA). Five-sixth of the data points were removed to create a manageable mesh. Triangulated surfaces of each bone were constructed by using the remaining data points. These triangulated surfaces were smoothed using the implicit fairing method so that the root mean square difference between the smoothened surface and the original data points did not exceed the voxel size. [7]

Using the custom-made software the volume of the talus and os trigonum was calculated. An ellipsoid was fitted to the data points, thus resulting in three perpendicular axes, where the X-axis was directed along the longest dimension. The dimensions were calculated by the intersection of the three axes with the triangulated surface. Subsequently, the minimal distance between os trigonum and talus, os trigonum and calcaneus, os trigonum and tibia and os trigonum and fibula was calculated, using a method with perpendicular lines from the surface triangles. The minimal distance was defined as the shortest perpendicular line that hit the surface of the opposing bone. (Figure 2)

Statistical analysis

Sample size calculation was based on the length of the os trigonum, since only data on this measurement were available. Previous studies reported the length of the os trigonum 6.5–8.9 mm (largest axis)[8], 11 (sagittal plane on MRI) and 14 (axial plane)[5] with a standard deviation of 2.4 mm and 3.1 mm, respectively. To detect a difference of 2 mm between the groups, it was estimated that with a standard deviation of 3 mm and an α-level of 0.05, at least 20 subjects in each group were required to obtain a power of 80% when using a paired sample t-test. Sample size calculations were performed using the G*Power software (version 3.1.9.4).

Descriptive data were presented as frequencies with percentages in case of categorical data, and continuous variables as mean with standard deviation (SD) in case of approximately normal distribution or median with interquartile range

(IQR) when data were not normally distributed. Distribution of the outcome measures was assessed using histogram, Q-Q plots and the Shapiro-Wilk test.

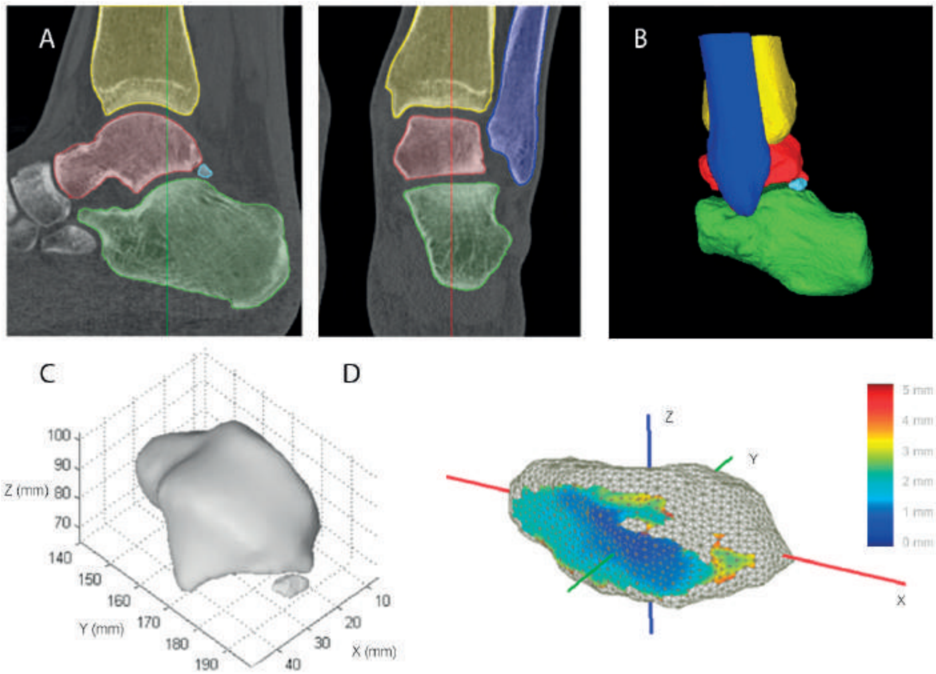


Figure 2. A. Segmentation of CT scan using Seg3D. B. Isosurface data points created using Seg3D. C. Triangulated surface models of talus and os trigonum as created in Matlab. D. Triangulated surface model of the os trigonum with the three geometric principal axes. The colour map represents the distance (mm) between os trigonum and talar bone as calculated in Matlab. A and B: yellow: tibia; red: talus; green: calcaneus; dark blue: fibula; light blue: os trigonum.

Outcomes of both groups were plotted using line graphs. For continuous variables differences between the two groups were tested using paired-sample T-test if difference between group was approximately normally distributed, or using paired samples Wilcoxon signed-rank test in case of non-normal distribution. For nominal or dichotomous data the Mc Nemar's test was used. Differences were considered statistically significant when p-value was <0.05.

Statistical analyses were performed using RStudio version 0.98.1103 (RStudio, Boston, MA, USA), R version 3.1.3 (The R Foundation, Vienna, Austria).

RESULTS

A total of 22 patients were included in this study, resulting in 22 ankles in each group. Ten patients were male, the median age was 28 years. (Table 1)

Table 1. Patient characteristics

Number of patients	22 (44 ankles)	
Age (years)	Median 28.0	IQR 22-34
Sex	Male 10 / Female 12	
Sport		
Ballet	5	
Gymnastics	3	
Tennis	3	
Basketball	1	
Baseball	1	
Athletics	1	
Unknown	*8*	

Median length of the major axis (X) of all ossa trigona was 9.5 mm (IQR 7.2-12.7) and the median volume 133.3 mm3 (IQR 40.0-324.4).

In seventeen of the 22 subjects, the symptomatic os trigonum was larger in terms of length in comparison with the non-symptomatic side. When testing the difference between both sides, the length of the three axes were significantly larger in the symptomatic ankles. In addition, in the same seventeen patient the symptomatic ossa trigona had a larger absolute and relative volume, however only the relative volume showed a statistical significant difference ($p = 0.03$). (Table 2 and Figure 3)

Distances between the ossa trigona and surrounding bones were similar in both groups. Regarding CT findings, calcifications were more frequently found around the os trigonum in the symptomatic group (p-value = 0.03). (Table 2) To test the robustness of the outcomes an additional analysis was performed without the two subjects with the largest difference between symptomatic and non-symptomatic os trigonum. This additional analysis confirmed the findings for length of major axis (Δ 2.1, p-value 0.02), volume of os trigonum (Δ 26.0 mm3) and relative volume (Δ 0.1%).

Table 2. Geometric characteristics of non-symptomatic and symptomatic ossa trigona. The median length, volume and distance between bones are presented for both ankles. In addition the median difference in measurements between the symptomatic and non-symptomatic ankle are presented. P-values of the Wilcoxon signed ranks and McNemar test are shown. Δ, difference; * statistically significant difference.

	Non-Symptomatic	Symptomatic	Median Δ	p-value
Number of ankles	22	22		
Type of os trigonum				
Seperated	9	9		*p= 0.69*
Partial	9	7		
Complete Tubercle	4	6		
Absolute size (mm)				
Major (X) axis	8. 9 (IQR 5.8-10.1)	10. 6 (IQR 7.7-13.7)	*2. 4(IQR -0.5-5.5)*	*p= 0.01 **
Y axis	5. 6 (IQR 3.4-7.8)	6. 4 (IQR 3.9-8.9)	*0. 9 (IQR 0-2.9)*	*p= 0.04 **
Z axis	4. 1 (IQR 2.3-5.1)	4. 9 (IQR 2.9-7.4)	*1. 0 (IQR -0.2-2.5)*	*p= 0.02 **
Relative size major axis *Percentage of major axis of talus (%)*	14. 0 (IQR 10.4-18.1)	18. 3 (IQR 13.2 -21.7)	*2. 1 (IQR -0.6-4.8)*	*p= 0.01 **
Shape *Ratio X/Y axis*	1. 66 (IQR 1.4-1.9)	1. 7 (IQR 1.5-1.8)	*0. 1(IQR -0.1-0.4)*	*p= 0.27*
Absolute volume (mm^3)	101. 5 (IQR 31.8-225.4)	159. 2 (IQR 48.7-525.5)	*27. 0 (IQR 3.2-182.9)*	*p= 0.05*
Relative volume *Percentage of volume of talus (%)*	0. 30 (IQR 0.07-0.67)	0. 45 (IQR 0.16-1.07)	*0. 09 (0.04-0.55)*	*p= 0.03 **
Distance between (mm)				
Os trigonum – Talus	0. 68 (IQR 0.43-1.07)	0. 66 (IQR 0.41-0.98)	*0. 1 (IQR -0.2-0.3)*	*p= 0.90*
Os trigonum - Tibia	14. 45 (IQR 0.89-2.30)	14. 62 (IQR 11.67-18.12)	*-0.8 (IQR -2.6-1.3)*	*p= 0.56*
Os trigonum -Calcaneus	1. 71 (0.89-2.30)	1. 61 (IQR 1.08-2.86)	*-0.1 (IQR -0.8-0.5)*	*p= 0.56*
Os trigonum -Fibula	15. 85 (IQR 11.73-19.36)	14. 73 (IQR 11.71-19.37)	*-1.3(IQR -4.0-2.7)*	*p= 0.63*
Degenerative changes				
Irregular synchondrosis	8/ 22	12/ 22		*p= 1.00*
Subchondral cysts	3/ 22	5/ 22		*p= 0.50*
Calcifications	3/ 22	10/ 22		*p= 0.04 **
Multiple parts	2/ 22	3/ 22		*p= 1.0*

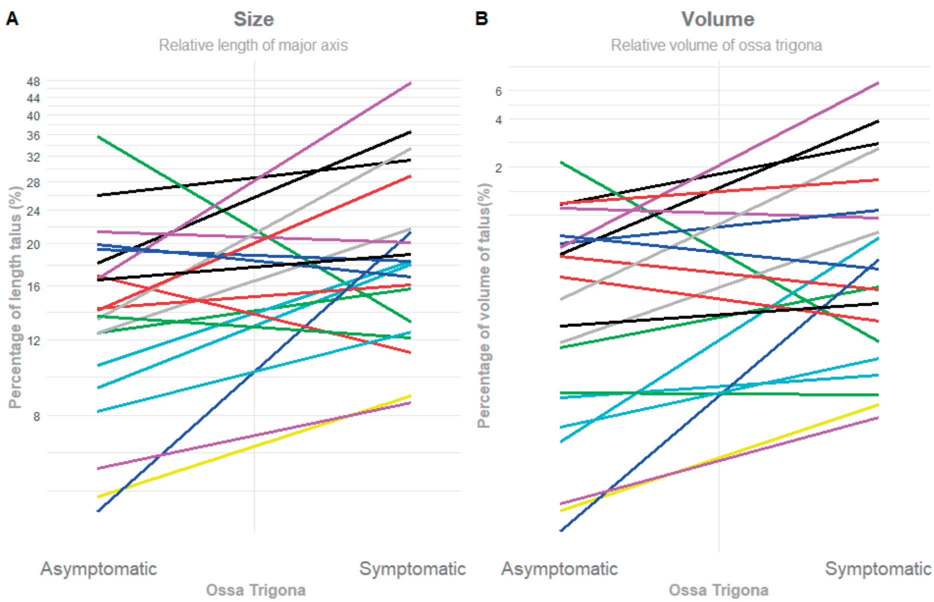


Figure 3. Plots of relative length of major axis (A) and volume ossa trigona relative to the volume of the talus (B). Each line represents one subject. For clarity of data presentation a logarithmic scale was used along the vertical axis.

DISCUSSION

This is the first study to report on the geometric characteristics of symptomatic ossa trigona and to determine differences in size and shape between the ipsilateral and contralateral sides in patients with a bilateral os trigonum. Our findings support the hypothesis that the os trigonum is larger, in both length and volume, in the symptomatic ankle compared with the non-symptomatic ankle. We did not find a smaller space between the os trigonum and surrounding bones between the symptomatic and non-symptomatic ankles. Calcifications around the os trigonum were found more frequently at the symptomatic side.

Hitherto, only two recent studies have reported on anatomical characteristics of the os trigonum. Tokgöz et al. reported on the size of the os trigonum in the axial and sagittal plane and the presence of degenerative changes of the flexor hallucis longus tendon. They found a larger os trigonum, measured in the sagittal plane, to be associated with more degenerative changes of the tendon and partial tears.[5] Fu et al. presented anatomical measurements of three types of ossa trigona.[8] The three types described in their study are different from the types we used in this study. Type III described in the study by Fu et al. is connected to the talus and is therefore considered a hypertrophic posterior talar process.

We hypothesized that in the symptomatic ankles the distance between the os trigonum and tibia would be smaller. When there is less space during plantar flexion, there is a higher change of impingement of soft tissue. However, a difference between the symptomatic and non-symptomatic ankles was not found. Probably the distance in neutral position, as in our models, does not correlate well with the anatomy in plantar flexion. Stability and mobility in the ankle joint plays a role in the development of impingement and was not be included in this static model. A recent study showed patients with chronic lateral ligament injury to have a higher risk for surgical treatment of posterior ankle impingement.[9] Anterior translation of the talus as result of ligament injury, probably increases the risk of impingement during planter flexion.[10] In addition, one can hypothesize that when the distance between the os trigonum and talus is larger, the synchondrosis is less rigid, allowing more (micro)-movement and resulting in symptoms. In this study we were not able to support this hypothesis. Another cause of pain is degenerative changes at the synchondrosis and indeed we found a significant difference in occurrence of calcifications around the os trigonum.

A large os trigonum should be distinguished from a talus bipartitus. An os trigonum is located at the posterolateral tubercle of the posterior talar process, whereas a talus bipartitus involves both the posterolateral and posteromedial tubercles. In addition, in contrast to an os trigonum, the talus bipartitus also extent into the ankle joint. This extension of the fragment makes it a different entity, in terms of clinical presentation, treatment and prognosis.[11]

Limitations

Sample size calculation was based on the size of the os trigonum, probably the sample size was not large enough for detecting differences in distance between os trigonum and surrounding bones.

Patients were asked whether they ever had the same complaints at the contralateral side, and if so they were excluded. However, we could not rule out that the symptoms may develop in the future. By choosing the contralateral ankle as matched control, the risk of confounding was reduced. Factors contributing to development of posterior impingement like activity level and age were controlled for. By excluding soccer and football players we prevented to include patients that had a dominant leg used for kicking that could bias the results. With this, the select group that was used makes the external validity of the findings limited.

In this study we did not study the relation between anatomy of the os trigonum and FHL pathology, but it is expected that in line with the previously mentioned study the size of the os trigonum is associated with FHL related complaints.

Although the sample size in this study is small, the findings help to better understand the role of the os trigonum in patients with posterior ankle impingement. To gain more information, MRI scans could be used, to better assess the appearance of the synchondrosis and surrounding soft tissue, like the posterior joint capsule and the intermalleolar ligament.

CONCLUSION

The findings in this study support the hypothesis that symptomatic ossa trigona are larger in comparison with non-symptomatic ossa trigona. Calcifications around the os trigonum were found more frequently in symptomatic than in non-symptomatic ossa trigona.

LITERATURE

1. Wenig J. Os trigonum syndrome. *Journal of the American Podiatric Medical Association* 1990;80(5):278-82.
2. Brown GP, Feehery Jr RV, Grant SM. Case study: the painful os trigonum syndrome. *Journal of Orthopaedic & Sports Physical Therapy* 1995;22(1):22-25.
3. Keles-Celik N, Kose O, Sekerci R, et al. Accessory Ossicles of the Foot and Ankle: Disorders and a Review of the Literature. *Cureus* 2017;9(11):e1881-e81. doi: 10.7759/cureus.1881
4. Zwiers R, Baltes TPA, Opdam KTM, et al. Prevalence of Os Trigonum on CT Imaging. *Foot & ankle international* 2018;39(3):338-42. doi: 10.1177/1071100717740937 [published Online First: 2017/12/23]
5. Tokgöz MA, Ataoğlu MB, Ergişi Y, et al. Is there any effect of presence and size of os trigonum on flexor hallucis longus tendon lesions? *Foot and Ankle Surgery* 2019
6. Seg3D: Volumetric Image Segmentation and Visualization. Scientific Computing and Imaging Institute (SCI), download from: http://www.seg3d.org [program], 2016.
7. Implicit fairing of irregular meshes using diffusion and curvature flow. Proceedings of the 26th annual conference on Computer graphics and interactive techniques; 1999. Citeseer.
8. Fu X, Ma L, Zeng Y, et al. Implications of Classification of Os Trigonum: A Study Based on Computed Tomography Three-Dimensional Imaging. *Med Sci Monit* 2019;25:1423-28. doi: 10.12659/MSM.914485
9. D'Hooghe P, Alkhelaifi K, Almusa E, et al. Chronic lateral ankle instability increases the likelihood for surgery in athletes with os trigonum syndrome. *Knee Surgery, Sports Traumatology, Arthroscopy* 2019;27(9):2813-17. doi: 10.1007/s00167-018-5183-0
10. Hubbard TJ, Olmsted-Kramer LC, Hertel J, et al. Anterior–posterior mobility of the talus in subjects with chronic ankle instability. *Physical Therapy in Sport* 2005;6(3):146-52.
11. Zwiers R, de Leeuw PAJ, Kerkhoffs G, et al. Talus bipartitus: a systematic review and report of two cases with arthroscopic treatment. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2018;26(7):2131-41. doi: 10.1007/s00167-017-4613-8

CHAPTER 4

EXOROTATED RADIOGRAPHIC VIEWS HAVE ADDITIONAL VALUE IN DETECTING AN OSSEOUS IMPEDIMENT IN PATIENTS WITH POSTERIOR ANKLE IMPINGEMENT

R. Zwiers
J.G.G Dobbe
G.J. Streekstra
J.I. Wiegerinck
L. Blankevoort
M. Maas
C.N. van Dijk
Ankle Platform Study Group

J ISAKOS 2019

ABSTRACT

Objectives

A standard lateral radiograph is the first step in the diagnostic workup in patients with posterior ankle pain. Because of overprojection by other structures at sub-optimal radiographic projection angle, often an os trigonum is not discovered or erroneously be mistaken for a hypertrophic posterior talar process.

The aim of this study was to identify the projection angles at which a radiograph is optimal for detecting bony impediments in patients suffering from posterior ankle impingement.

Methods

Using ankle CT scans of patients with posterior ankle impingement, digitally reconstructed radiographs (DRRs) simulating 13 different radiographic projection angles were generated. The ankle CT scans served as a reference for the detection of an os trigonum and hypertrophic posterior talar process. Members of the Ankleplatform Study Group were invited to assess the DRRs, for presence or absence of an os trigonum or hypertrophic posterior talar process. Diagnostic accuracy and interobserver reliability were estimated for each projection angle. In addition, the diagnostic accuracy of the standard lateral view in combination with the rotated views was calculated.

Results

High sensitivity for detecting an os trigonum was found for +15° (90.3%), +20° (81.7%) and +25° (89.7%) degrees of exorotation. Specificity in this range of projection angles was between 89.6% and 97.8%. Regarding the presence of a hypertrophic posterior talar process, increased sensitivity was found for +15° (65.7%), +20° (61.0%), +25° (60.7%), +30° (56.3%) and +35° (54.5%). Specificity ranged from 78.0% to 94.7%. The combination of the standard lateral view in combination with exorotated views showed higher sensitivity. For detecting an os trigonum, a negative predictive value of 94.6% (+15°), 94.1% (+20°) and 96.1% (+25°) was found.

Conclusion

This study underlines the additional diagnostic value of exorotated views instead of, or in addition to the standard lateral view in detecting an osseous impediment. We recommend to use the 25° exorotated view in combination with the routine standard lateral ankle view in the work up of patients with posterior ankle pain.

INTRODUCTION

Posterior ankle impingement is a condition characterized by pain at the posterior aspect of the ankle during plantar flexion.[1] Posterior ankle impingement is most often accompanied by the presence of bony anomalies like an os trigonum or hypertrophic posterior talar process. The os trigonum is an accessory bone of the foot localized posterior to the lateral tubercle of the posterior talar process.[2] A prevalence up to 32% in patients with foot and ankle pathology has been reported.[3] An os trigonum usually does not come with symptoms. However, sport activities, such as ballet, soccer or football, may cause repetitive stress and chronic micro traumas to the hindfoot. In the non-athlete population, posterior ankle impingement may result from a hyperplantarflexion-supination trauma. In those patients, the presence of an os trigonum predisposes to persisting posterior ankle pain.

An os trigonum can be detected using a standard lateral radiograph. However, because of overprojection by other structures, often an os trigonum is not discovered or erroneously mistaken for a hypertrophic posterior talar process. Additional imaging methods like CT and MRI have disadvantages in terms of higher costs and waiting time. Hence, a 25° exorotated lateral view (posterior impingement (PIM) view) for better detection of bony posterior ankle impingement has been developed.[1] In a prospective study, this PIM view was compared with a standard lateral weight-bearing radiograph and CT as a reference. Although both the sensitivity and specificity for detecting an os trigonum increased with this PIM view, the diagnostic value of this radiologic view may be further optimized for evaluation of posterior ankle pathology by determining the optimised exorotation angle during image acquisition.[4] In the initial study, the radiographic projection angle was empirically chosen and did not result from a systematic analysis to detect the optimal projection angle, the posterior talar process as impediment was not taken into account, and the observers showed substantial interobserver differences.

The aim of this study was to identify the optimal projection angle for detection of a bony impediment in patients suffering from posterior ankle impingement complaints by evaluating the visibility of an os trigonum and hypertrophic posterior talar process at a range of projection angles in simulated radiographic images.

METHODS

Subjects

Ankle CT scans of a consecutive series of patients who visited the Orthopaedic department of the Academic Medical Centre in Amsterdam with posterior ankle complaints between 1 January 2012 and 31 December 2012 were evaluated. Low-quality CT scans were excluded. Only CT scans with the ankle in the neutral anatomical position were included, resulting in a total of 40 CT scans.

Creating digitally reconstructed radiographs

A digitally reconstructed radiograph (DRR) is a simulated radiograph generated from volume data of a CT scan.[5] DRRs usually play an important role in image-guided therapy and patient positioning in radiation therapy for oncological patients. In this study, we used DRRs to easily compare images observed from different projection angles. Generation of DRRs in this study was based on a method described by Schroeder et al.[6]

To allow comparing DRRs between different subjects, DRRs were needed to be generated in a standard orientation of the ankle relative to the propagation direction of the simulated X-rays. The orientation of the X-ray beam in a standard lateral radiograph was used as reference. In a standard lateral radiograph, the ankle is positioned such that the beam passes through the centre of the medial and lateral malleolus.[7] (Figure 1A)

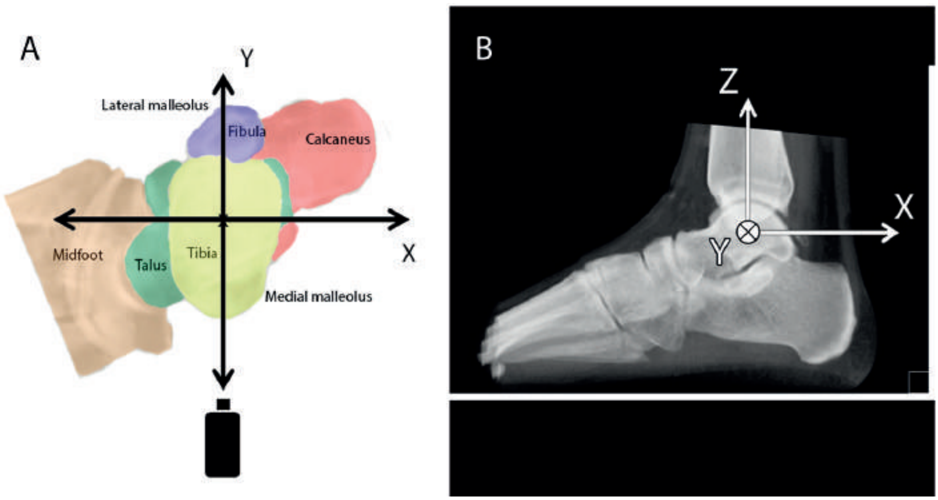


Figure 1. A. Top view of an ankle and coordinate system. B. A digitally reconstructed radiographic (DRR) image representing a Standard Lateral View. In this view the coordinate system is defined.

DRRs were generated using custom software that enables observers to simulate a standard lateral radiograph. Criteria for a standard lateral radiograph included (1) alignment of the medial and lateral malleoli, (2) overlap of medial and lateral talar domes and (3) a completely visible tibiotalar joint space. To this end, the observer effectively oriented the CT volume, while a corresponding DRR was displayed, until the DRR represents the projection image of a standard lateral radiograph. This orientation defined the y-axis within the CT volume. To ensure a correct orientation of the projection image in the XZ plane, the observer rotated the in-plane projection image about the y-axis such that the foot seems standing on a horizontal surface (X-axis). This procedure defined an anatomical coordinate system (CS) with the Z-axis perpendicular to the X and Y-axes (Figure 1B).

To estimate the precision in orientation of this manually defined CS, we asked three observers to independently position a CS ten times, resulting in 30 CSs per ankle. The mean orientation of these 30 CSs served as reference CS. The rotational error between each CS and the reference CS was calculated and the SD, represented the reproducibility of orienting the reference CS. Interobserver and intraobserver variations were determined (supplementary appendix I).

Starting at -10° rotation around the z-axis in relation to the reference CS, the projection line was rotated in steps of +5° around the z-axis, as if the ankle was exorotated in steps of 5°, until 50° of exorotation was reached. (Figure 2) This range was chosen based on the anatomy of the synchondrosis between the talar body and the os trigonum assessed on axial CT scan slices. At all positions, a DRR was obtained for each of the 40 CT scans, resulting in 520 unique DRRs. Brightness and contrast of the DRR's were set at a level that reflects the properties of conventional radiographic images. (Figure 3)

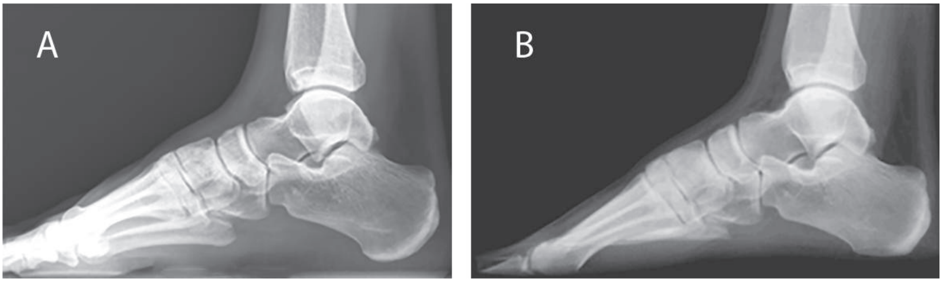


Figure 2. A. Conventional radiographic image, Standard Lateral View. B. Digitally Reconstructed Radiograph (DRR) of the same ankle.

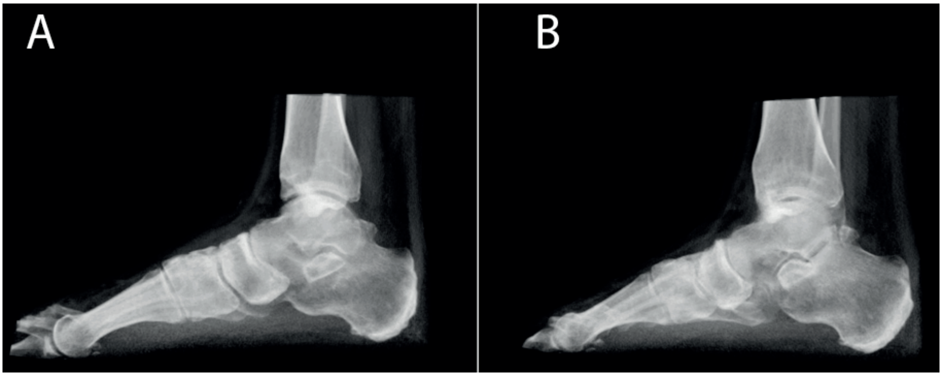


Figure 3. Image showing DRRs of the projection angles of both the Standard Lateral View (A) and 25° exorotation view (B).

Assessing radiographic images

The images were distributed as DICOM-files (Digital Imaging and Communications in Medicine) using a web-based rating application with a built-in DICOM viewer following an eight-block balanced split-plot design. Each block consisted of all 13 DRRs of 5 different patients. Images were randomly assigned to the eight blocks. Each independent observer was randomly assigned to one of the blocks (supplementary appendix I). Each observer was asked to assess 65 (13×5) images for the presence of an os trigonum or a hypertrophic posterior process of the talus.

Members of the Ankleplatform Study Group were invited to assess the images on the web¬based study platform, research.ankleplatform.com. Only orthopaedic surgeons or residents experienced with posterior ankle pathology were invited to participate in this study. An image was defined as 'positive' for the presence of an os trigonum if it was recognised as a non-united part of the lateral tubercle of the posterior process of the talar bone. The lateral tubercle of the posterior process of the talus was assessed as being 'hypertrophic' (an elongated or prominent lateral tubercle) or 'without bony impediment'.

For each projection angle, the sensitivity, specificity, percentage correctly classified images (diagnostic accuracy) and interobserver reliability for both the presence of an os trigonum and hypertrophic lateral tubercle of the posterior process of the talus were calculated. In addition, the diagnostic accuracy of the standard lateral view in combination with the rotated views were calculated.

Reference standard

CT scans were used as reference test, since CT scans are the gold standard in detecting osseous impediments. All CT scans were made according to the local high-resolution ankle CT protocol (axial slices with an increment of 0.3 mm and a thickness of 0.6 mm, and coronal and sagittal reconstructions of 1 mm) with the patients in the supine position. These scans were assessed for the presence of an os trigonum or hypertrophic posterior process of the talus by an experienced musculoskeletal radiologist (MM). An os trigonum was defined as an osseous structure located posterior to and separated from the lateral tubercle of the posterior talar process in the axial plane, and in the same sagittal plane as the lateral tubercle of the posterior talar process. If an osseous structure was identified on CT with any connection to the lateral tubercle, this was defined as a hypertrophic posterior talar process instead of an os trigonum.[4]

Statistical analysis

Sensitivity and specificity were estimated using a generalised logistic linear mixed model (GLMM) approach.[8 9] The model with the observer score as outcome variable consisted of two random intercepts and a fixed intercept. Random intercepts were used to account for clustering at the level of both observers and cases. The fixed intercept was used to estimate the sensitivity and specificity, after inverse-log transformation. For sensitivity, the analysis was performed on the positive cases, for specificity on the negative cases. By using a generalised linear mixed model to estimate the sensitivity and specificity, we were able to correct for clustering of outcome at both the level of observer as well as within cases, and thus avoid bias. Agreement among observers was calculated for each projection angle, using the Krippendorff's α interobserver reliability coefficient.[10 11] This is an interobserver reliability coefficient without restrictions for sample size or number of coders, and can handle missing data. Therefore, it can be used for incomplete designs. If $\alpha = 0$, this indicates no reliability and the agreement to be a result of chance alone, $\alpha = 1$ represents perfect agreement. Krippendorff's α values were interpreted using the guidelines proposed by Landis and Koch values of 0.01–0.20 indicate slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement and more than 0.81, almost perfect agreement.[12] For estimation of the positive and negative predictive values the formulas based on Bayes' theorem were used. Statistical analyses were performed using RStudio V.0.98.1103 (RStudio, Boston, Massachusetts, USA), R V. 3.1.3 (The R Foundation, Vienna, Austria), packages 'lme4' and 'irr'.

RESULTS

Coordinate system orientation

Interobserver variation of the orientation of the CS was 0.45° - 1.45° around the x-axis, 1.22°-2.19° around the y-axis and 1.34° - 2.08° around the z-axis. Regarding the intraobserver variation, for observer 1, the SD varied between 0.43° and 1.25°, for observer 2 between, 0.29° and 2.00°, and for observer 3 between 0.58° and 1.79° (supplementary appendix II).

Images

In 17 of the 40 included CT scans, an os trigonum was present (42.5%). In 18 ankles, the posterior process of the talus was classified as 'hypertrophic' (45%). The images of the eight blocks were assessed by 13, 15, 18, 17, 12, 16, 15 and 15 observers, respectively, resulting in a total of 121 different observers from 39 different countries. Given the 65 images per block, a total of 7865 images were assessed by these observers.

Diagnostic accuracy

Sensitivity for detecting an os trigonum varied between 16.0% and 90.3%, with high sensitivity for +15° (90.3%), +20° (81.7%) and +25° (89.7%) degrees of exorotation. Specificity varied between 89.6% and 97.8%. Percentage of correctly classified images varied between 62.1% and 82.3 %. Highest percentage was found for 15° exorotation projection.

Regarding the presence of a hypertrophic posterior process, sensitivity varied between 9.8% and 65.7%. Higher sensitivity was found for +15° (65.7%), +20° (61.0%), +25° (60.7%), +30° (56.3%) and +35° (54.5%). Specificity ranged from 78.0% to 94.7%. Between 46.6% and 73.9% of the images was correctly classified. (Table 1, Figure 4)

When combined with the standard lateral view, sensitivity improved to above 90% for the +15°, +20° and +25° exorotation view, with a negative predictive value of 94.6% (+15°), 94.1% (+20°) and 96.1% (+25°). Positive predictive value for the exorotated views in combination with the standard lateral view was about 80% for all angles. (Table 2)

Interobserver reliability

Krippendorff's α for the detection of an os trigonum ranged from 0.33 (95% CI 0.02 to 0.58) to 0.68 (95% CI 0.53 to 0.83). Two projections scored 'substantial agreement' and 25° (α= 0.68). Regarding the detection of hypertrophic posterior process of the talus, the interobserver reliability varied between 0.16 and 0.41, with 15° as the only projection that scored 'moderate' reliability. (Table 3, Figure 4)

Table 1. Diagnostic accuracy (95% CI) of the different projection angles. Sensitivity, specificity and percentage correctly classified were presented for both os trigonum and hyperthrophic posterior talar process. SLV, standard lateral view.

Projection angle	**Os trigonum**						**Hypertrophic posterior talar process**					
	Sensitivity		**Specificity**		**% Correctly classified**		**Sensitivity**		**Specificity**		**% Correctly classified**	
-10°	32. 0%	(9.6-62.3)	97. 5%	(88.6-99.5)	70. 1%	(66.3-74.2)	22. 7%	(11.8-37.0)	82. 1%	(69.4-92.2)	49. 9%	(45.9-53.9)
-5°	33. 0%	(17.7-52.9)	96. 4%	(88.6-99.6)	66. 8%	(62.9-70.5)	48. 9%	(32.6-59.7)	78. 0%	(62.9-89.8)	58. 7%	(54.7-62.6)
SLV	49. 6%	(22.4-76.9)	95. 4%	(86.5-98.6)	71. 9%	(68.1-75.4)	37. 7%	(25.1-51.5)	79. 2%	(64.6-90.1)	55. 7%	(51.7-59.6)
+5°	51. 9%	(19.5-81.9)	91. 0%	(84.1-96.3)	72. 4%	(68.6-75.9)	51. 7%	(38.2-64.9)	82. 3%	(69.8-91.6)	63. 3%	(59.4-67.0)
+10°	69. 9%	(34.6-92.6)	92. 5%	(85.3-87.3)	76. 2%	(72.6-79.5)	55. 0%	(39.4-69.7)	78. 8%	(66.6-89.0)	63. 3%	(59.4-67.0)
+15°	90. 3%	(57.8-99.6)	96. 0%	(90.0-99.3)	81. 3%	(77.9-84.3)	65. 7%	(49.9-79.3)	91. 1%	(83.2-96.7)	73. 9%	(70.2-77.2)
+20°	81. 7%	(51.2-95.0)	89. 2%	(79.9-95.8)	76. 2%	(72.6-79.5)	61. 0%	(44.6-75.7)	91. 8%	(80.3-96.9)	70. 6%	(66.8-74.1)
+25°	89. 7%	(60.5-99.3)	95. 6%	(87.5-99.3)	77. 4%	(73.8-80.6)	60. 7%	(42.7-76.5)	90. 7%	(78.1-97.7)	69. 1%	(65.3-72.7)
+30°	70. 3%	(42.9-88.1)	94. 8%	(88.1-98.7)	77. 0%	(73.4-80.3)	56. 3%	(37.6-73.6)	87. 6%	(78.9-94.4)	68. 3%	(64.5-71.9)
+35°	63. 2%	(38.1-83.8)	95. 9%	(90.1-99.2)	77. 4%	(73.8-80.6)	54. 5%	(30.8-77.1)	87. 8%	(78.5-94.9)	66. 9%	(63.1-70.5)
+40°	45. 2%	(26.5-65.3)	97. 0%	(88.8-99.3)	72. 4%	(68.6-75.9)	42. 5%	(24.2-62.9)	91. 3%	(82.8-95.7)	64. 3%	(60.4-68.0)
+45°	34. 4%	(13.3-59.8)	93. 0%	(87.9-96.6)	70. 7%	(66.9-74.3)	30. 2%	(16.4-47.8)	94. 7%	(83.0-98.5)	58. 7%	(57.7-62.6)
+50°	16. 3%	(7.6-31.4)	97. 8%	(87.4-99.7)	62. 1%	(58.1-66.0)	9. 8%	(3.4-19.7)	87. 5%	(77.0-94.9)	46. 6%	(42.0-50.6)

Table 2. Diagnostic accuracy (95% CI) of combination of the Standard Lateral view and exorotated views. SLV, standard lateral view; PPV, positive predictive value, NPV, negative predictive value.

Projection angle	Sensitivity		Specificity		PPV		NPV	
				Os trigonum				
SLV and +10°	76, 9	*(46,2-94,7)*	86, 2	*(76,6-93,5)*	80, 5	*(59,3-91,5)*	83, 5	*(65,8-96,0)*
SLV and +15°	93, 2	*(70,7-99,7)*	87, 2	*(77,7-94,4)*	84, 3	*(70,1-92,9)*	94, 6	*(78,2-99,8)*
SLV and +20°	93, 1	*(70,6-99,6)*	80, 9	*(70-89,9)*	78, 3	*(63,5-87,9)*	94, 1	*(76,3-99,7)*
SLV and +25°	95, 7	*(73,6-99,4)*	85, 3	*(74,3-93,5)*	82, 8	*(67,9-91,9)*	96, 4	*(79,2-99,5)*
SLV and +30°	85, 9	*(63.0-97.0)*	84, 6	*(75,7-92)*	80, 5	*(65,7-90,0)*	89, 0	*(73,5-97,6)*
SLV and +35°	87, 3	*(68.0-97,1)*	89, 1	*(79,4-95,7)*	85, 5	*(70,9-94,3)*	90, 5	*(77,0-97,8)*
				Hypertrophic posterior process				
SLV and +10°	67, 8	*(51,7-80,6)*	62, 3	*(46,5-76,8)*	57, 1	*(41,7-72,0)*	72, 4	*(56,6-84,3)*
SLV and +15°	77	*(61,3-87,6)*	69, 5	*(55,3-81,6)*	65, 1	*(50,3-77,9)*	80, 3	*(65,9-89,9)*
SLV and +20°	74, 3	*(58,4-85,6)*	65, 8	*(50,5-79,3)*	61, 6	*(46,6-75,3)*	77, 6	*(62,2-88,2)*
SLV and +25°	77, 7	*(62,2-88,1)*	64, 8	*(52,4-75,4)*	62, 0	*(49,1-72,6)*	79, 7	*(65,2-89,6)*
SLV and +30°	75, 5	*(55,9-89,8)*	61, 8	*(48,8-73,9)*	59, 4	*(44,7-71,8)*	77, 3	*(60,0-90,7)*
SLV and +35°	73, 7	*(55,8-88.0)*	60, 5	*(46,8-73,3)*	58, 0	*(43,7-70,9)*	75, 7	*(58,9-89,2)*

Table 3. Interobserver reliability, using Krippendorff's α (95%CI).

Projection	Os Trigonum			Hypertrophic posterior talar process		
	α	**95% CI**	**Interpretation**	**α**	**95% CI**	**Interpretation**
-10°	0. 41	(0.17-0.63)	*Moderate*	0. 16	(0.08-0.38)	*Slight*
-5°	0. 38	(0.15-0.59)	*Fair*	0. 24	(0.02-0.45)	*Fair*
SLV	0. 42	(0.22-0.63)	*Moderate*	0. 24	(0.01-0.42)	*Fair*
+5°	0. 43	(0.23-0.63)	*Moderate*	0. 26	(0.06-0.47)	*Fair*
+10°	0. 53	(0.33-0.71)	*Moderate*	0. 27	(0.07-0.46)	*Fair*
+15°	0. 68	(0.53-0.83)	*Substantial*	0. 41	(0.20-0.58)	*Moderate*
+20°	0. 55	(0.38-0.71)	*Moderate*	0. 39	(0.20-0.58)	*Fair*
+25°	0. 63	(0.46-0.79)	*Substantial*	0. 40	(0.22-0.58)	*Fair*
+30°	0. 52	(0.35-0.70)	*Moderate*	0. 34	(0.16-0.52)	*Fair*
+35°	0. 51	(0.35-0.70)	*Moderate*	0. 38	(0.19-0.58)	*Fair*
+40°	0. 43	(0.20-0.62)	*Moderate*	0. 33	(0.13-0.54)	*Fair*
+45°	0. 42	(0.18-0.65)	*Moderate*	0. 24	(0.03-046)	*Fair*
+50°	0. 33	(0.02-0.58)	*Fair*	0. 23	(0.05-0.49)	*Fair*

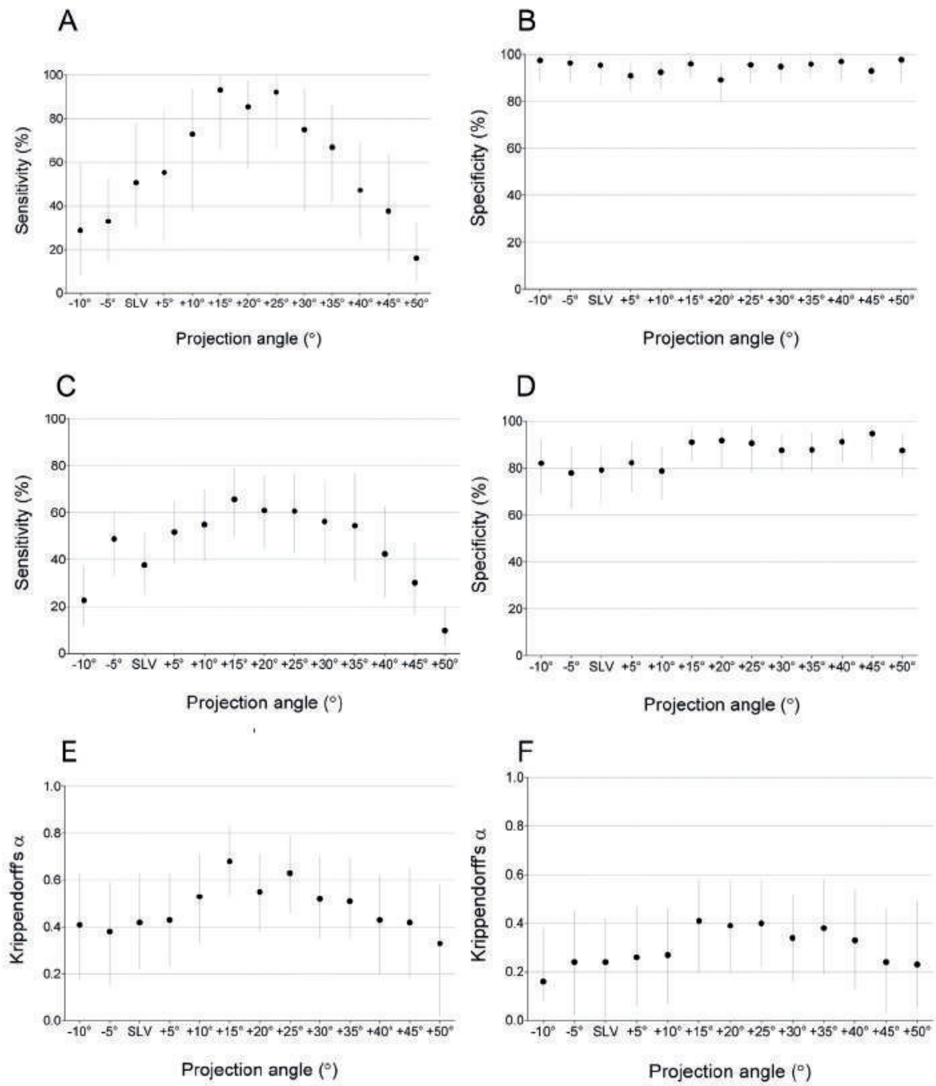


Figure 4. A. Sensitivity for detecting an os trigonum per projection angle. B. Specificity for detecting an os trigonum per projection angle. C Sensitivity for detecting an hypertropic posterior talar process per projection angle. D Specificity for detecting an hypertropic posterior talar process per projection angle. E. Interobserver reliability for detecting an os trigonum per projection angle. F. Interobserver reliability for detecting an hypertropic posterior talar process per projection angle. SLV, standard lateral view

DISCUSSION

This study shows that for detection of an osseous impediment, highest sensitivities are found for radiographic views with the foot in 15°, 20° or 25° degrees of exorotation for an os trigonum and 15°, 20°, 25°, 30° and 35° degrees of exorotation for a hypertrophic posterior talar process. Specificity is less dependent of the projection angle. Highest interobserver reliability is also found for the 15°, 20° and 25° degrees exorotated radiographic views. In this study, the sensitivity for detecting an os trigonum was higher in the exorotated views in comparison with the standard lateral view. As expected the combination of the routine standard lateral view in combination with exorotated views showed higher sensitivity. Similar results were found for the hypertrophic posterior process of the talus.

The results of the previous study by Wiegerinck et al. on the PIM-view are in line with the results in this study.[4] In that study, only the detection of an os trigonum was studied at a single projection angle of 25° of exorotation. Sensitivity and specificity of the PIM view were 82%-88% and 78%-93%, respectively, compared with 41%-71% (sensitivity) and 63%-83% (specificity) for the standard lateral radiograph.[4] In this study, we compared a wide range of projection angles to detect the optimal view in patients with posterior ankle impingement complaints for the detection of both os trigonum and hypertrophic posterior talar process. Historically, adapted radiographic projection angles have also been described for other ankle pathologies like anterior ankle impingement and fractures of the medial tubercle of the posterior talar process.[7 13-16] Both projection angles improved the diagnostic accuracy for conventional radiography, and have now a place in the standard diagnostic workup of these pathologies.

The use of DRR images enabled comparison of a large number of projection angles of the same ankle. Advantages of the use of DRRs are the limited costs and short time needed to achieve a large number of radiographs without exposing patients to additional radiation. Since the quality of the DRR images generally is slightly lower in comparison with real radiographs, it is expected that the accuracy found in this study is an underestimation of the true diagnostic accuracy. However, it should be taken into account that standard lateral radiographs are made in standing position, whereas CT scans are made without weight bearing. Therefore, DRR images generated from these CTs reflect a situation without weight bearing.

We did also determine the diagnostic accuracy of the combination of the standard lateral view and the oblique views. In general practice, routine radiographs (anteroposterior and standard lateral) will be made of each patient. In case of a large posterior process or clear separation of the os trigonum and talus the standard lateral view might be sufficient. Especially the smaller sized posterior talar process, small os trigonum and os trigonum with a close anatomical relation to the talus will benefit from the additional exorotated views.

The number of cases is relatively low, however, the large number of observers resulted in an acceptable number of observations. Interobserver differences in diagnostic imaging are a well- known problem, and it is evident that the observers affect the outcome of diagnostic studies.[17 18] The large number of different observers (121) from 39 different countries, with largely varying level of experience, increases the external validity of the results of this study.

Since there is no clear definition on the normal size of the lateral tubercle of the posterior talar process, the term hypertrophic or enlarges is somewhat arbitrary. As a result, the imperfect reference test resulted in a less reliable estimation of the diagnostic accuracy. However, the assessment of the posterior talar process or os trigonum, an exorotated view showed a higher sensitivity.

Projection angles were determined using a manually positioned CS. As reported there is an inaccuracy of a few degrees in orientation of the CS. The reproducibility was taken into account when choosing the 5°step size in changing the DRR projection angles. In clinical practice, there will be also a variation in orienting the foot relative to the direction of the X-ray projection.

This study underlines the additional diagnostic value of an exorotated view in comparison with the standard lateral view, with especially a higher sensitivity for detecting an os trigonum. Although CT and MRI are superior in the detection of causes of bony abnormalities, conventional radiographs are usually chosen as initial imaging modality in patients with posterior ankle impingement. The additional exorotated radiographic view can be made directly at the outpatient clinic, whereas in most clinics a new appointment has to be made for an additional MRI of CT scan. In cases of posterior ankle pain, the exorotated PIM view should be considered over, or in addition to, the standard lateral view. With the high negative predictive value, an os trigonum can be ruled out as cause of the complaints.

However, the initial diagnosis of posterior ankle impingement is by means of clinical examination. The exorotated lateral view can play a role in the preoperative planning. It can help determine whether the impediment is an os trigonum, a hypertrophic posterior talar process or soft-tissue.

Since this study did not show one single exorotated view to be superior, but a range of exorotated views with improved diagnostic accuracy, for clinical practice, we recommend to use a radiographic view with the foot in 25° of exorotation in the workup of patients with posterior ankle complaints. For this view, the patient is positioned with the medial side of the foot against the detector plate, thereby exorotating the foot approximately 25° in relation to the standard lateral view. This position makes the radiograph easy to reproduce.

In conclusion, this study underlines the additional diagnostic value of an exorotated view instead of or in addition to the standard lateral view in detecting an osseous impediment. We recommend to use the 25° exorotated view in combination with the routine standard lateral ankle view in the work up of patients with posterior ankle impingement.

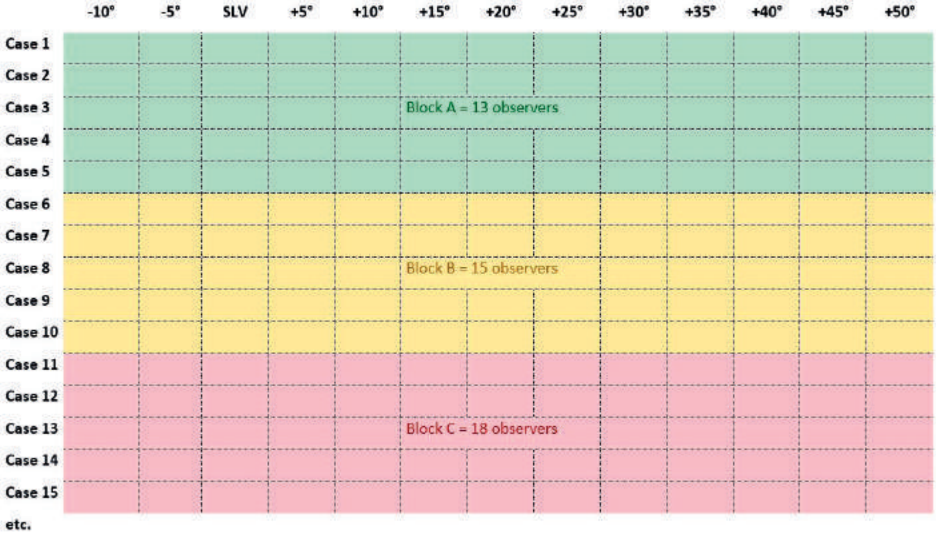
LITERATURE

1. van Dijk CN. Anterior and posterior ankle impingement. *Foot Ankle Clin* 2006;11(3):663-83.
2. Grogan DP, Walling AK, Ogden JA. Anatomy of the os trigonum. *J Pediatr Orthop* 1990;10(5):618-22.
3. Zwiers R, Baltes TPA, Opdam KTM, et al. Prevalence of Os Trigonum on CT Imaging. *Foot & ankle international* 2018;39(3):338-42. doi: 10.1177/1071100717740937 [published Online First: 2017/12/23]
4. Wiegerinck JI, Vroemen JC, van Dongen TH, et al. The posterior impingement view: an alternative conventional projection to detect bony posterior ankle impingement. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2014;30(10):1311-6. doi: 10.1016/j.arthro.2014.05.006 [published Online First: 2014/07/16]
5. Birkfellner W, Seemann R, Figl M, et al. Wobbled splatting--a fast perspective volume rendering method for simulation of x-ray images from CT. *Physics in medicine and biology* 2005;50(9):N73-84. doi: 10.1088/0031-9155/50/9/n01 [published Online First: 2005/04/22]
6. Schroeder WJ, Lorensen B, Martin K. The visualization toolkit: an object-oriented approach to 3D graphics: Kitware 2004.
7. van Dijk CN, Wessel RN, Tol JL, et al. Oblique radiograph for the detection of bone spurs in anterior ankle impingement. *Skeletal radiology* 2002;31(4):214-21.
8. Pepe MS. Comparing binary tests and regression analysis. The statistical evaluation of medical tests for classification and prediction: Oxford University Press, USA 2003:35-66.
9. Rasbash J, Goldstein H. Efficient Analysis of Mixed Hierarchical and Cross-Classified Random Structures Using a Multilevel Model. *Journal of Educational and Behavioral Statistics* 1994;19(4):337-50.
10. Hayes AF, Krippendorff K. Answering the Call for a Standard Reliability Measure for Coding Data. *Communication Methods and Measures* 2007;1(1):77-89. doi: 10.1080/19312450709336664
11. Krippendorff K. Estimating the reliability, systematic error and random error of interval data. *Educational and Psychological Measurement* 1970;30(1):61-70.
12. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *biometrics* 1977:159-74.
13. Tol JL, Verhagen RA, Krips R, et al. The anterior ankle impingement syndrome: diagnostic value of oblique radiographs. *Foot & ankle international* 2004;25(2):63-68.
14. Ebraheim NA, Karkare N, Gehling DJ, et al. Use of a 30-degree external rotation view for posteromedial tubercle fractures of the talus. *Journal of orthopaedic trauma* 2007;21(8):579-82. doi: 10.1097/BOT.0b013e31804ea0d9 [published Online First: 2007/09/07]
15. Ebraheim NA, Mekhail AO, Haman SP. External rotation-lateral view of the ankle in the assessment of the posterior malleolus. *Foot & ankle international* 1999;20(6):379-83.
16. Ebraheim NA, Patil V, Frisch NC, et al. Diagnosis of medial tubercle fractures of the talar posterior process using oblique views. *Injury* 2007;38(11):1313-17. doi: http://dx.doi.org/10.1016/j.injury.2007.04.025

17. Robinson PJ. Radiology's Achilles' heel: error and variation in the interpretation of the Rontgen image. *The British journal of radiology* 1997;70(839):1085-98. doi: 10.1259/bjr.70.839.9536897 [published Online First: 1998/04/16]
18. Brealey S, Westwood M. Are you reading what we are reading? The effect of who interprets medical images on estimates of diagnostic test accuracy in systematic reviews. *The British journal of radiology* 2007;80(956):674-7. doi: 10.1259/bjr/83042364 [published Online First: 2007/09/01]

APPENDIX

Appendix I. Example of the split-plot design used in this study.



Appendix II. Intra-observer variation of estimating local coordinate system in degrees rotation in relative to reference.

		Observer 1			Observer 2			Observer 3		
		x	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*
CT 1	*Mean difference*	0, 952	1, 222	-0,575	-0,503	-0,241	0, 847	-0,459	-0,974	-0,311
	SD	*0, 791*	*0, 656*	*0, 757*	*0, 709*	*2, 003*	*0, 298*	*0, 581*	*0, 873*	*0, 782*
CT 2	*Mean difference*	-0,272	0, 153	0, 555	0, 356	0, 793	-0,138	-0,158	-0,994	-0,806
	SD	*0, 549*	*0, 559*	*1, 192*	*0, 772*	*0, 757*	*0, 887*	*0, 840*	*1, 268*	*1, 797*
CT 3	*Mean difference*	-0,246	0, 551	1, 053	0, 215	0, 132	-0,017	0, 053	-0,675	-1,037
	SD	*0, 710*	*0, 438*	*1, 251*	*0, 579*	*0, 599*	*1, 141*	*1, 023*	*0, 671*	*1, 052*

CHAPTER 5

ENDOSCOPIC TREATMENT FOR POSTERIOR ANKLE IMPINGEMENT; HIGH PATIENT SATISFACTION AND LOW RECURRENCE RATE AT LONG TERM FOLLOW-UP

R. Zwiers
T.P.A. Baltes
J. I. Wiegerinck
G.M.M.J. Kerkhoffs
C. N. van Dijk

J ISAKOS 2018

ABSTRACT

Objectives

Good short-term outcomes have been described for endoscopic treatment of posterior ankle impingement. However, long-term outcome is unknown. The aim of this study is to determine the long-term patient satisfaction after endoscopic treatment and evaluate the recurrence rate of posterior ankle impingement. In addition, the aim of this study is to identify factors associated with favorable long-term outcome.

Methods

A consecutive series of patients treated endoscopically for posterior ankle impingement between 2000 and 2011 in the Academic Medical Centre in Amsterdam were retrospectively reviewed. Primary outcome was patient satisfaction. Secondary outcome measures were function, pain, recurrence rate and Foot Ankle Outcome Scores. In addition, factors associated with long-term outcome were identified.

Results

Two-hundred and three patients with 5-15 years of follow-up were included. Median satisfaction score was 8/10 and for 9/10 for function. Patients had no pain at follow-up. Outcome was similar for different types of impingement and type or level of sport participation. Symptoms recurred in 5% of the patients. In a multivariable analysis, additional flexor hallucis longus (FHL) tendinopathy was associated with lower satisfaction and a higher recurrence rate.

Conclusion

Long-term outcome of endoscopic treatment for posterior ankle impingement demonstrated good results, with high patient satisfaction, good functional outcome scores and a low rate of recurrence for all types of posterior ankle impingement. Type and level of sports did not influence outcome. Only the presence of FHL tendinopathy was associated with lower satisfaction and a higher recurrence rate.

INTRODUCTION

Posterior ankle impingement is a condition characterised by posterior ankle pain during plantar flexion. It is caused by a hyperplantarflexion trauma, recurrent microtrauma or overuse. It is often combined with anatomical variations like an os trigonum or a hypertrophic lateral tubercle of the posterior talar process.[1 2] Posterior ankle impingement is common in football players and ballet dancers and frequently associated with flexor hallucis longus (FHL) tendinopathy.[3]

Initial treatment is conservative, with ankle taping in order to avoid hyperplantarflexion in combination with corticosteroid injections. Since posterior ankle impingement is more common in a demanding active population, surgical treatment is often indicated. Surgical treatment consists of excision of the impediments, with or without release and debridement of the FHL tendon. Historically, surgery has been performed by an open technique. In 2000, an two- portal endoscopic hindfoot approach was described by the senior author.[4] For both open and endoscopic surgery, good short-term functional outcomes have been described,[5-9] although with less complications and shorter recovery time associated with endoscopic treatment.[10-12] It could be hypothesized that surgical treatment for posterior impingement could lead to formation of scar tissue, which on the long term could result in recurrence of complaints. However, no studies with long-term follow-up have been published.

Aim of this study is to determine the long-term patient satisfaction after endoscopic treatment and evaluate the recurrence rate of posterior impingement symptoms. In addition, the aim of this study is to identify factors associated with favourable long-term outcome.

METHODS

Population

A consecutive series of patients treated endoscopically for complaints associated with posterior ankle impingement between 2000 and 2011 in the Academic Medical Centre in Amsterdam were retrospectively recruited for this study. Diagnosis was made by two experienced orthopaedic surgeons (GK and CD) based on medical history, physical examination and the posterior impingement hyperplantarflexion test.[1] Other possible causes of posterior ankle pain were ruled out by using diagnostic imaging including conventional radiographs (posterior impingement view[13]), CT or MRI. Patients with a history of posterior ankle surgery or with severe ankle pathology, like osteoarthritis, rheumatoid arthritis or congenital bone deformations, were excluded. Furthermore, patients with complaints of bilateral impingement or those that underwent an additional procedure, like osteochondral defect repair or ligament reconstruction during the same surgical procedure were not included.

Study procedure

All patients were invited by mail to participate in this study. With the invitation, patients received a questionnaire containing Numeric Rating Scales (NRS) for satisfaction, pain and function, Foot Ankle Outcome Score (FAOS)[14], and additional questions on recurrence of complaints, function and satisfaction.

Demographic data and intraoperative findings were extracted from patient records and surgical reports, respectively. Intraoperative findings included the type of excision, for example, an os trigonum, hypertrophic lateral tubercle of the posterior talar process or soft tissue only. During surgery, the FHL tendon was assessed for signs of inflammation, partial rupture or degeneration.

This study was approved by the local Medical Ethical Committee (W12_237#12.17.0270).

Outcome measures

Patient satisfaction with treatment, functioning and pain were measured using an 11-point numeric rating scale, ranging from 0 to 10. For satisfaction and function, a score of 10 was regarded as the maximum score. For NRS pain, a score of 0 indicated no pain.

Functional outcome was assessed using the Dutch version of the FAOS. The FAOS is a self-administered questionnaire, validated in a Dutch speaking population, intending to evaluate functional limitations and symptoms during the last week related to foot and ankle disorders. The FAOS contains five domains: activities of daily living, symptoms, pain, sport activities and quality of life. High scores indicate less limitation. The Dutch version of the FAOS has showed good clinimetric properties in similar populations.[15] In addition, patients were asked whether they assessed their level of functioning as being normal, if they had returned to their pre-injury level of activity and whether they would choose to undergo the same procedure again.

In a subgroup analysis outcome of bony (excision of os trigonum or hypertrophic lateral tubercle) and soft tissue impingement were compared. In addition, outcome of football players, ballet dancers and professional athletes were presented separately. Outcomes of professional athletes were compared with those of patients who were not professional athletes.

Factors

The following factors were tested for association with outcome: gender, age at surgery, BMI, cause of onset (trauma or overuse), duration of symptoms, follow-up time, level of sport (professional, competitive or recreative), type of sport, type of impingement (bony or soft tissue), conservative treatment (corticosteroid injections or not) and presence of FHL tendinopathy.

Statistical analysis

Presentation of data was descriptive. Descriptive data were presented as frequencies with percentages in case of categorical data, and continuous variables as mean with standard deviation (SD) in case of approximately normal distribution or median with inter-quartile range (IQR) when data were not normally distributed. Distribution of the outcome measures was assessed using the Shapiro-Wilk test.

For subgroup analysis, differences were tested using the Mann-Whitney U test (two groups) and Kruskal-Wallis test (three groups).

Identification of factors associated with outcome was performed using multivariable logistic regression analysis using stepwise backward selection based on the AIC-criterion. Factors with a p-value <0.05 were considered statistically significant. Factors were presented as odds ratio (OR) with 95% CI.

Data were collected and entered in a SPSS database, statistical analyses were performed using Rstudio V.0.98.1103 (RStudio, Boston, Massachusetts, USA) and R V.3.1.3 (The R Foundation, Vienna, Austria).

RESULTS

Of the 333 patients who underwent ankle endoscopy for posterior ankle impingement, 66 were excluded due to bilateral symptoms, additional procedures and pre-existent severe ankle pathology. As a results, 267 patients were invited by mail, of whom 203 did return a completed questionnaires (response rate 76%).

Of the 203 respondents, 50% were men. The mean age at the time of surgery was 28 years. Median time from the onset of symptoms to surgery was 20 months. The median follow-up time was 10.8 years. The large majority was preoperatively involved in sports (97%), with a median Ankle Activity Score16 of 8. In 53% of the patients, there was a traumatic cause for onset of the symptoms. In a majority of the patients, there was a bony impingement, most commonly an os trigonum. Additional tendinopathy of the FHL was observed in 40% of the cases. (Table 1)

Soft tissue impingement appeared to be less common in men. The group of patients who underwent excision of an os trigonum were younger in comparison

Table 1. Baseline characteristics of 203 consecutive patient which had endoscopic surgery for posterior ankle impingement. FHL, flexor hallucis longus.

	Total		Bony impingement		Os trigonum		Hypetrophic lateral tubercle		Soft tissue		p-value
N=	203		168		91		48		35		
Male sex	103	*51%*	92	*55%*	47	*52%*	26	*54%*	11	*31%*	0. 01
Age (years)	28	*IQR 21-39*	28	*IQR 21-38*	24	*IQR 19-28*	30	*IQR 23-40*	33	*IQR 24-40*	<0.01
BMI	24. 2	*IQR 22.5-26.5*	24. 2	*IQR 22.7-26.6*	24. 1	*IQR 22.5-26.5*	24. 3	*IQR 22.7-25.9*	23. 8	*IQR 22.0-26.4*	0. 6
Duration of symptoms (months)	20	*IQR 10.0-40.5*	20. 5	*IQR 10-47.25*	20	*IQR 8-49*	20	*IQR 13-45.8*	12	*IQR 10.5-34*	0. 6
Traumatic cause	109	*54%*	90	*54%*	53	*58%*	25	*56%*	19	*54%*	0. 86
FHL tendinopathy	80	*39%*	62	*37%*	31	*34%*	19	*40%*	18	*51%*	0. 20
Ankle activity score [16]	8	*IQR 6-9*	8	*IQR 6-9*	9	*IQR 6-9*	8	*IQR 6-9*	8	*IQR 6-9*	0. 32
Level of sport											
Professional	37	*20%*	32	*21%*	22	*27%*	8	*19%*	5	*16%*	0. 29
Competitive	101	*55%*	84	*56%*	47	*57%*	21	*51%*	17	*23%*	
Recreational	45	*25%*	35	*23%*	14	*17%*	12	*29%*	10	*31%*	
Type of sport											
Football	69	*37%*	62	*41%*	36	*43%*	14	*35%*	7	*21%*	0. 54
Ballet	13	*7%*	12	*8%*	7	*8%*	4	*10%*	1	*3%*	
Running	17	*9%*	11	*7%*	7	*8%*	3	*8%*	6	*18%*	
Follow up time	10. 8	*SD 3.7*	10. 4	*SD 3.7*	10. 3	*SD 3.7*	9. 7	*SD 3.7*	12. 8	*SD 3.5*	<0.01

with the patients who underwent excision of a hypertrophic lateral tubercle or soft tissue.

Twenty percent of the respondents were professional athletes with football being the most common sport (33%). In comparison with the football players, ballet dancers were younger and more likely women. The patients participating in football more often reported a traumatic onset of complaints. (Table 2)

At follow-up high satisfaction and function scores were reported (median 8, IQR 7-10). Patients reported little residual pain both in rest and during sporting activities, with median NRS 0 (IQR 0-1.75) and NRS 1 (IQR 0-4), respectively. Similar results were found for the different types of impingement. (Figure 1)

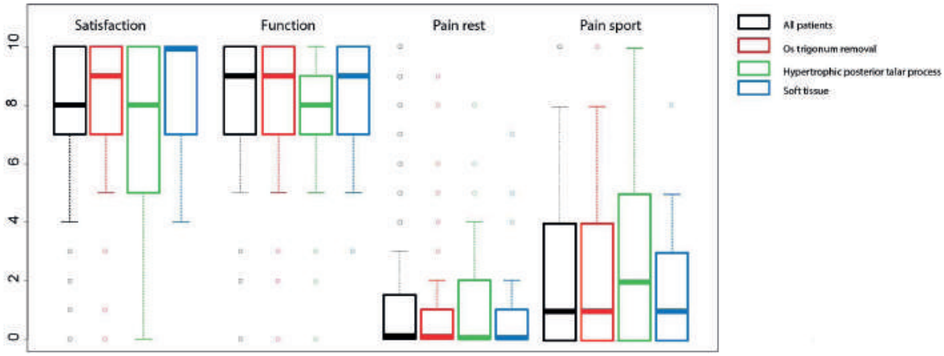


Figure 1. Boxplots (median, IQR, minimum and maximum) of the numerical rating scales for satisfaction, function, pain in rest and pain during sports activities for different types of posterior ankle impingement.

Ninety-one percent of patients assessed their ankle function as normal. Recurrence of symptoms only occurred in 5% of the patients. Eighty per cent would undergo the same operation under the same circumstances again and another 14% would consider it. (Table 3)

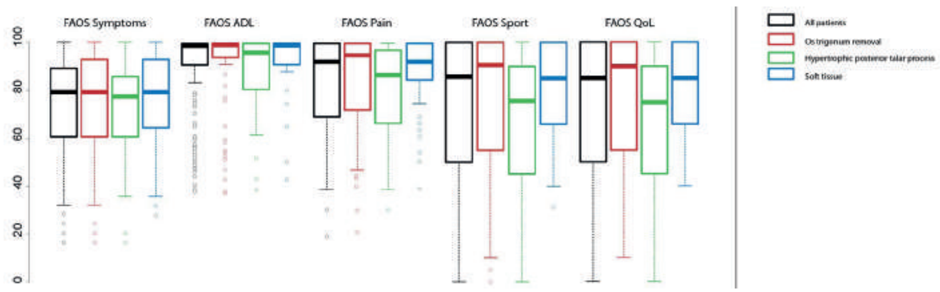


Figure 2. Boxplots (median, IQR, minimum and maximum) of the FAOS domains for different types of posterior ankle impingement.

Table 2. Characteristics of a subgroups of 69 athletes which underwent endoscopic treatment for posterior ankle impingement.

	N=	Age		Male		Traumatic onset		FHL tendinopathy		Type of impingement					
										Os trigonum		*Hypertrophic lateral tubercle*		*Soft tissue*	
Football	69	26	IQR 21.3-30.6	55	80%	40	56%	22	31%	36	63%	14	24%	7	12%
Ballet	13	21	IQR 16.3-26.2	1	8%	3	23%	6	46%	7	58%	4	33%	1	8%
p-value		*0. 01*		*<0.01*		*0. 03*		*0. 35*		*0. 86*					
Professional athletes	37	21	IQR 17.3-26.2	16	43%	19	51%	16	43%	22	65%	7	21%	5	15%
p-value		*<0.01*		*0. 20*		*0. 85*		*0. 70*		*0. 37*					

Table 3. Overview of recurrence rate and percentages of patients willing to undergo the same operation (endoscopic treatment for posterior ankle impingement) again in the same situation.

		Total	Os trigonum	Hypertrophic lateral tubercle	Soft tissue	Football	Ballet	Professional athlete
Recurrence rate		10 (5%)	5 (5%)	3 (7%)	0 (0%)	6 (9%)	0 (0%)	3 (8%)
Same operation again?	*Yes*	160 (80%)	75 (83%)	31 (70%)	28 (80%)	53 (78%)	12 (92%)	30 (83%)
	No	12 (6%)	5 (6%)	5 (11%)	1 (3%)	3 (4%)	1 (8%)	3 (8%)
	Maybe	28 (14%)	10 (11%)	8 (18%)	6 (17%)	12 (18%)	0 (0%)	3 (8%)

FAOS domains showed high scores for all types of impingement. (Figure 2) Regarding satisfaction, functional outcome and pain, football players, ballet dancers and professional athletes reported similar outcomes. (Figure 3)

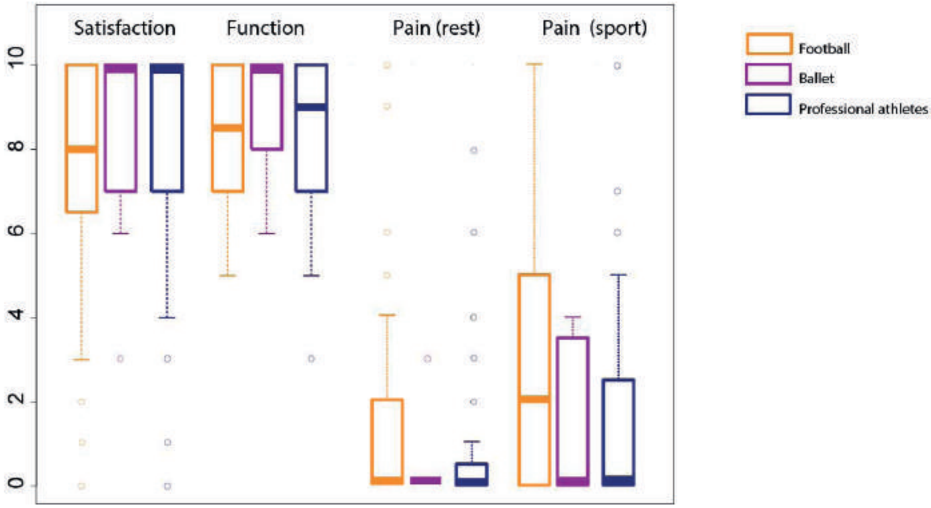


Figure 3. *Boxplots (median, IQR, minimum and maximum) of the numerical rating scales for satisfaction, function, pain in rest and pain during sports activities for football players, ballet dances and professional athletes.*

Factors

Regarding factors associated with outcome, the presence of FHL tendinopathy negatively correlated with satisfaction (OR 0.88) and positively with recurrence rate (OR 2.42). (Table 4)

Table 4. Overview of factors remaining in multivariable regression after stepwise backward selection. Showing the odds ratios and 95% CI. FHL, flexor hallucis longus; BMI, body mass index. * statistically significant.

	Beta	*p-value*	*Odds Ratio*	*95% CI*
Satisfaction				
FHL tendinopathy	-0.12	0. 04 *	0. 88	0. 78-0.98
Function				
Traumatic onset	0. 07	0. 06	1. 08	0. 99-1.17
Recurrence				
BMI	0. 30	0. 09	1. 35	0. 87-2.11
FHL tendinopathy	0. 44	0. 03 *	2. 42	1. 02-5.76

DISCUSSION

This study with a median follow-up of 10.8 years demonstrates that endoscopic treatment for posterior ankle impingement results in high patient satisfaction (NRS 8/10), good ankle function (NRS 9/10) and little residual pain (NRS 0/10). Recurrence rate of impingement after endoscopic treatment for posterior ankle impingement is low with 5% of the patients reporting return of complaints. In addition, the long-term outcome is not related to the type of posterior ankle impingement. Football players, ballet dancers and professional athletes reported similar results regarding functional outcome and satisfaction. Only the presence of FHL tendinopathy was associated with lower satisfaction (OR 0.88) and a higher recurrence rate (OR 2.42).

Literature

Studies with short term follow-up have shown good functional outcome, less complications and short recovery when compared with open surgery.[3 10-12] The results of this study demonstrate the good outcome to maintain over time. There is little literature on the difference in outcome between different types of impingement.[3] In a previous report of partially the same cohort of patients, favourable outcome was found for impingement which resulted from overuse when compared with post-traumatic impingement. These patients had higher AOFAS scores, shorter time to return to sport and were more likely to rate their outcome as 'excellent' or 'good'. Regarding bony and soft tissue impingement, in our earlier study we reported patients with bony impingement to have higher AOFAS scores and return to sport sooner when compared with soft tissue impingement.[7] However, another study found sooner return to sport activities after treatment of soft tissue impingement.[8] In this study we were not able to demonstrate an association between type of impingement and outcome. It seems likely that a soft tissue type of impingement carries a higher risk of recurrence of complaints based on the formation of scar tissue. However, the results of this study do not support that hypothesis. Also high-level athletes, football players and ballet dancers do not show a worse or better outcome. In previous studies, the type and level of sports are rarely reported, and there are no data on differences in outcome. Only the paper of Hamilton et al. reported better results for professional compared with amateur dancers.[5] In addition, in the current study, no differences in recurrence rates were found between professional athletes and non-professional athletes. There is no literature on recurrence rates after treatment of posterior ankle impingement. The combination of posterior impingement and FHL tendinopathy is frequently described. Hamilton et al. found the FHL tendon to be involved in 83%

of the dancers with posterior impingement. A recent systematic review showed associated FHL pathology to be present in 35% of the patients, this is in line with the findings in the current study (39%).[3] Hamilton et al. reported dancers with bony impingement without involvement of the FHL tendon, to have a shorter time to return to activity, compared with dancers with FHL tendinopathy or combined pathology.[5] However, this is the first study to report a negative correlation between the presence of FHL tendinopathy and satisfaction or recurrence rate. One of the strengths of this study is that in contrast to the majority of previous series, a validated outcome measure was used.

Limitations

Although we report on a large cohort with an acceptable response rate, the results should be interpreted in the light of its limitations. The retrospective design comes with inherent disadvantages, such as missing preoperative data on function and pain and the risk of recall bias. Since our orthopaedic department is a specialized ankle clinic and tertiary referral centre, the included population might differ from posterior ankle impingement populations in other series. In addition, among our patients were several high level athletes including some top level soccer players and ballet dancers who had emigrated and were therefore unavailable for follow-up. Since the aim of this study was to determine the long-term outcome, we did not report on early complications. Data on complications of the endoscopic technique were reported in previous studies.[7,17] The current cohort of patients is part of that report.

CONCLUSION

Long-term outcome of endoscopic treatment for posterior ankle impingement demonstrated good results, with high patient satisfaction, good functional outcome scores and a low rate of recurrence for all types of posterior impingement. Type and level of sports did not influence outcome. Only the presence of FHL tendinopathy was associated with lower satisfaction and a higher recurrence rate.

LITERATURE

1. van Dijk CN. Anterior and posterior ankle impingement. *Foot Ankle Clin* 2006;11(3):663-83.
2. Van Dijk CN, Vuurberg G, Batista J, et al. Posterior ankle arthroscopy: current state of the art. *Journal of ISAKOS: Joint Disorders & Orthopaedic Sports Medicine* 2017;2(5):269.
3. Ribbans WJ, Ribbans HA, Cruickshank JA, et al. The management of posterior ankle impingement syndrome in sport: a review. *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2015;21(1):1-10. doi: 10.1016/j.fas.2014.08.006 [published Online First: 2015/02/16]
4. van Dijk CN, Scholten PE, Krips R. A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2000;16(8):871-76.
5. Hamilton WG, Geppert MJ, Thompson FM. Pain in the posterior aspect of the ankle in dancers. Differential diagnosis and operative treatment. *J Bone Joint Surg Am* 1996;78(10):1491-500.
6. Abramowitz Y, Wollstein R, Barzilay Y, et al. Outcome of resection of a symptomatic os trigonum. *J Bone Joint Surg Am* 2003;85-A(6):1051-57.
7. Scholten PE, Sierevelt IN, van Dijk CN. Hindfoot endoscopy for posterior ankle impingement. *J Bone Joint Surg Am* 2008;90(12):2665-72.
8. Calder JD, Sexton SA, Pearce CJ. Return to training and playing after posterior ankle arthroscopy for posterior impingement in elite professional soccer. *Am J Sports Med* 2010;38(1):120-24. doi: 0363546509346390 [pii];10.1177/0363546509346390 [doi]
9. Galla M, Lobenhoffer P. Technique and results of arthroscopic treatment of posterior ankle impingement. *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2011;17(2):79-84. doi: 10.1016/j.fas.2010.01.004 [published Online First: 2011/05/10]
10. Zwiers R, Wiegerinck JI, Murawski CD, et al. Surgical treatment for posterior ankle impingement. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2013;29(7):1263-70. doi: 10.1016/j.arthro.2013.01.029 [published Online First: 2013/04/02]
11. Georgiannos D, Bisbinas I. Endoscopic Versus Open Excision of Os Trigonum for the Treatment of Posterior Ankle Impingement Syndrome in an Athletic Population: A Randomized Controlled Study With 5-Year Follow-up. *The American journal of sports medicine* 2017;45(6):1388-94. doi: 10.1177/0363546516682498 [published Online First: 2017/01/24]
12. Guo QW, Hu YL, Jiao C, et al. Open versus endoscopic excision of a symptomatic os trigonum: a comparative study of 41 cases. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2010;26(3):384-90. doi: S0749-8063(09)01034-2 [pii];10.1016/j.arthro.2009.08.029 [doi]
13. Wiegerinck JI, Vroemen JC, van Dongen TH, et al. The posterior impingement view: an alternative conventional projection to detect bony posterior ankle impingement. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of*

the Arthroscopy Association of North America and the International Arthroscopy Association 2014;30(10):1311-6. doi: 10.1016/j.arthro.2014.05.006 [published Online First: 2014/07/16]

14. Roos EM, Brandsson S, Karlsson J. Validation of the foot and ankle outcome score for ankle ligament reconstruction. *Foot & ankle international* 2001;22(10):788-94. doi: 10.1177/107110070102201004 [published Online First: 10/20]
15. Sierevelt I, Beimers L, Bergen C, et al. Validation of the Dutch language version of the Foot and Ankle Outcome Score. *Knee Surgery, Sports Traumatology, Arthroscopy* 2015;23(8):2413-19.
16. Halasi T, Kynsburg A, Tallay A, et al. Development of a new activity score for the evaluation of ankle instability. *Am J Sports Med* 2004;32(4):899-908.
17. Zengerink M, van Dijk CN. Complications in ankle arthroscopy. *Knee Surgery, Sports Traumatology, Arthroscopy* 2012;20(8):1420-31.

CHAPTER 6

OPEN VERSUS ENDOSCOPIC SURGICAL TREATMENT OF POSTERIOR ANKLE IMPINGEMENT; A META-ANALYSIS

R. Zwiers
T.N. Miedema
J.I. Wiegerinck
L. Blankevoort
C.N. van Dijk

Am J Sports Med 2020

ABSTRACT

Background

Surgical treatment of symptomatic posterior ankle impingement consists of resection of the bony impediment and/or debridement of soft tissue. Historically, open techniques were used to perform surgery with good results. However, since the introduction of endoscopic techniques, advantages attributed to these techniques are shorter recovery time, less complications and less pain.

Purpose

Primary purpose of this study was to answer the question whether endoscopic surgery for posterior ankle impingement was superior to open surgery in terms of functional outcome (American Orthopaedic Foot & Ankle Society [AOFAS] score). The secondary aim is to determine differences in return to full activity, patient satisfaction and complications.

Methods

MEDLINE, EMBASE (Classic), and CINAHL databases were searched. Publication characteristics, patient characteristics, surgical techniques, AOFAS scores, time to return to full activity, patient satisfaction and complication rates were extracted. The AOFAS score was the primary outcome measure. Data were synthesized, and continuous outcome measures (postoperative AOFAS score and time to return to full activity) were pooled using a random-effects inverse variance method. Random-effects meta-analysis of proportions using continuity correction methods was performed to determine the proportion of patients who were satisfied and who experienced complications.

Results

Thirty two studies were included in this review. No statistically significant difference was found in postoperative AOFAS scores between open surgery (88.0 [95%CI: 82.1-94.4]) and endoscopic surgery (94.4 [95%CI: 93.1-95.7]). There was no difference in proportion of patients that rated their satisfaction as good or excellent, 0.92 [95%CI: 0.88-0.95] versus 0.87 [95%CI: 0.79-0.96]), respectively. No significant difference in time to return to activity was found, 10.8 weeks [95%CI: 7.3-15.9] versus 9.1 weeks [95% CI: 7.8-10.5]. Pooled proportions of patients with postoperative complications were 0.15 [95%CI 0.11-0.19] for open surgery versus 0.08 [95% CI 0.05-0.14] for endoscopic surgery. Without the poor-quality studies this difference was statistically significant, 0.24 [95%CI 0.14-0.35] versus 0.02 [95%CI 0.00-0.06], respectively.

Conclusion

There was no statistically significant difference in postoperative AOFAS scores, patient satisfaction, and return to preinjury level of activity between open and endoscopic techniques. The proportion of who experienced a complication was significantly lower with endoscopic treatment when studies of poor methodological quality were excluded.

INTRODUCTION

Posterior ankle impingement is a clinical condition characterized by posterior ankle pain during plantar (hyper) flexion. Osseous impediments like an os trigonum or enlarged posterolateral talar process are often associated with this clinical entity. Pain can result from osseous or soft tissue impingement and be caused by a traumatic event or recurrent microtrauma caused by repetitive plantar flexion of the ankle. Posterior ankle impingement often occurs in the active population where activities require repetitive plantar flexion, for example in athletes and dancers, predominantly soccer players and ballet dancers. Diagnosis is made by the (hyper-)plantarflexion test, which is pathognomonic if the patient experiences recognizable pain.[1] Conventional radiographs and additional CT or MRI scan are used to confirm the diagnosis or rule out other pathology. Although evidence for its effectiveness is lacking, the initial intervention often consists of non-surgical treatment. Non-surgical treatment consists of physiotherapy, anti-inflammatory drugs and taping. Infiltration with corticosteroid has also been described as treatment. When these treatments fail and symptoms continue to be activity limiting, surgery may be indicated. [2]

Surgical treatment consists of resection of the bony impediment or resection of the hypertrophic soft tissue or scar tissue. The first description of surgical treatment of posterior ankle impingement was by Howse in 1982, he used a posteromedial approach to remove a bony impediment. [3] A posterolateral approach was introduced by Quirk. [4] Several studies reported good results after open surgery. In 1997 the first reports of an arthroscopic technique were published.[5] However, since the introduction of the 2-portal hindfoot technique in 2000, the endoscopic approach gained more popularity.[6] Advantages attributed to endoscopic techniques are shorter recovery time, less complications and less pain.[7] In a systematic review in 2013 endoscopic treatment was associated with less complications and shorter time to return to full activity. However the level of evidence was low and the methodological quality of the included studies limited.[8] Since then, studies with longer follow-up, larger sample size and higher methodological quality were published.[9-11]

Aim of this study is to answer the question whether endoscopic surgery for posterior ankle impingement is superior to open surgery in terms of functional outcome (AOFAS score). The secondary aim is to determine differences in return to full activity, patient satisfaction and complications.

METHODS

Search strategy and study selection

Study selection and data collection were performed using the PRISMA statement (Preferred Reporting Items of Systematic Reviews and Meta-Analysis).[12] To identify all available literature on surgical treatment of posterior ankle impingement the same systematic literature search was used as in the previous review.[8] MEDLINE, EMBASE (Classic), and CINAHL databases were searched using the search terms: ((ankle AND impingement) OR (ankle AND impingement AND syndrome) OR (os trigonum AND impingement) OR (os trigonum AND symptomatic) OR (Stieda AND process) OR ((talar or talus) AND compres*) OR (ankle AND osteophy*) OR ((talar OR talus) AND osteophy*) OR ((talar OR talus) AND impingement)) AND ((arthrosc*) OR (surgery OR procedures) OR (treatment)). The Cochrane Database of Clinical and Randomized Controlled Trials was additionally searched using the terms: "impingement" or "trigonum". There were no language or study type restrictions applied. Also no time frame was specified with respect to date of publication. A review of the reference lists of relevant papers was subsequently performed to verify that no relevant articles not identified through the database search were missing.

Identified titles and abstracts were screened by two independent reviewers and were excluded if they did not evaluate the outcome of surgical treatment of posterior ankle impingement. All potentially eligible articles were selected for full-text review.

Studies that met the following inclusion criteria were included: 1) reporting outcomes of surgical treatment for posterior ankle impingement (at least one of the following outcome measures: AOFAS score, patient satisfaction, time to return to full activity or complication rate), 2) reporting on more than ten subjects.

Exclusion criteria included reporting on patients that underwent combined treatment of other pathology in same procedure. Although, if studies reported the outcome of a subgroup of patients treated for posterior ankle impingement alone, separately, the study was included. Also excluded were studies reporting only on a pediatric population. All review and expert opinion articles were excluded from this study. No minimum follow-up was set.

Differences between the reviewers were discussed until agreement was achieved, the senior authors were consulted in case of persisting disagreement.

Data Extraction

Data extraction was performed independently by two reviewers. Publication characteristics, population characteristics, surgical techniques, AOFAS scores, time to return to full activity, patient satisfaction and complication rates were extracted. Level of evidence was assessed.[13] If necessary, additional information was requested from the authors of the studies in question.

Return to full activity was defined as either return to pre-injury level of activity, return to previous sports level or return to play. Regarding patient satisfaction, subjective outcomes were divided in excellent to good and fair to poor satisfaction. In case of Numeric Rating Scale (NRS) or Visual Analogue Scale (VAS) of satisfaction, a score of >7 was arbitrarily chosen as good to excellent satisfaction. Complications were defined as any deviation from the normal postoperative course. [14] Complications were further classified as “major” or “minor” complications. Deep infection, complex regional pain syndrome, severe nerve injury and re-operations within 30 days were defined as “major complications”.

Quality Assessment

The Downs and Black score was used to assess the methodological quality of the studies included in this review.[15] The Downs and Black checklist is composed of 27 questions. Question 27 was modified, instead of rating according to an available range of study powers, whether the study performed a power calculation. The maximum score of question 27 was 1 instead of 5 in the original checklist and therefore the maximum score was 28.[16] Downs and Black score ranges were given corresponding quality levels: excellent (26–28); good (20–25); fair (16–19); and poor (≤15). [17]

Disagreement was resolved after discussion among the reviewers and in consultation with the senior author.

Statistical analysis

Statistical analyses were performed using R Studio, version 1.0.153 (R Studio, Boston, MA, USA) R version 3.6.0 (the R Foundation, Vienna, Austria).

Mean with standard deviations were extracted. In case only the range and no measure of variance was reported, standard deviation was estimated according to the formulas of Wan et al.[18]

Pooled estimates were calculated for continuous outcomes using inverse-variance methods. A random-effects model using log transformed means was performed with the metamean function of the meta package in R.

For binomial data a random-effects meta-analysis for proportions was performed to calculate pooled proportions with the metaprop function of the meta package. The commonly used logit transformation with a continuity corrections was used for binomial outcome equal to 0 or 1 were used.

Pooled estimates were presented using forest plots. The DerSimonian-Laird method was used to estimate the between-study variance (Tau-squared).[19] Heterogeneity was assessed using I^2 and 95% confidence intervals were presented for all pooled estimates.

In addition to the analysis of pooled data from all studies, an sub-analysis was performed of pooled data from studies scoring 'fair' to 'excellent' methodologic quality according to the Downs and Black score (>15). For post-operative AOFAS score sub-analyses were performed for short-term (<24 months), mid-term (24-60 months) and long-term follow-up (>60 months). In addition, sub-analyses were performed for studies reporting on return to full activity with a postoperative rehabilitation protocol without weight-bearing restrictions or immobilization, and studies reporting on an athlete population.

Spearman's ρ correlation coefficient was used to assess the relation between year of publication and methodological quality score.

RESULTS

Of the 2331 titles identified during the initial search, a total of 32 articles were included in this review (Figure 1). Of the included studies, only one was a randomized controlled trial (RCT) [10], the remaining were level IV studies. Twenty-three studies were of 'poor' methodological quality (Downs and Black score ≤15), eight scored 'fair' and the quality of the only randomized trial was rated as 'good' (Downs and Black score 24). The median (modified) Downs & Black score was 15 (IQR 13-16). (Table 1) There was a statistically significant correlation between publication year and methodological quality (ρ 0.34, p= 0.03) (Figure 2).

A total of twenty-two studies reported on endoscopic treatment. Nine studies reported on open surgical techniques and one reported on both. There was a considerable heterogeneity regarding population characteristics, outcome measures and follow-up time. (Table 1)

Six different surgical approaches were identified, i.e. two open and four endoscopic techniques. (Table 1) For open surgery a lateral [10 20 27], medial [26 43 47 50] or both approaches [11 23 25] were used. Regarding endoscopic techniques, the two-portal hindfoot technique [7 10 21 22 28 30 32-35 37-39 41 42 44-46 48 49], the two-lateral-portal technique [24 29], the three-lateral-portal technique [40] and a lateral subtalar arthroscopy [44] technique were identified.

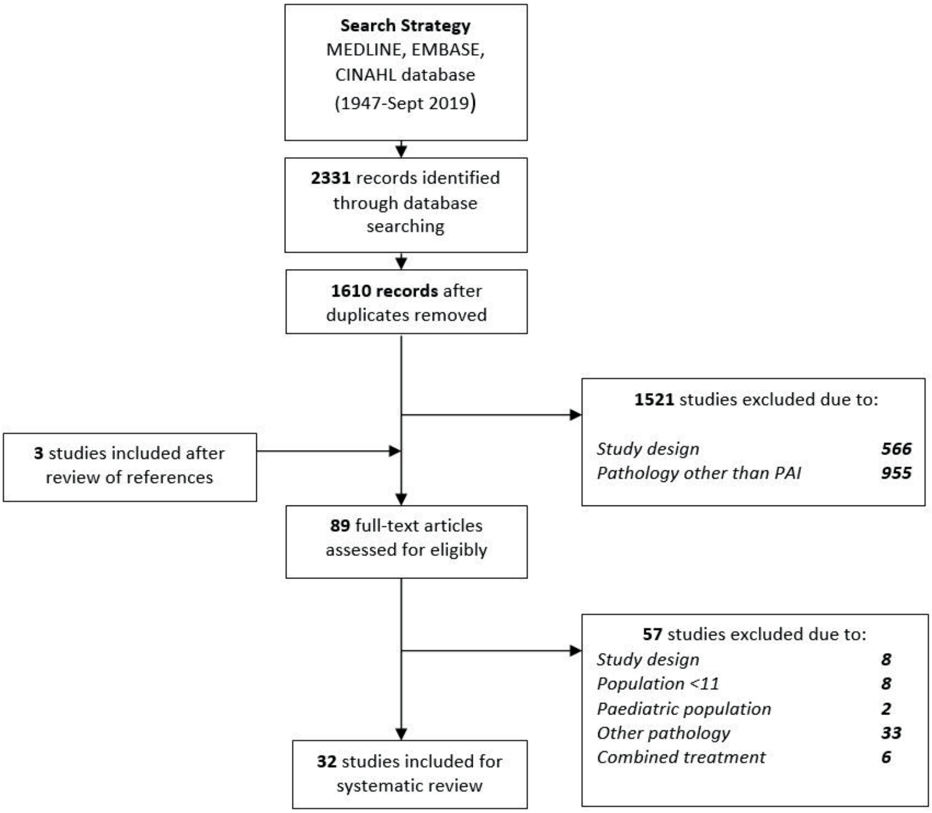


Figure 1. Flowchart of search and selection procedure.

Clinical outcome – postoperative AOFAS score

Nineteen studies (500 patients) reported the post-operative AOFAS score, of which one presented both short-term and long-term follow up. (Table 2) Since most studies did not report the difference in AOFAS score before and after treatment with the variance, it was not possible to pool the treatment effect. There was no statistically significant difference in the post-operative AOFAS score between open surgery (88.0 [95%CI: 82.1-94.4]) and endoscopic surgery (94.4 [95%CI: 93.1-95.7]). If only the studies of fair and good methodological quality were included, 6 studies (251 patients), there was no statistically significant difference between both groups 85.4 [95%CI: 81.3-89.7] versus 90.6 [95%CI: 87.4-94.0] for endoscopic treatment. In addition, subgroup analyses of different duration of follow-up (short-term-, mid-term- and long-term follow-up) did not reveal a difference between open and endoscopic surgery. (Figures 3 and 4)

Table 1. Overview of included studies and population characteristics. AOFAS, American Orthopaedic Foot & Ankle Society; FAOS, Foot and Ankle Outcome Score; FHL, flexor hallucis longus; NR, not reported; VAS, visual analog scale.

Study	Year	Type of study	Level of evidence	Patients (ankles)	M/F	Included pathologies	Type of Surgery	Primary outcome measure	Quality Assessment Downs & Black [15]
Abramowitz [20]	2003	Retrospective Case Series	IV	41	33/ 8	Symptomatic os trigonum	Open, *lateral*	AOFAS score	17
Calder [21]	2010	Retrospective Case Series	IV	27	33/ 0	Bony and soft-tissue impingement	Endoscopic, *2-portal hindfoot*	Return to Sport	16
Galla [22]	2011	Retrospective Case Series	IV	30	19 / 11	Bony impingement	Endoscopic, *2-portal hindfoot*	VAS	15
Hamilton [23]	1996	Retrospective Case Series	IV	28 (31)	11/ 18	Bony and soft-tissue impingement, with and without FHL tendinopathy	Open, *lateral/medial*	Patient Satisfaction	13
Horibe [24]*	2008	Retrospective Case Series	IV	11	NR	Symptomatic os trigonum	Endoscopic, *2-lateral portals*	AOFAS score	7
Jourdel [25]	2005	Retrospective Case Series	IV	21	17 / 4	Bony and soft-tissue impingement	Open, *lateral/medial*	AOFAS score	12
Labs [26]	2002	Retrospective Case Series	IV	24	4 /20	Bony impingement	Open, *medial*	Kitaoka score	13
Marotta [27]	1992	Retrospective Case Series	IV	12 (15)	3 / 9	Symptomatic os trigonum	Open, *lateral*	Pain/ Complaints	10
Nickisch [28] *	2012	Retrospective Case Series	IV	80	33/ 47	Symptomatic os trigonum	Endoscopic, *2-portal hindfoot*	Complications	19
Noguchi [29]	2010	Retrospective Case Series	IV	12	9/ 3	Bony and soft-tissue impingement	Endoscopic, *2-lateral portals*	AOFAS score	13
Ogut [30] *	2011	Retrospective Case Series	IV	14	10/ 4	Bony and soft-tissue impingement	Endoscopic, *2-portal hindfoot*	AOFAS score	16
Scholten [31] *	2008	Prospective Case series	IV	55	30/ 25	Bony and soft-tissue impingement	Endoscopic, *2-portal hindfoot*	AOFAS score	17

Table 1. Overview of included studies and population characteristics. AOFAS, American Orthopaedic Foot & Ankle Society; FAOS, Foot and Ankle Outcome Score; FHL, flexor hallucis longus; NR, not reported; VAS, visual analog scale. (continued)

Study	Year	Type of study	Level of evidence	Patients (ankles)	M/F	Included pathologies	Type of Surgery	Primary outcome measure	Quality Assessment Downs & Black [15]
Smith [32] *	2009	Retrospective Case Series	IV	14	NR	Symptomatic os trigonum with and without FHL tendinopathy	Endoscopic, *2-portal hindfoot*	Patient satisfaction	8
Tey [33]	2007	Retrospective Case Series	IV	13 (15)	6 / 7	Bony impingement	Endoscopic, *2-portal hindfoot*	AOFAS score	14
Willits [34]	2008	Retrospective Case Series	IV	15 (16)	8 / 7	Bony impingement	Endoscopic, *2-portal hindfoot*	AOFAS score	14
Wredmark	1991	Retrospective Case Series	IV	13	4 / 9	Bony impingement	Open, *medial*	Return to Sport	11
Zwiers [35]	2018	Retrospective Case Series	IV	203	103/ 100	Bony and soft-tissue impingement	Endoscopic, *2-portal hindfoot*	Patient satisfaction	18
Weiss [36]	2015	Retrospective Case Series	IV	24	13/ 11	Symptomatic os trigonum	Endoscopic, *2-portal hindfoot*	AOFAS score	14
Vila [37]	2014	Retrospective Case Series	IV	38	21/ 17	Bony impingement	Endoscopic, *2-portal hindfoot*	AOFAS score	14
Smyth [38]	2013	Retrospective Case Series	IV	22	9/ 13	Bony impingement	Endoscopic, *2-portal hindfoot*	FAOS score	15
Rietveld <1> [11]	2018	Retrospective Case Series	IV	190	34/ 156	-	*Open, Medial and lateral approach*	Patient satisfaction	15
Rietveld <2> [39]	2018	Retrospective Case Series	IV	42	4/ 38	-	Endoscopic, *2-portal hindfoot***	Patient satisfaction	10
Park [40]	2013	Retrospective Case Series	IV	23	20/ 3	Symptomatic os trigonum	Endoscopic, 3-portal lateral	AOFAS score	10
Morelli [41]	2017	Retrospective Case Series	IV	12	3/ 9	Symptomatic os trigonum	Endoscopic, *2-portal hindfoot*	AOFAS score	15

Table 1. Overview of included studies and population characteristics. AOFAS, American Orthopaedic Foot & Ankle Society; FAOS, Foot and Ankle Outcome Score; FHL, flexor hallucis longus; NR, not reported; VAS, visual analog scale. (continued)

Study	Year	Type of study	Level of evidence	Patients (ankles)	M/F	Included pathologies	Type of Surgery	Primary outcome measure	Quality Assessment Downs & Black [15]
Miyamoto [42]	2017	Retrospective Case Series	IV	61	46/ 15	-	Endoscopic, *2-portal hindfoot*	AOFAS score	16
Georgiannos [10]	2017	Randomized controlled trial	I	52	38/ 14	Symptomatic os trigonum	Endoscopic, *2-portal hindfoot* vs open surgery	AOFAS score	24
Coetzee [43]	2015	Retrospective Case Series	IV	37	6/ 31	Symptomatic os trigonum	Open, medial approach	AOFAS score	8
Ahn [44]	2013	Retrospective comparative study	IV	28	20/ 8	Symptomatic os trigonum	Endoscopic, *2-portal hindfoot* vs subtalar arthroscopy	AOFAS score	18
Cuellar-Avaroma [45]	2017	Retrospective Case Series	IV	24	19/ 5	Bony impingement	Endoscopic, *2-portal hindfoot*	AOFAS score	15
Carreira [46]	2015	Retrospective Case Series	IV	20	6/ 14	Symptomatic os trigonum	Endoscopic, *2-portal hindfoot*	AOFAS score	13
Heyer [47]	2017	Retrospective Case Series	IV	40	39/ 1	Symptomatic os trigonum	Open, medial approach	Patient satisfaction	14
Lopez Valerio [48]	2015	Retrospective Case Series	IV	20	19/ 1	Symptomatic os trigonum	Endoscopic, *2-portal hindfoot*	VAS	14

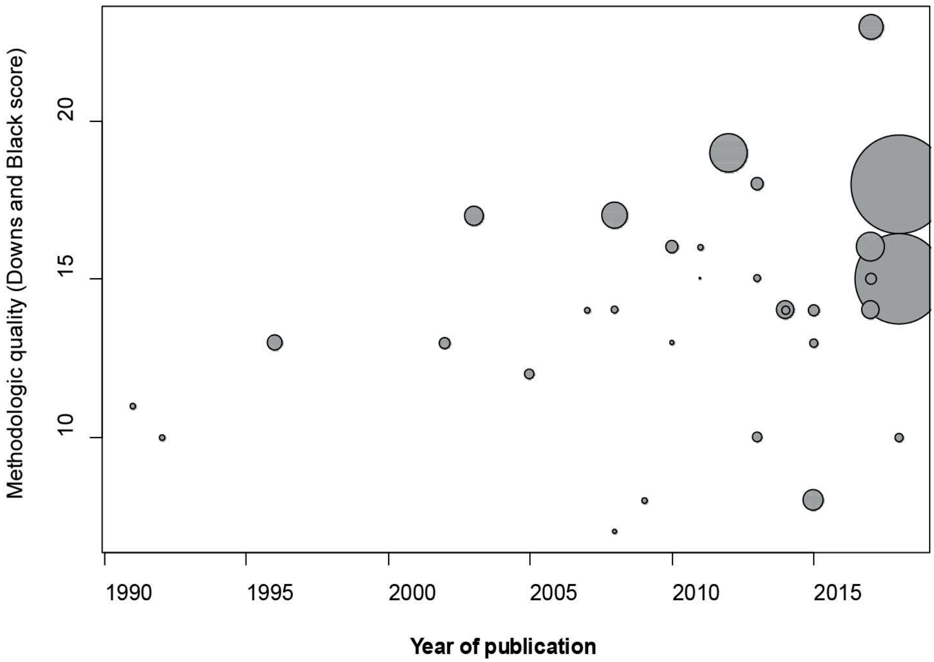


Figure 2. Plot of included studies, size of the dots represents the sample size of the study.

Patient satisfaction

Thirteen studies (717 patients) reported on patient satisfaction. (Table 2) There was no difference in proportion of patients that rated their satisfaction as good or excellent between open and endoscopic surgery, 0.92 [95%CI: 0.88-0.95] versus 0.87 [95%CI: 0.79-0.96). (Figure 5)

Time to return to full activity

Return to full activity or sport was reported in twenty studies (534 patients). (Table 2) No statistically significant difference in time to return to activity was found between open surgery and endoscopic surgery, i.e. 10.8 weeks [95%CI: 7.3-15.9] versus 9.1 weeks [95% CI: 7.8-10.5]. (Figure 6A) The subgroup analysis of fair and good quality studies also did not show a statistically significant difference between open and endoscopic surgery (15.2 weeks [95%CI 8.8-25.9] versus 8.1 weeks [95%CI 6.8-9.6]). (Figure 6B) The subgroup analyses of studies reporting on an athlete population and comparing early range of motion and weight-bearing as tolerated versus immobilization did not show a difference.

Table 2. Overview of outcome measures. * = part of the population of the study included, ** = Author requested for additional information, # = Data originally reported as mean. § = 27 patients were also included in the study by Scholten et al.[7], these patient were excluded from meta-analysis. AOFAS, American Orthopaedic Foot & Ankle Society; FAOS, Foot and Ankle Outcome Score; FHL, flexor hallucis longus; NR, not reported; VAS, visual analog scale.

	Patients (procedures)	Age (years)	Follow-up (months)	AOFAS (pre-op)	AOFAS (post-op)	Return to Full Activity (weeks)	Patient Satisfaction		Complications		
							Excellent/ Good	Fair/ Poor	Major	Minor	Total
Open surgery, lateral approach											
Abramowitz 2003 [20]	41	27. 0	44. 0	51. 7	87. 6	20. 0	37	4	1 (2.4%)	9 (22.0%)	10 (24.4%)
Marotta 1992 [27]	12 (15)	23. 0	28. 0	-	-	12. 0	-	-	0 (0.0%)	2 (13.3%)	2 (13.3%)
Rietveld 2018 <1> [11]	84	19	3. 7	-	-	-	76	8	0 (0.0%)	10 (12.0%)	10 (12.0%)
Georgiannos 2017 [10]	26	26. 0	60. 0	66. 2	87. 5	11. 5	-	-	1 (3.8%)	5 (19.2%)	6 (23.1%)
Open surgery, medial approach											
Labs 2002 [26]	24	21. 9	26. 2	-	-	-	18	6	0 (0.0%)	2 (14.2%)	2 (14.2%)
Wredmark 1991	13	20. 0	22. 0	-	-	7. 0	-	-	0 (0.0%)	0 (0.0%)	0 (0.0%)
Rietveld 2018 <1> [11]	101	19	6. 3	-	-	-	92	9	2 (2.0%)	10 (9.9%)	12 (11.9%)
Heyer 2017 [47]	40	19. 2	48. 0	-	-	7. 9	38	2	0 (0.0%)	4 (10.0%)	4 (10.0%)
Coetzee 2015 [43]	44	18. 8	46. 1	-	-	-	42	2	1 (2.3%)	2 (4.5%)	3 (6.8%)
Open surgery, medial and lateral approach											
Jourdel 2005 [25]	21	33. 0	60. 0	-	96. 3	-	19	1	2 (9.5%)	3 (14.3%)	5 (23.8%)
Hamilton 1996 [23]	32	21. 5	83. 5	-	-	-	24	8	0 (0.0%)	6 (18.8%)	6 (18.8%)
Endoscopic surgery, 2-portal hindfoot endoscopy [6]											
Galla 2011 [22] **	30	46. 0	9. 7	60. 0	90. 0	-	-	-	3(10.0%)	3 (10.0%)	6 (20.0%)
Nickisch 2012 [28] **	80	33. 8	15. 4	-	-	-	-	-	1 (1.3%)	5 (6.3%)	6 (7.5%)
Ogut 2011 [30] **	14	33. 3	31. 6	53. 6	84. 2	-	-	-	0 (0.0%)	0 (0.0%)	0 (0.0%)

Scholten 2008 [31] # **	55	31. 5	38. 0	71. 1	90. 0	12. 9	41	14	0 (0.0%)	1 (1.8%)	1 (1.8%)
Smith 2009 [32] **	14	-	12. 0	-	-		12	2	1 (7.1%)	1 (7.1%)	2 (14.2%)
Tey 2007 [33]	13(15)	21. 0	36. 0	84. 4	98. 5	12. 0	-	-	0 (0.0%)	1 (6.7%)	1 (6.7%)
Willits 2008 [34]	15(16)	25. 0	32. 0	-	91. 0	23. 2	15	0	0 (0.0%)	6 (37.5 %)	6 (37.5%)
Zwiers 2018 [35] §	203	28. 0	129. 6	-	-	-	167	36	-	-	-
Weiss 2015 [49]	24	36. 7	26. 0	55. 3	92. 3	`6.0	-	-	0 (0.0%)	1 (4.2%)	1 (4.2%)
Vila 2014 [37]	38	27. 9	27. 6	67. 4	97. 1	11. 8	-	-	0 (0.0%)	0 (0.0%)	0 (0.0%)
Smyth 2013 [38] +	18	28. 6	25. 0	-	-	12. 6	-	-	1 (5.6%)	1 (5.6%)	2 (11.1%)
Rietveld 2018 <2> [39] *	19	21. 9	23. 0	-	98. 7	-	15	4	0 (0.0%)	10 (52.6%)	10 (52.6%)
Morelli 2017 [41]	12	26. 3	38. 9	67. 8	96. 0	8. 7			0 (0.0%)	1 (8.3%)	1 (8.3%)
Miyamoto 2017 [42]	61	27. 5	24. 0	73. 4	95. 4	9. 2			0 (0.0%)	0 (0.0%)	0 (0.0%)
Cuellar-Avaroma 2017 [45]	24	31. 8	27. 3	76. 7	97. 2	18. 4	23	1	1 (4.2%)	1 (4.2%)	2 (8.4%)
Carriera 2015 [46]	20	21	38. 2	75. 0	94. 9	-	-	-	0 (0.0%)	2 (10.0%)	2 (10.0%)
Lopez Valerio 2014 [48]	20	24. 8	78. 6	-	-	6. 7	-	-	0 (0.0%)	0 (0.0%)	0 (0.0%)
Ahn 2013 [44]	12	29. 9	30. 0	64. 8	89. 9	8. 0	-	-	0 (0.0%)	1 (3.6%)	1 (3.6%)
Georgiannos 2017 [10]	26	25. 4	60. 0	`65.8	92. 4	7. 1	-	-	1 (3.8%)	0 (0.0%)	1 (3.8%)
Calder 2010 [21]	27	25. 0	23. 0	-	-	5. 9	-	-	0 (0.0%)	1 (3.7%)	1 (3.7%)
Endoscopic surgery, 3-lateral portal subtalar arthroscopy technique [40]											
Park 2013 [40]	23		18. 0	71. 3	94. 7	6. 7	-	-	0 (0.0%)	0 (0.0%)	0 (0.0%)
Endoscopic surgery, 2- posterolateral portal subtalar arthroscopy technique [24]											
Horibe 2008 [24] **	11	21. 4	33. 8	71. 0	99. 0	< 12.0	-	-	0 (0.0%)	0 (0.0%)	0 (0.0%)
Noguchi 2010 [29]	12	46. 0	9. 7	68	98. 3	5. 9	-	-	0 (0.0%)	1 (8.3%)	1 (8.3%)
Endoscopy surgery, original 2-portal subtalar arthroscopy technique [5]											
Ahn 2013 [44]	16	29. 8	30. 0	63. 8	89. 9	7. 5	-	-	0 (0.0%)	1 (6.3%)	1 (6.3%)

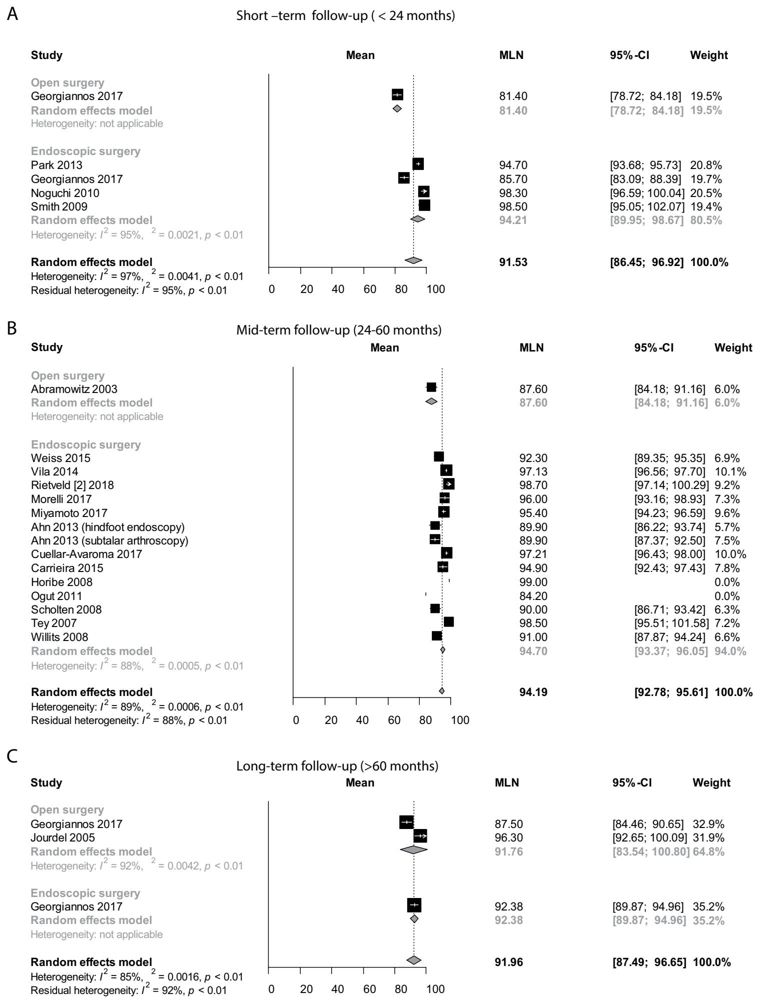


Figure 3. Forest plot of postoperative AOFAS scores. A. Studies with short-term follow-up. B. Studies with mid-term follow-up. C. Studies with long-term follow-up.

Complications

Complications were reported in 31 studies (1028 patients). (Table 2) Pooled proportions of patients with postoperative complications were 0.15 [95%CI 0.11-0.19] for open surgery versus 0.08 [95% CI 0.05-0.14] for endoscopic surgery. (Figure 7A) Without the 'poor' quality studies this difference was statistically significant 0.24 [95%CI 0.14-0.35] versus 0.02 [95%CI 0.00-0.06], respectively. (Figure 7B) Types of complications were different between endoscopic and open surgery. (Table 3)

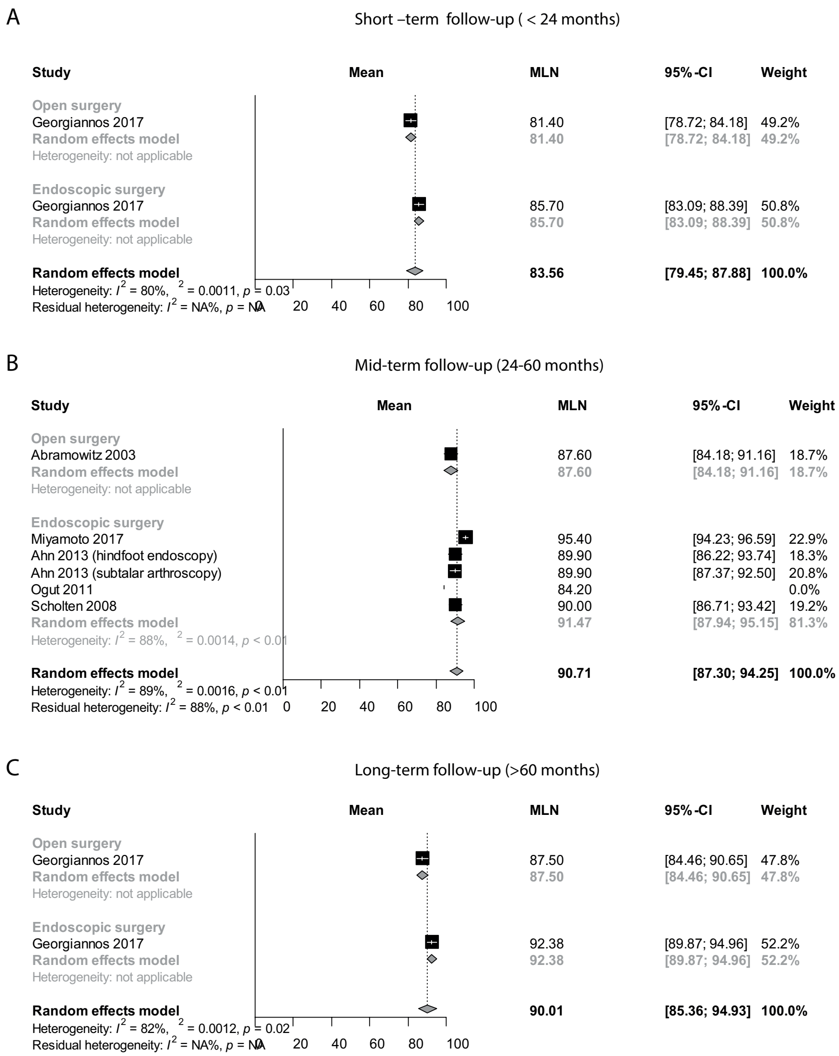


Figure 4. Forest plot of postoperative AOFAS scores, sub analysis with only studies with fair or good methodological quality included (Downs and Black score >15). A. Studies with short-term follow-up. B. Studies with mid-term follow-up. C. Studies with long-term follow-up.

DISCUSSION

This systematic review underlines the good clinical outcomes of surgical treatment of posterior ankle impingement with open and with endoscopic surgery. Pooling the data of the available studies showed no statistically significant difference in postoperative AOFAS score, patient satisfaction, return to pre-injury level of activity and major complication rate between open and endoscopic techniques.

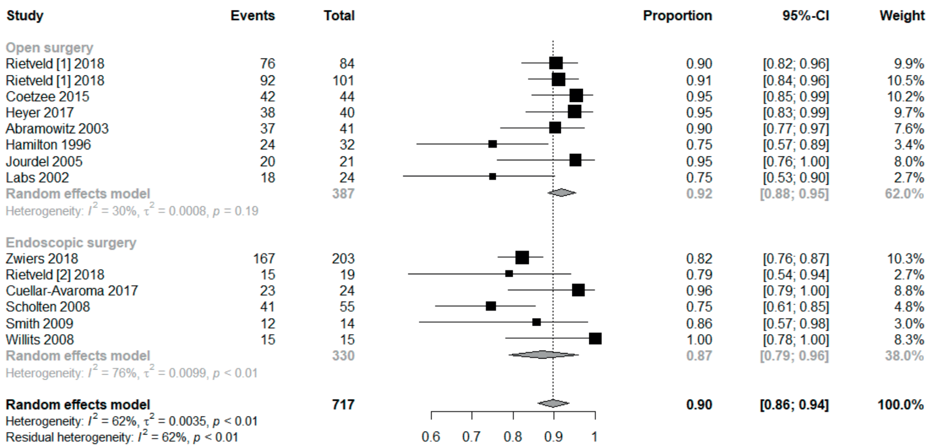


Figure 5. Forest plot of proportion of patients with good or excellent satisfaction.

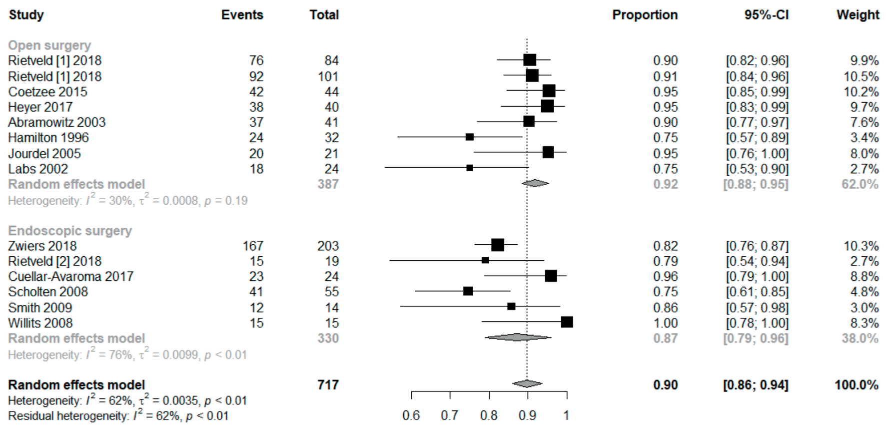


Figure 6. A. Forest plot of mean time to return to full activity after surgery. B. Forest plot of mean time to return to full activity after surgery, sub analysis with only studies with fair or good methodological quality included (Downs and Black score >15).

However, the complication rate was statistically significantly lower with endoscopic treatment, when studies of poor methodological quality were excluded. The only study with good methodological quality, i.e. a RCT, reported favorable outcomes for endoscopic surgery in terms of lower complication rate and lower time to return to pre-injury level of sports as compared to open surgery.[10]

After the first systematic review in 2013[8], two literature reviews were published. Ribbans et al.[51] performed a literature review on the management of posterior ankle impingement in athletes, whereas Rietveld et al.[52] focused on outcome in dancers in particular. Both reviews did not pool the outcomes of the included studies, due to heterogeneity in population and outcome measures. Over

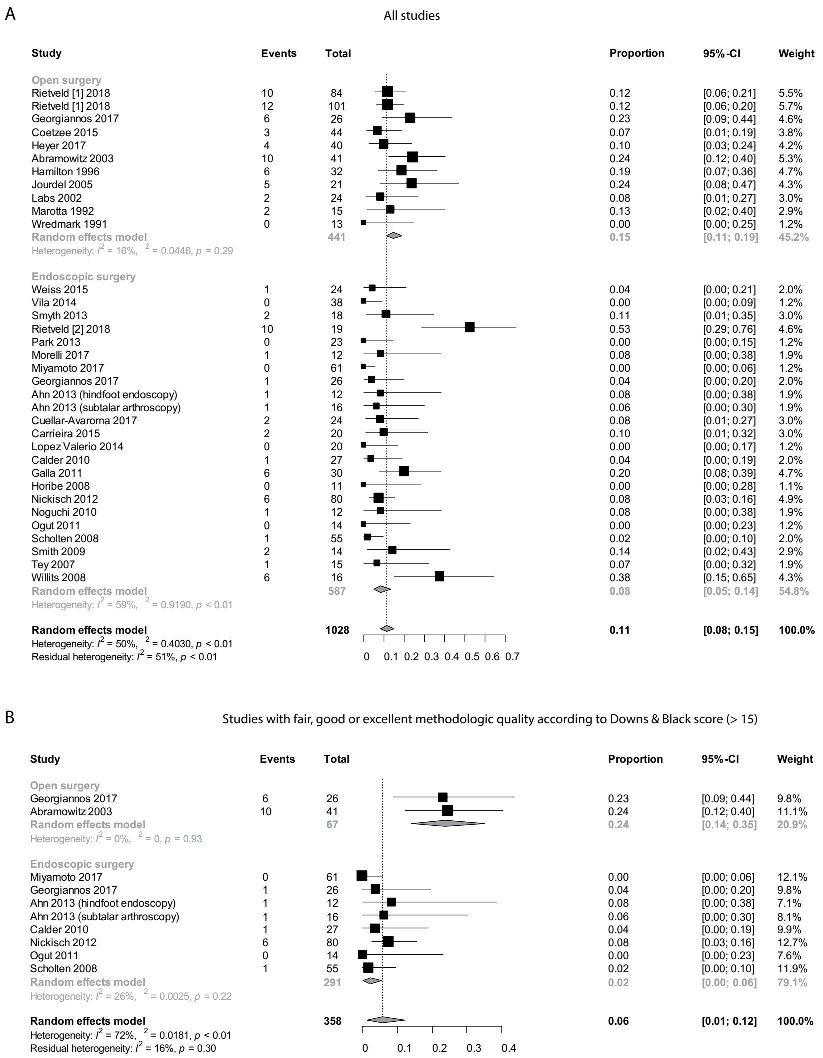


Figure 7. A. Forest plot of proportion of complications in all studies. B. Forest plot of proportion of complication, sub analysis with only studies with fair or good methodological quality included (Downs and Black score >15).

the last years there has been an increase in publications assessing the outcomes of the surgical treatment of posterior ankle impingement. Guo et al. compared open and endoscopic treatment in a study that included patients with additional anterior ankle arthroscopy.[53] This study was excluded in the current review. They reported similar outcome in terms of functional outcome, patient satisfaction and complications. However, time to return to sport was shorter in the endoscopic group. Complications rates in the current review were 13.6% and 7.7% for open and endoscopic treatment respectively, confirming the data reported in the 2013

Table 3. List of reported complications

		Open surgery *(n=440)*	Endoscopic surgery *(n=587)*	Total *(n=1027)*
Major				
	Deep infection	0	2	2
	Complex regional pain syndrome (CRPS)	7	2	9
	Re-operation needed	1	4	5
		8 (1.8%)	**8 (1.4%)**	**16 (1.6%)**
Minor				
	Mild nerve symptoms (temporary)	21	19	40
	Mild nerve symptoms (persistent)	6	0	6
	Superficial infection	11	3	14
	Haematoma	7	6	13
	Persistent leakage	3	4	7
	Scar problems	3	0	3
	Achilles tightness/stiffness	1	5	6
		52 (11.8%)	**37 (6.3%)**	**89 (8.7%)**
Total		**60 (13.6%)**	**45 (7.7%)**	**105 (10.2%)**

review. Ribbans et al. in their review reported a complication rate of 14.7% for open surgery versus 4.8% for endoscopic treatment.[51]

The findings of this study should be interpreted in the light of its limitations. Although this is the first study to provide pooled estimates of outcome, caution is warranted when extrapolating the estimated means to the general population. The methodological quality of the included studies is limited, with the majority of the studies being retrospective small case series. These studies come with their corresponding bias. For example, it is expected that there is a large amount of publication bias, since good outcomes are more likely to be published. Sub-analysis with exclusion of the poor quality studies were performed to explore their effect on outcome measures. In this additional analysis the statistically significant difference in postoperative AOFAS score at short- and midterm follow-up disappeared. In contrast, the difference regarding minor complications was only significant in the sub-analysis.

The included studies had a large heterogeneity in terms of level of activity of the study population, follow-up time and outcome measures. To minimize the heterogeneity strict inclusion criteria were used and sub-analyses for activity level, postoperative treatment and follow up time were performed. Unfortunately, this resulted in low numbers for definitive analysis. Outcome measures used in this study also have their disadvantages. Since most of the included studies did not provide a variance of the difference in pre and postoperative AOFAS scores, we were not able to pool the treatment effect. Time to return to full activity was not clearly defined in each study. When the description did not fit our definition of return to full activity, the study was not included in the analysis.

The results of this study provide evidence for good clinical outcome of surgical treatment of patients with posterior ankle impingement. Endoscopic approaches yield similar clinical and functional outcomes in comparison with open techniques, however, with lower complication rates. In addition, according to the only randomized study endoscopic treatment may result in shorter recovery time, an important outcome measure in the high demanding population of ballet dancers and professional athletes. More unbiased studies are needed to draw more robust conclusions on superiority of one of the surgical treatment options.

CONCLUSION

This meta-analysis showed no statistically significant difference in postoperative AOFAS score, patient satisfaction and return to pre-injury level of activity between open and endoscopic techniques. The proportion of who experienced a complication was significantly lower with endoscopic treatment when studies of poor methodological quality were excluded.

LITERATURE

1. van Dijk CN. Anterior and posterior ankle impingement. *Foot Ankle Clin* 2006;11(3):663-83.
2. Van Dijk CN. Anterior and posterior ankle impingement. *Foot and ankle clinics* 2006;11(3):663-83.
3. Howse AJ. Posterior block of the ankle joint in dancers. *Foot Ankle* 1982;3(2):81-84.
4. Quirk R. Talar compression syndrome in dancers. *Foot & ankle* 1982;3(2):65-68.
5. Marumoto JM, Ferkel RD. Arthroscopic excision of the os trigonum: a new technique with preliminary clinical results. *Foot & ankle international* 1997;18(12):777-84.
6. van Dijk CN, Scholten PE, Krips R. A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2000;16(8):871-76.
7. Scholten P, Sierevelt I, Van Dijk C. Hindfoot endoscopy for posterior ankle impingement. *The Journal of Bone & Joint Surgery* 2008;90(12):2665-72.
8. Zwiers R, Wiegerinck JI, Murawski CD, et al. Surgical treatment for posterior ankle impingement. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2013;29(7):1263-70. doi: 10.1016/j.arthro.2013.01.029 [published Online First: 2013/04/02]
9. Zwiers R, Baltes TP, Wiegerinck JI, et al. Endoscopic treatment for posterior ankle impingement: high patient satisfaction and low recurrence rate at long-term follow-up. *Journal of ISAKOS: Joint Disorders & Orthopaedic Sports Medicine* 2018;3(5):269-73.
10. Georgiannos D, Bisbinas I. Endoscopic Versus Open Excision of Os Trigonum for the Treatment of Posterior Ankle Impingement Syndrome in an Athletic Population: A Randomized Controlled Study With 5-Year Follow-up. *The American journal of sports medicine* 2017;45(6):1388-94. doi: 10.1177/0363546516682498 [published Online First: 2017/01/24]
11. Rietveld A, Haitjema S. Posterior Ankle Impingement Syndrome and M. Flexor Hallucis Longus Tendinopathy in Dancers Results of Open Surgery. *Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science* 2018;22(1):3-10. doi: 10.12678/1089-313x.22.1.3 [published Online First: 2018/03/08]
12. Moher D, Liberati A, Tetzlaff J, et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *Journal of Clinical Epidemiology* 2009;62(10):1006-12. doi: 10.1016/j.jclinepi.2009.06.005
13. Wright JG, Swiontkowski MF, Heckman JD. Introducing levels of evidence to the journal: LWW, 2003.
14. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Annals of surgery* 2004;240(2):205-13. doi: 10.1097/01.sla.0000133083.54934.ae [published Online First: 2004/07/27]
15. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998;52(6):377-84.

16. Korakakis V, Whiteley R, Tzavara A, et al. The effectiveness of extracorporeal shockwave therapy in common lower limb conditions: a systematic review including quantification of patient-rated pain reduction. *British journal of sports medicine* 2018;52(6):387-407.
17. Hooper P, Jutai JW, Strong G, et al. Age-related macular degeneration and low-vision rehabilitation: a systematic review. *Canadian Journal of Ophthalmology* 2008;43(2):180-87.
18. Wan X, Wang W, Liu J, et al. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC medical research methodology* 2014;14(1):135.
19. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Controlled clinical trials* 1986;7(3):177-88.
20. Abramowitz Y, Wollstein R, Barzilay Y, et al. Outcome of resection of a symptomatic os trigonum. *J Bone Joint Surg Am* 2003;85-A(6):1051-57.
21. Calder JD, Sexton SA, Pearce CJ. Return to training and playing after posterior ankle arthroscopy for posterior impingement in elite professional soccer. *Am J Sports Med* 2010;38(1):120-24. doi: 0363546509346390 [pii];10.1177/0363546509346390 [doi]
22. Galla M, Lobenhoffer P. Technique and results of arthroscopic treatment of posterior ankle impingement. *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2011;17(2):79-84. doi: 10.1016/j.fas.2010.01.004 [published Online First: 2011/05/10]
23. Hamilton WG, Geppert MJ, Thompson FM. Pain in the posterior aspect of the ankle in dancers. Differential diagnosis and operative treatment. *J Bone Joint Surg Am* 1996;78(10):1491-500.
24. Horibe S, Kita K, Natsu-ume T, et al. A novel technique of arthroscopic excision of a symptomatic os trigonum. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2008;24(1):121-24. doi: S0749-8063(07)00535-X [pii];10.1016/j.arthro.2007.04.019 [doi]
25. Jourdel F, Tourne Y, Saragaglia D. [Posterior ankle impingement syndrome: a retrospective study in 21 cases treated surgically]. *Revue de chirurgie orthopedique et reparatrice de l'appareil moteur* 2005;91(3):239-47. [published Online First: 2005/06/25]
26. Labs K, Leutloff D, Perka C. Posterior ankle impingement syndrome in dancers—a short-term follow-up after operative treatment. *Foot and ankle surgery* 2002;8(1):33-39.
27. Marotta JJ, Micheli LJ. Os trigonum impingement in dancers. *Am J Sports Med* 1992;20(5):533-36.
28. Nickisch F, Barg A, Saltzman CL, et al. Postoperative complications of posterior ankle and hindfoot arthroscopy. *Journal of Bone and Joint Surgery - Series A* 2012;94(5):439-46. doi: http://dx.doi.org/10.2106/JBJS.K.00069
29. Noguchi H, Ishii Y, Takeda M, et al. The advantage of arthroscopic excision of posterior ankle impingement syndrome. *Arthroscopy - Journal of Arthroscopic and Related Surgery* 2012;28(6 SUPPL. 1):e30. doi: http://dx.doi.org/10.1016/j.arthro.2012.04.115
30. Ogut T, Ayhan E, Irgit K, et al. Endoscopic treatment of posterior ankle pain. *Knee Surg Sports Traumatol Arthrosc* 2011;19(8):1355-61. doi: 10.1007/s00167-011-1428-x [doi]
31. Scholten PE, Sierevelt IN, van Dijk CN. Hindfoot endoscopy for posterior ankle impingement. *J Bone Joint Surg Am* 2008;90(12):2665-72.

32. Smith WB, Berlet GC. Posterior ankle impingement: the role of posterior ankle arthroscopy. *Techniques in Foot & Ankle Surgery* 2009;8(2):94-98.
33. Tey M, Monllau JC, Centenera JM, et al. Benefits of arthroscopic tuberculoplasty in posterior ankle impingement syndrome. *Knee Surgery, Sports Traumatology, Arthroscopy* 2007;15(10):1235-39.
34. Willits K, Sonneveld H, Amendola A, et al. Outcome of posterior ankle arthroscopy for hindfoot impingement. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2008;24(2):196-202.
35. Zwiers R, Baltes TPA, Wiegerinck JI, et al. Endoscopic treatment for posterior ankle impingement: High patient satisfaction and low recurrence rate at long-term follow-up. *Journal of ISAKOS* 2018;3(5):269-73. doi: http://dx.doi.org/10.1136/jisakos-2017-000175
36. Weiss W, Crates J, Barber FA. An arthroscopic technique for the excision of a symptomatic os trigonum. *Arthroscopy - Journal of Arthroscopic and Related Surgery* 2014;30(6 SUPPL. 1):e28-e29. doi: http://dx.doi.org/10.1016/j.arthro.2014.04.063
37. Vila J, Vega J, Mellado M, et al. Hindfoot endoscopy for the treatment of posterior ankle impingement syndrome: a safe and reproducible technique. *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2014;20(3):174-9. doi: 10.1016/j.fas.2014.03.002 [published Online First: 2014/08/12]
38. Smyth NA, Murawski CD, Levine DS, et al. Hindfoot arthroscopic surgery for posterior ankle impingement: a systematic surgical approach and case series. *The American journal of sports medicine* 2013;41(8):1869-76. doi: 10.1177/0363546513489489
39. Rietveld A, Hagemans FMT. Operative Treatment of Posterior Ankle Impingement Syndrome and Flexor Hallucis Longus Tendinopathy in Dancers Open Versus Endoscopic Approach. *Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science* 2018;22(1):11-18. doi: 10.12678/1089-313x.22.1.11 [published Online First: 2018/03/08]
40. Park CH, Kim SY, Kim JR, et al. Arthroscopic excision of a symptomatic os trigonum in a lateral decubitus position. *Foot & ankle international* 2013;34(7):990-4. doi: 10.1177/1071100712475062 [published Online First: 2013/05/23]
41. Morelli F, Mazza D, Serlorenzi P, et al. Endoscopic Excision of Symptomatic Os Trigonum in Professional Dancers. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2017;56(1):22-25. doi: 10.1053/j.jfas.2016.09.015 [published Online First: 2016/12/19]
42. Miyamoto W, Miki S, Kawano H, et al. Surgical outcome of posterior ankle impingement syndrome with concomitant ankle disorders treated simultaneously in patient engaged in athletic activity. *Journal of orthopaedic science : official journal of the Japanese Orthopaedic Association* 2017;22(3):463-67. doi: 10.1016/j.jos.2016.12.017 [published Online First: 2017/01/15]
43. Coetzee JC, Seybold JD, Moser BR, et al. Management of Posterior Impingement in the Ankle in Athletes and Dancers. *Foot & ankle international* 2015;36(8):988-94. doi: 10.1177/1071100715595504 [published Online First: 2015/07/15]
44. Ahn JH, Kim YC, Kim HY. Arthroscopic versus posterior endoscopic excision of a symptomatic os trigonum: a retrospective cohort study. *The American journal of sports medicine* 2013;41(5):1082-9. doi: 10.1177/0363546513480614 [published Online First: 2013/03/22]

45. Cuellar-Avaroma A, King-Hayata MA, Martinez-de Anda MC, et al. [Endoscopic treatment for the posterior impingement of the ankle]. *Acta ortopedica mexicana* 2017;31(1):24-29. [published Online First: 2017/07/26]
46. Carreira DS, Vora AM, Kozy J. Arthroscopic treatment of posterior impingement of the hindfoot. *Orthopaedic Journal of Sports Medicine* 2015;3(7 Supplement 2) doi: http://dx.doi.org/10.1177/2325967115S00043
47. Heyer JH, Rose DJ. Os Trigonum Excision in Dancers via an Open Posteromedial Approach. *Foot & ankle international* 2017;38(1):27-35. doi: 10.1177/1071100716665576 [published Online First: 2016/08/24]
48. Lopez Valerio V, Seijas R, Alvarez P, et al. Endoscopic repair of posterior ankle impingement syndrome due to os trigonum in soccer players. *Foot & ankle international* 2015;36(1):70-4. doi: 10.1177/1071100714552078 [published Online First: 2014/09/25]
49. Weiss WM, Sanders EJ, Crates JM, et al. Arthroscopic Excision of a Symptomatic Os Trigonum. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2015;31(11):2082-8. doi: 10.1016/j.arthro.2015.04.086 [published Online First: 2015/06/17]
50. Wredmark T, Carlstedt CA, Bauer H, et al. Os trigonum syndrome: a clinical entity in ballet dancers. *Foot & ankle* 1991;11(6):404-06.
51. Ribbans WJ, Ribbans HA, Cruickshank JA, et al. The management of posterior ankle impingement syndrome in sport: a review. *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2015;21(1):1-10. doi: 10.1016/j.fas.2014.08.006 [published Online First: 2015/02/16]
52. Rietveld A, Hagemans FMT, Haitjema S, et al. Results of Treatment of Posterior Ankle Impingement Syndrome and Flexor Hallucis Longus Tendinopathy in Dancers: A Systematic Review. *Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science* 2018;22(1):19-32. doi: 10.12678/1089-313x.22.1.19 [published Online First: 2018/03/08]
53. Guo QW, Hu YL, Jiao C, et al. Open versus endoscopic excision of a symptomatic os trigonum: a comparative study of 41 cases. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2010;26(3):384-90. doi: S0749-8063(09)01034-2 [pii];10.1016/j.arthro.2009.08.029 [doi]

CHAPTER 7

SURGICAL TREATMENT FOR POSTEROMEDIAL TALAR PROCESS FRACTURES

R. Zwiers
P.A.J. de Leeuw
E.M.A. Wiegerinck
C.N. van Dijk

Foot Ankle Surg 2019

ABSTRACT

Purpose

The first descriptions on medial talar tubercle fractures are attributed to Cedell. He described avulsion fractures of the insertion of the posterior talotibial ligament. However the true etiology has not been established. Since little is known about these fractures, they are easily misdiagnosed as simple ankle sprains. Untreated, these fractures may lead to chronic ankle pain. To improve the understanding of the etiology and outcome of these fractures a systematic review was conducted of all cases of isolated fractures of the medial tubercle of the posterior talar process. In addition we present the first series of competitive athletes treated by means of the two-portal hindfoot approach for isolated medial talar tubercle fractures.

Methods

A systematic search was performed to identify all cases of medial tubercle fractures. Data on trauma mechanism, clinical presentation, imaging and treatment were extracted. In addition we retrospectively report on the results of endoscopically treated patients in our institution over the last fifteen years. Of all patients Numeric Rating Scores (NRS) for Satisfaction, Pain and Function, Foot Ankle Outcome Scores (FAOS), return to sport and complications were reported.

Results

Eighteen articles were included reporting on 33 patients with an isolated fracture or avulsion of the posteromedial talar process. Most of the fractures occurred during sport activities (58%), followed by motor vehicle accidents (21%) and fall from height (12%). Of the activities during sport, 73% resulted following an ankle sprain. Reasonable to good outcomes are described in cases treated with immobilization, open reduction internal fixation or open excision.

Of the nine patients treated in our institution, five were male and the median age was 29. All were participating in sports at a competitive level, with four of them being a professional athlete. In most patients the diagnosis was made more than a year after initial trauma. Ankle sprain was most common trauma mechanism. In some patients it was evident the avulsion was part or the deep portion of the deltoid ligament, however in two cases it was more likely an avulsion of the flexor hallucis longus (FHL) retinaculum.

The median follow-up was 69 months (IQR 12.0-94.3). At final follow-up patients had little pain, NRS 1. Median NRS for satisfaction and function were 7 and 8, respectively. All patients did resume sport activities, however only four reached the preinjury level. Of the five patients that did not return to their pre-injury

level of activity, two were professional athletes at the end of their career, and retired not due to ankle complaints. One complication was reported.

Conclusion

Fractures of the medial tubercle are rare and based on the available literature there is not one distinct trauma mechanism. Based on literature no recommendation for treatment can be made. Our results show endoscopic excision of the fragment as a save alternative for open surgical treatment.

INTRODUCTION

The posterior talar process comprises a medial and a lateral tubercle. Although the tubercles vary considerably in size, the lateral tubercle is usually larger.[1] Fractures of the posterior talar process are mentioned in early reports on the origin of the os trigonum. Several surgeons and anatomists thought the os trigonum originates following a fracture of the posterior talar process.[2 3] Nowadays, it is generally accepted that the os trigonum is the result of a non¬fused secondary ossification center and that a fracture of the lateral tubercle (Shepherd's fracture) and an os trigonum are distinct entities.

The first descriptions on medial tubercle fractures are attributed to Cedell.[4] However, a true medial tubercle fracture was first addressed by Borsay in 1952.[5] He reported on two cases in which he distinguished the injury from a lateral tubercle fracture or os trigonum. Cedell described four cases of an avulsion fracture of the insertion of the posterior talotibial ligament or the posterior part of the deltoid ligament, he assumed this to be the result of forceful dorsiflexion with a pronated foot. Other mechanisms mentioned are direct trauma to the posteromedial talus,[6] impingement of the sustentaculum tali on the posterior process during supination[7] or forced dorsiflexion.[8] (Figure 1)

The incidence of medial tubercle fractures is unknown, the available evidence consists of case reports. In the early phase these fractures can easily be misdiagnosed as deltoid ankle sprains, since patient presentation is identical and fragments are usually not visible on 'standard' anteroposterior and lateral radiographs. However, untreated medial tubercle fractures might lead to chronic ankle pain in case they do not heal.[9]

To improve the understanding of etiology and treatment options, a systematic review is performed of all cases of isolated medial tubercle fractures published in literature. In addition, a series of cases treated with endoscopic removal of the osseous fragments is presented.

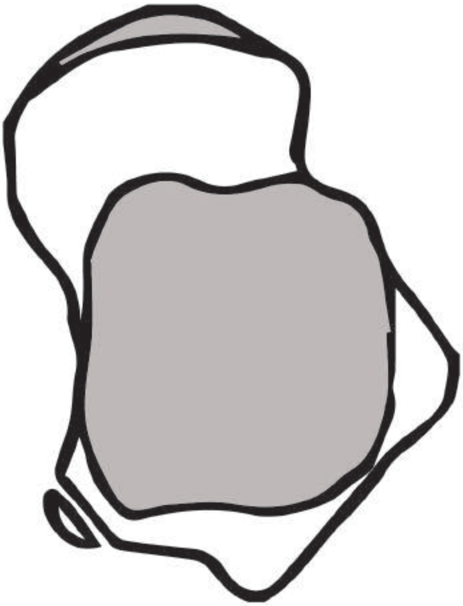


Figure 1. Schematic top view of the talus showing a fracture of the posteromedial talar tubercle.

METHODS

Literature overview

Medline and Embase databases were searched for relevant publications, using the following terms (until 1 August 2019): *(Cedell OR ((Posteromedial OR Medial OR Posterior) AND (process OR tubercle))) AND (talus OR talar) AND (fracture OR avulsion)*. In addition, the CINAHL, Google Scholar and Web of Science databases were searched for scientific papers, book chapters and abstracts. Reference lists of relevant articles were reviewed to identify any additional articles potentially not identified through the database search. Titles were screened on relevance, and subsequently, full-text articles were assessed by two reviewers independently. Disagreements were settled by discussion.

Studies were included if at least one case of a fracture of the medial tubercle of the posterior talar process was described. No language restrictions were applied. Studies that additionally describe a fracture of the lateral tubercle or complete posterior process were excluded. Also studies that describe cases with multiple injuries and additional fractures of the ankle or foot were excluded. Data on clinical presentation, trauma mechanism, imaging and treatment were extracted independently by two reviewers. The presentation of data was descriptive.

A retrospective case series of patients that underwent endoscopic treatment for a fracture of the medial tubercle of the posterior talar process was reviewed. Surgical and patients records were searched for patients with a medial tubercle fracture. A series of patients treated endoscopically for complaints associated with a fracture of the medial tubercle of the posterior talar process between 2000 and 2018 in the Academic Medical Centre in Amsterdam was retrospectively recruited for this study. Diagnosis was made by CT or MRI. All patients were invited by mail to participate in this study. With the invitation, patients received a questionnaire containing Numeric Rating Scores (NRS) for Satisfaction, Pain and Function, Foot Ankle Outcome Score (FAOS), and additional questions on recurrence of complaints, function and satisfaction. Demographic data and intraoperative findings were extracted from patient records and surgical reports, respectively. Collection of data for this study was approved by the local research ethics committee (W12_237#12.17.0270).

Statistical analysis

Presentation of data was descriptive. Numerical data were reported as median with inter-quartile range (IQR). Categorical data was presented as frequencies with percentages.

Operative technique

Patient positioning and portals are made according to the standard two-portal hindfoot technique.[10 11] Once the flexor halluces longus is identified, the flexor retinaculum is opened by means of a punch. The flexor tendon sheath of the flexor hallucis longus is opened below the level of the subtalar joint. By means of a probe the flexor hallucis longus can be mobilized medially. (Figure 2) The probe can subsequently be replaced by a punch. Using the punch, the FHL tendon is pushed to the medial side, slightly out of its groove. Hereby the insertion of the FHL retinaculum onto the posteromedial tubercle comes into focus. The insertion of the flexor retinaculum is released over its full length by means of the punch. Since the retinaculum inserts onto the medial tubercle the avulsion fragment can now be recognized. The fibers of the deep portion of the deltoid ligament are released from the fragment by using the punch or a small sized curved periosteal elevator. By means of this periosteal elevator, the fragment can be fully released and subsequently removed. Portals are closed with 3.0 Ethilon. A sterile compression dressing is applied. Postoperative treatment consists of weight bearing, as tolerated, supported by crutches for three days. The dressing is taken off after three days. As soon as possible following the surgery patients are advised to start functional range of motion exercises, as tolerated.[12]

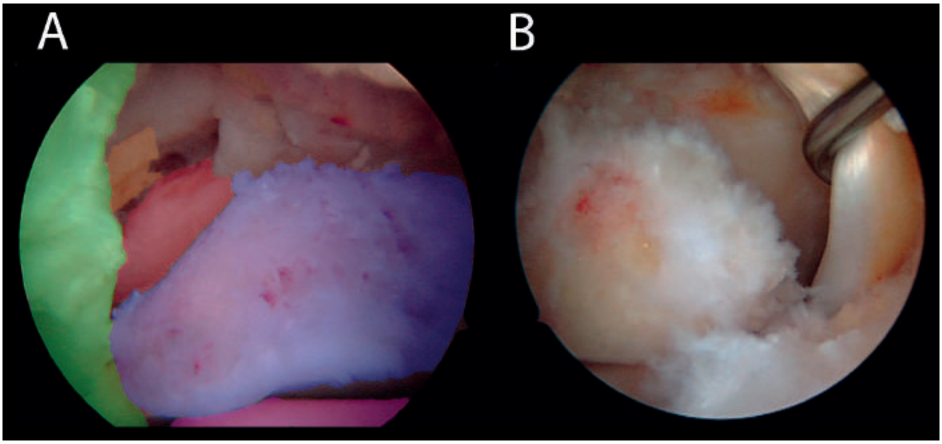


Figure 2. A. Endoscopic view of the workspace in the left ankle, showing the FHL tendon (green), the posterolateral tubercle (blue), posteromedial tubercle (red) and an avulsion fragment (orange). B. Endoscopic view of right ankle, the FHL is moved medially so that the posteromedial tubercle comes in view.

RESULTS

Literature overview

The search yielded 202 unique articles. Of these, 81 articles were selected for full-text screening. Eighteen articles were included (Figure 3). These studies reported on 33 patients with a fracture of the posteromedial talar process. The majority (84%) of the patients were male, with a median age of 31 years. Of the cases in which the trauma mechanism was reported, 58% (14/24) occurred during sport activities and 33% (8/24) of the cases were involved in high-energy accidents.

Of the cases in which the trauma mechanism was reported, in 58% (7/12) the injury was a result of an inversion sprain. 25% (3/12) reported a direct impact during sport, one a pronation/extension distortion and one a landing in dorsiflexion. Of the high-energy injuries, 5 patients were involved in a motor vehicle accident and 3 patients had a fracture following a fall from height. In 33% of the cases the diagnosis was made directly following the trauma. Diagnosis at initial assessment occurred more often after high-energy accident.

73% (24/33) of the patients underwent operative treatment, consisting of open reduction and internal fixation (12/24) or excision of the fragment (12/24). (Table 1)

Retrospective case series

Since 1997 eleven patients were identified who underwent endoscopic treatment for a fracture of the medial tubercle. Of these eleven patients, one was excluded because he underwent open surgery for the same condition before. Another patient was lost to follow-up.

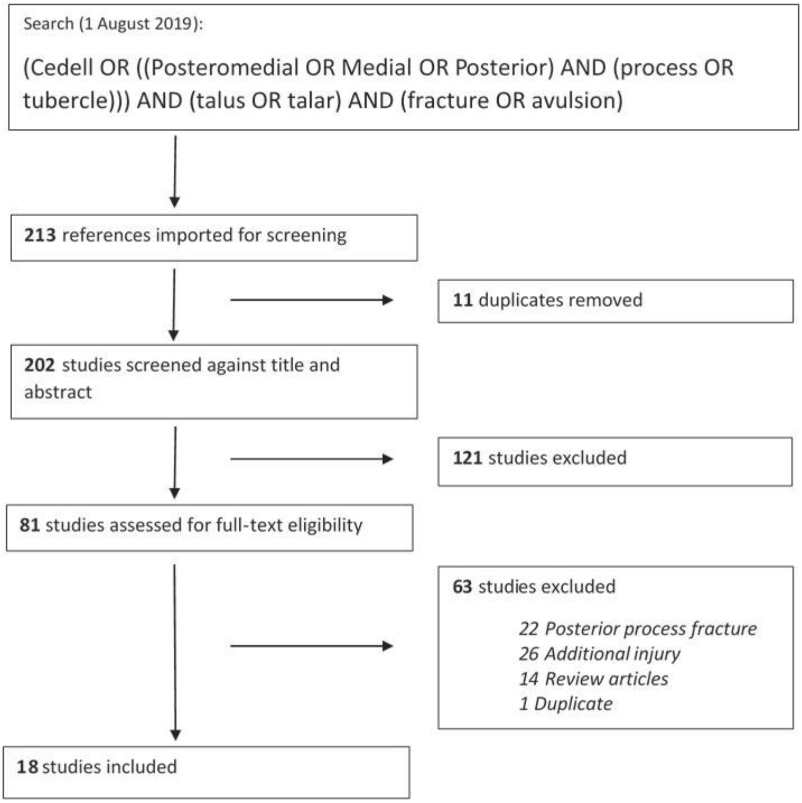


Figure 3. Flowchart literature search and exclusions.

Of the nine patients, five were male and the median age was 29. All were participating in sports at a competitive level, with four of them being a professional athlete. Football was the most common sport. In all patients the diagnosis was made more than three months after the initial trauma and in seven out of nine patients the delay after initial trauma was more than 16 months. An ‘ankle sprain’ was most common trauma mechanism. Unfortunately the exact sprain mechanism was not documented, however most patients reported an eversion trauma. Two of the patients underwent surgery for the same complaints before the diagnosis of medial tubercle fracture was made, resection of an os trigonum and arthroscopy for anteromedial ankle impingement was performed in another hospital. Intra-operatively the size of the fragments varied between a small avulsion to a fragment measuring 15 x 12 x 10 mm. Intra- operatively, it was not

Study	Year	Case	Age	M/F	Trauma situation	Mechanism	L/R	Diagnose at first assessment
Borsay [5]	**1952**	1	25	M	Cycle vs motorcycle		L	No
		2	25	M	Sport: football	Direct	L	No
Cedell [4]	**1974**	1	20	M	Sport; football	Sprain	R	No
		2	22	M	Sport; football	Sprain	R	No
		3	25	M	Sport; football	Sprain	R	No
		4	38	M		Sprain	R	No
Banks [13]	**1994**	1	17	F	Motor vehicle accident		L	Yes
		2	20	M	Motor vehicle accident		R	Yes
Stefko [14]	**1994**	1	42	M	Sport; basketball	Extension/pronation	L	No
Dougall [8]	**1997**	1	55	M	Motor vehicle accident		R	Yes
Gutierres [15]	**1998**	1	28	M	Fall from Height		R	No
		2	37	M	Fall from Height		L	Yes
Wolf [6]	**1998**	1	22	M	Sport; football	Direct	R	No Exam
Cohen [7]	**2000**	1	48	M	Motor vehicle accident		R	Yes
Kim [9]	**2003**		32 *					
		2			Sport			Yes
		3			Sport			No
Tongel, van [16]	**2007**	1	17	M	Sport; football	Direct	R	No
Yiannakopoulos [17]	**2017**	1	21	M	Sport; basketball	Landing in dorsiflexion	R	No
O'Loughlin [18]	**2009**	1	36	F		Supination	R	No
Rogosic [19]	**2010**	1	23	M	Fall from Height		L	No
Chen [20]	**2011**	1	24	M	Slipping injury		R	Yes
Shi [21]	**2013**	6#	42*	4M /2F				-
Albert [22]	**2014**	1	34	M		Sprain	R	No
Watanabe [23]	**2017**	1	16	M	Sport; basketball.	Sprain	R	No
Park [24]	**2018**	1	25	M	Bicycle accident		L	Yes

Table 1. Overview included studies and case characteristics. *,median; #, not all patients of

Initial treatment	Time to Diagnosis	X-ray	CT/ MRI	Size	Dis-placed	Definitive treatment	Follow up
Rest	9 months	Yes				Open excision	2 months return to work
Rest 2 weeks	4 months	Yes				Open excision	2 months return to sport
Rest, bandage, no immobilization	> 1 year	Yes		0, 5x1x2		Open excision	
Rest, bandage, no immobilization	> 1 year	Yes		0, 5x1x2		Open excision	
Rest, bandage, no immobilization	> 1 year	Yes		0, 5x1x2		Open excision	
Rest, bandage, no immobilization	> 1 year	Yes					
Surgery	-	?	Yes	Yes		ORIF	4 months: no symptoms
Surgery	-	Yes	Yes			ORIF	not mentioned
RICE	4 months	No	Yes	2x 1x1,5		Open excision	7 weeks: no pain. 1 year: no pain.
Surgery	-	Yes	Yes		Yes	ORIF	16 months: no pain
Short leg cast	6 weeks	No	Yes			Open excision	6 weeks: FROM, no pain
Immobilization	-	Yes	Yes			Splint 8 weeks	no pain, return to work, FROM
None	9 months	Yes	Yes		Yes	Open excision	16 months: asymptom-atic, FROM
Surgery	-	Yes	Yes		Yes	ORIF	1 year: no symptoms
NWB cast	-					NWB cast	AOFAS 95*
Non-specific support-ive, no immobilization	19 months (8-24)					Open Excision	resumption of sports. AOFAS 91*
Rest, Physiotherapy	8 months	No	NU			Refused treat-ment	succes with insoles
RICE	3 weeks	Yes	Yes		No	Walking short leg cast	27 months: return to sport
RICE	4 weeks	No	Yes			2 wks cast / 4 wks CAM boot	return to activity
Short leg, NWB cast	2 months	No	NU	2x 1.5x1 cm	Yes	Open excision	18 months no pain.
Surgery	-	30 gr	Yes		Yes	ORIF	3 years: no symptoms AOFAS 97
-	-					ORIF	12 /18 months: median AOFAS 87*
Brace	6 years	NU	NU	1, 6x1,0x1,8	No	Refused treat-ment	
None	3 weeks	No	Yes		No	Cast	1 year: no symptoms
Surgery	-	Yes	Yes		Yes	ORIF	6 months pain free, AOFAS 100

study; NU, non-union; ORIF, open reduction internal fixation; NWB, Non weight bearing.

possible to differentiate between an avulsion of the deep portion of the deltoid ligament or an avulsion of the FHL retinaculum. (Table 2)

Table 2. Patient characteristics. AAS = Ankle Activity Score[25.]

Case	Age	Sex	Sport	Level	AAS	Trauma mechanism	Time to diagnosis	Surgery prior to diagnosis
1	29	M	Football	Competitive	9	Unknown	24 months	
2	19	M	Football	Professional	10	Distortion with direct trauma medial	3 months	
3	20	F	Football	Competitive	9	Distortion	28 months	
4	30	M	Football	Competitive	9	Direct trauma medial	7 months	
5	21	M	Hockey	Professional	10	Unknown	19 months	Resection os trigonum
6	33	F	Hockey	Competitive	9	Distortion	30 months	
7	17	F	Gymnastics	Competitive	9	Distortion during landing	19 months	
8	34	M	Football	Professional	10	Unknown, multiple sprains	16 months	Multiple ankle arthroscopies
9	32	F	Swimming	Professional	3	Unknown	16 months	

The median follow-up was 69 months. At final follow-up patients had little pain, NRS 1. Median NRS for satisfaction and function were 7 and 8, respectively. All patients did resume sport activities, however only four at their pre-injury level. Of the five patients that did not return to their pre injury level of activity, two were professional athletes at the end of their career, and retired not due to the ankle complaints. One complication was reported, a patient developed a CPRS, type 1, in the weeks following surgery. (Table 3)

In addition to these eleven patients, we found one patient that had a clear avulsion fragment of the medial tubercle of the posterior talar process without complaints. He visited the outpatient clinic for assessment of his left ankle. On CT scan the fragment in his right ankle was identified. (Figure 4)

Table 3. Outcome measures.

Follow-up time (months)		69 (IQR 12.0-94.3)
Pain (NRS)		
	Rest	1 (IQR 0-2)
	During sport	1 (IQR 0-4)
Satisfaction (NRS)		7 (IQR 5-8.5)
Function (NRS)		8 (IQR 7-10)
FAOS		
	Symptoms	57. 14 (IQR 39.28-67.86)
	Pain	80. 56 (IQR 63.89- 97.22)
	ADL	92. 64 (IQR 72.06 – 97.05)
	Sport	75. 0 (IQR 40.0 – 80.0)
	QOL	50. 0 (IQR 43.75- 62.5)
Return to Sport		9 / 9
Return to previous level of sport		4 / 9
Complications		1 / 9 (CRPS type I)

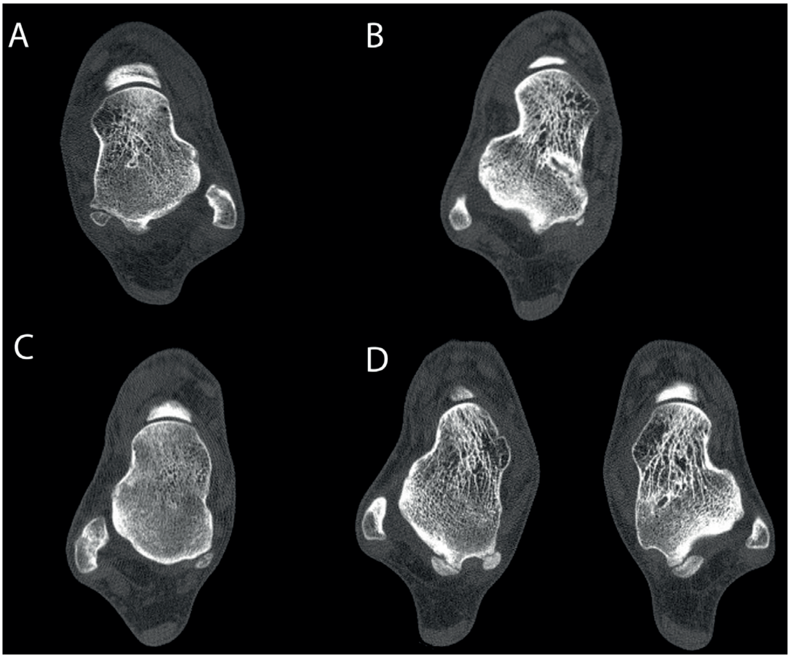


Figure 4. Medial tubercle fractures on CT imaging. A. Large fragment. B. Small avulsion. C. Image of an asymptomatic nonunion of avulsion fragment. D. Image of patient with bilateral os trigonum and medial tubercle fracture of his right ankle.

DISCUSSION

The main finding of this study is that different types of posteromedial talar process fractures exist depending on the specific trauma mechanism. The fracture as described by Cedell is only one of several different mechanisms resulting in a posteromedial talar tubercle fracture. Furthermore, endoscopic excision of an avulsion fragment of the posteromedial talar process is a safe and effective treatment method in symptomatic patients.

There is only little literature on the posteromedial tubercle fracture, consisting of mainly case reports and a few small case series. Thereby, most of the publications lack a detailed description of the patients and their treatment. The terms tubercle and process fractures are used interchangeably, however, there are important differences. Complete posterior process fractures are usually the result of a high-energy impact and affect often both joints, are frequently displaced and accompanied by dislocation of the subtalar joint. We included only the isolated medial tubercle fractures. To limit the heterogeneity of the included cases we excluded the cases with additional injuries.

This review consisted of 33 cases of medial tubercle fractures. Of them around 58% was involved in sports activities, whereas 30% occurred in high-energy accidents. One should realize that in this study only a group of isolated medial tubercle fractures was included. A significant amount of high-energy trauma cases was accompanied by additional injuries and therefore excluded from this review. Of the sport injuries, in 58% an inversion trauma was reported as mechanism of injury. Reporting the mechanism of ankle distortions based on patient's perception is error-prone. The majority of the patients in this review underwent surgical treatment. However, there is a high change of publication bias, since surgeons in general are more prone to publish on surgically treated cases. Together with the rarity of the fracture and heterogeneity of the cases it was not possible to pool the cases. Therefore we were not able to compare different treatment options with their corresponding outcomes.

All the patients in our series had an avulsion type fracture and were involved in sport activities. With nine cases this is the largest and first series of isolated fracture or avulsion of the posteromedial tubercle treated endoscopically. Since it is a retrospective case series with long-term follow-up, outcomes are difficult to interpret. The outcome on patient satisfaction is good, all patients returned to sport activities and there was one complication, not necessarily due to the treatment itself. However, the presumed advantages of endoscopic treatment over open surgery, such as less complications and a quicker rehab was not subject to this study.

The posteromedial tubercle fracture is often referred to as the 'Cedell fracture'.[6 17 22 23 26 14] It is assumed that the avulsion results from forced dorsiflexion-pronation and eversion on the posterior tibiotalar ligament (or deep portion of the deltoid ligament). Besides this ligament, the medial talocalcaneal ligament and the flexor hallucis longus retinaculum also insert in the posteromedial talar tubercle.

As already postulated by Cedell, injury to de posterior talotibial ligament may not be as rare as literature tells us. It is known that only a few of the ligament ruptures around the ankle present as a bony avulsion. The paucity of data on these kind of avulsions of the medial tubercle is possibly a result of the relative good prognosis.[4] This is supported by our single case of an asymptomatic avulsion.

Following the high-energy impact injuries this fracture is more often diagnosed at first assessment. Probably in these cases a CT scan is made frequently. If the injury occurs during sport activities it is difficult to distinguish it from a simple ankle sprain. On the 'standard' anteroposterior and lateral radiographs a posteromedial tubercle fracture is usually not detected. Ebraheim proposed an additional view in 30, 45 and 70 degrees of exorotation. CT scan has the highest sensitivity to detect a fracture and is also important in assessing the exact location, size and displacement of the fracture.[27] Whereas on MRI in the acute setting the bone marrow edema pattern can inform about the trauma mechanism.[23]

Watanabe et al. proposed a treatment algorithm. They distinguished an avulsion type, split type and comminuted fracture type. The avulsion type and split type fractures are the result of indirect trauma, dorsiflexion-pronation (Cedell-type) and plantarflexion-supination (impingement) respectively. Following this classification the split-type should be treated conservatively, the comminuted with ORIF and the avulsion type with excision of the fragment in case it was old or displaced. In addition, when focusing on the non- high impact or indirect trauma fractures, endoscopy should be considered more frequently. Our proposal for treatment of the posteromedial talar process fractures would be that non-displaced or extra-articular fractures should be treated non-operatively with immobilization. In case of small displaced fragments (<0.5cm) endoscopic excision is indicated. Fragments sized between 0.5 and 1 cm should be evaluated endoscopically, and depending on the findings excised or reduced. For fracture fragments larger than 1 cm fixation should be the treatment of choice, endoscopically or open, depending on surgical experience.[28]

The standard two-portal hindfoot approach has proved its value in treatment of posterior ankle pathology. Recently, this approach was described to be an option in treatment of a malunion of a posteromedial tubercle fracture.[29] However, hitherto no cases of endoscopic treatment of posteromedial tubercle fractures has been published. With this study we show endoscopy to be a safe and effective treatment option for excision of medial tubercle fragments.

CONCLUSION

Fractures of the medial tubercle are rare and based on the available literature there is not one type of the posteromedial tubercle fracture with a typical trauma mechanism. Based on literature no conclusions can be made on which treatment option is superior. Our results show endoscopic excision of the fragment as a safe and effective alternative for open surgical treatment.

LITERATURE

1. McDougall A. The os trigonum. *J Bone Joint Surg Br* 1955;37-b(2):257-65. [published Online First: 1955/05/01]
2. Shepherd FJ. A hitherto undescribed fracture of the astralagus. *The Journal of anatomy and physiology* 1882;17(April):79-81.
3. Bennett E. Ossicle occasionally found on the posterior border of the astragalus. *J Anat Physiol* 1886;21(Pt 1):59.
4. Cedell CA. Rupture of the posterior talotibial ligament with the avulsion of a bone fragment from the talus. *Acta Orthop Scand* 1974;45(3):454-61. [published Online First: 1974/01/01]
5. Borsay J, Kardos G. [Isolated fracture of the posterior process of the talus]. *Zeitschrift fur Orthopadie und ihre Grenzgebiete* 1952;82(3):430-5. [published Online First: 1952/01/01]
6. Wolf RS, Heckman JD. Case report: Fracture of the posterior medial tubercle of the talus secondary to direct trauma. *Foot and Ankle International* 1998;19(4):255-58.
7. Cohen AP, Conroy JL, Giannoudis PV, et al. Impingement fracture of the posteromedial process of the talus--a case report. *Acta Orthop Scand* 2000;71(6):642-4. doi: 10.1080/000164700317362325 [published Online First: 2001/01/06]
8. Dougall TW, Ashcroft GP. Flexor hallucis longus tendon interposition in a fracture of the medial tubercle of the posterior process of the talus. *Injury* 1997;28(8):551-2. [published Online First: 1998/06/09]
9. Kim DH, Berkowitz MJ, Pressman DN. Avulsion fractures of the medial tubercle of the posterior process of the talus. *Foot and Ankle International* 2003;24(2):172-75.
10. van Dijk CN, Scholten PE, Krips R. A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2000;16(8):871-76.
11. van Dijk CN, de Leeuw PA, Scholten PE. Hindfoot endoscopy for posterior ankle impingement. Surgical technique. *J Bone Joint Surg Am* 2009;91 Suppl 2:287-98. doi: 91/Supplement_2/287 [pii];10.2106/JBJS.I.00445 [doi]
12. van Dijk CN. Deltoid Ligament Pathology Treated by Means of a Two-Portal Hindfoot Approach. Ankle Arthroscopy: Springer 2014:275-82.
13. Banks AS, Caldarella D. Fractures of the posteromedial process of the talus. *J Am Podiatr Med Assoc* 1994;84(2):66-70. doi: 10.7547/87507315-84-2-66 [published Online First: 1994/02/01]
14. Stefko RM, Lauerman WC, Heckman JD. Tarsal tunnel syndrome caused by an unrecognized fracture of the posterior process of the talus (Cedell fracture). A case report. *Journal of Bone and Joint Surgery - Series A* 1994;76(1):116-18.
15. Gutierres, M., Cabral, T., Miranda, A., Almeida, L. Fractures of the posteromedial process of the talus. *International orthopaedics 1998; 22*(6), 394-396.
16. Van Tongel A, Matricali GA. Fracture of the posterior medial tubercle of the talus: A case report and review of the literature. *Acta Orthopaedica Belgica* 2007;73(6):804-06.
17. Yiannakopoulos CK, Kanellopoulos AD. Avulsion fracture of the medial tubercle of the posterior process of the talus. Three-dimensional (3D) computed tomography features. *Foot* 2007;17(1):38-41. doi: http://dx.doi.org/10.1016/j.foot.2006.04.004

18. O'Loughlin P, Sofka CM, Kennedy JG. Fracture of the medial tubercle of the posterior process of the talus: magnetic resonance imaging appearance with clinical follow-up. *HSS journal : the musculoskeletal journal of Hospital for Special Surgery* 2009;5(2):161-4. doi: 10.1007/s11420-009-9113-z [published Online First: 2009/04/07]
19. Rogosic S, Bojanic I, Boric I, et al. Unrecognized fracture of the posteromedial process of the talus--a case report and review of literature. *Acta clinica Croatica* 2010;49(3):315-20. [published Online First: 2011/04/06]
20. Chen CW, Hsu SY, Wei YS. Fracture of the medial tubercle of the posterior process of the talus. *Formosan Journal of Musculoskeletal Disorders* 2011;2(2):62-65. doi: http://dx.doi.org/10.1016/j.fjmd.2011.03.005
21. Shi Z, Zou J, Yi X. Posteromedial approach in treatment of talar posterior process fractures. *Journal of Investigative Surgery* 2013;26(4):204-09. doi: http://dx.doi.org/10.3109/08941939.2012.740146
22. Albert P, Patel J, Katz JI, et al. Magnetic resonance imaging, computed tomography, and radiographic correlation of nonunion of the posteromedial tubercle of the talus: a case report. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2014;53(6):787-90. doi: 10.1053/j.jfas.2014.07.003 [published Online First: 2014/09/03]
23. Watanabe H, Majima T, Takahashi K, et al. Split Fracture of the Posteromedial Tubercle of the Talus: Case Report and Proposed Classification System. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2017;56(1):187-90. doi: 10.1053/j.jfas.2016.02.001 [published Online First: 2016/03/08]
24. Park J, Che JH. Talus Fracture of the Medial Tubercle of the Posterior Process: Interposition of the Flexor Hallucis Longus Tendon. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2018;57(3):615-17. doi: 10.1053/j.jfas.2017.10.028 [published Online First: 2018/02/20]
25. Halasi T, Kynsburg A, Tallay A, et al. Development of a new activity score for the evaluation of ankle instability. *Am J Sports Med* 2004;32(4):899-908.
26. Ebraheim NA, Padanilam TG, Wong FY. Posteromedial process fractures of the talus. *Foot and Ankle International* 1995;16(11):734-39.
27. Ebraheim NA, Skie MC, Podeszwa DA. Medial subtalar dislocation associated with fracture of the posterior process of the talus: A case report. *Clinical orthopaedics and related research* 1994(303):226-30.
28. d'Hooghe P, Krivokapic B, Kerkhoffs GM, et al. "Small" Fractures Below the Knee: Do Not Miss—Do Not Mistreat! ESSKA Instructional Course Lecture Book: Springer 2018:15-31.
29. Mas Martinez J, Verdu Roman C, Martinez Gimenez E, et al. Arthroscopic Treatment of a Malunion of a Posteromedial Tubercle Fracture of the Talus. *Arthroscopy techniques* 2017;6(6):e2107-e10. doi: 10.1016/j.eats.2017.08.020 [published Online First: 2018/01/20]

CHAPTER 8

TALUS BIPARTITUS: A SYSTEMATIC REVIEW AND REPORT OF TWO CASES TREATED WITH ARTHROSCPIC TREATMENT

R. Zwiers
P.A.J. de Leeuw
G.M.M.J. Kerkhoffs
C.N. van Dijk

Knee Surg Sports Traumatol Arthrosc 2018

ABSTRACT

Purpose

The aim of this study was to provide a literature review on talus bipartitus and to introduce an arthroscopic treatment option.

Methods

A systematic review of published case reports and small case series was performed. Medline, Embase, CINAHL, Google Scholar and Web of Science databases were searched for relevant publications. In addition, three cases of talus bipartitus treated in our institute were discussed.

Results

Eleven articles were identified, reporting on 23 patients, of whom one patient had a bilateral talus bipartitus. Fourteen were males (61%). The median age at presentation was 15.5 years (IQR 14-24.3). In 21 of the symptomatic cases (96%), the patient experienced ankle pain, and 13 had a restricted range of motion (54%). In our institution, two patients were treated arthroscopically and had excellent short- and long-term outcomes.

Conclusion

Talus bipartitus is a rare anatomical anomaly. Symptoms are characterized by pain and restricted subtalar motion in young patients. Surgical treatment is focused on either fixation or excision of the bony fragment. Our two cases have demonstrated that an arthroscopic approach can be a safe and effective treatment option in patients with a symptomatic talus bipartitus.

INTRODUCTION

Talus bipartitus is a rare bony anomaly of the talus. It is defined as two non-fused talar fragments, with the posterior fragment located at the level of the posterior talar process. Strehle in his dissertation on talar anomalies described the first case in 1928.[1] Talus bipartitus needs to be distinguished from the more common os trigonum (or Shepherd fracture), which only includes the posterolateral tubercle of the posterior talar process.[2] Also it should be distinguished from the Cedell fracture, for both its location and its etiology. The Cedell fracture is an avulsion of the posteromedial tubercle of the posterior talar process and is thought to occur due to tensile forces from the posterior tibiotalar ligament.[3]

The prevalence of the talus bipartitus is unknown, and only a few case reports and small case series have been published. Little is known about its aetiology, clinical manifestations, treatment and outcome. Therefore, the purpose of this study was to provide an overview of the current literature. A systematic review of published case reports and small case series was performed. In addition, all patients that were treated over the last 15 years in our institution were reviewed. In this study, both the diagnostic process and the treatment of these patients will be described, including the long-term follow-up.

MATERIALS AND METHODS

Medline and Embase databases were searched for relevant publications, using the following terms (until 1 December 2015): *(Talus OR Talar OR Astragalus) AND (bipart* OR partit* OR secondary OR fragment) OR frontal split*. In addition, the CINAHL, Google Scholar and Web of Science databases were searched for scientific papers, book chapters and abstracts. Reference lists of relevant articles were reviewed. Titles were screened on relevance, and subsequently, full-text articles were assessed. The search was limited to articles describing humans.

Studies were only included if at least one case of a talus bipartitus was described, no language restriction was applied. Data on aetiology, clinical presentation, imaging and treatment were extracted. Due to the small amount of data, the presentation of data was descriptive.

In addition to the literature review, three patients with a symptomatic talus bipartitus treated in our institution over the last 15 years were presented. Collection of data for this study was approved by the local research ethics committee (W12_237#12.17.0270).

RESULTS

The literature search yielded 956 articles, of which 22 articles were selected for full-text screening. Of these, 11 articles were considered eligible. One article was added after screening literature lists on relevant papers. The included articles consisted of seven case reports[4-10], one case description in a dissertation[1] and four small case series[11-14]. These articles reported on 23 patients, of whom one patient had a bilateral talus bipartitus. Fourteen of them were males (61%). The median age at presentation was 15.5 years (IQR 14-24.3). In 21 of the symptomatic cases (96%), the patient experienced ankle pain, mainly on weight bearing. Thirteen had a restricted range of motion (54%). Two cases were coincidently detected following an ankle trauma. Most of the patients had no history of ankle trauma. In nine cases (38%), radiological imaging showed some signs of subtalar- and or talocrural joint degeneration. The size of the osseous fragment and extent of joint involvement varied widely. Surgical treatment had been performed in 19 cases (90%). In 13 cases (68%), excision of the fragment was performed by open surgery. Of these, due to ongoing symptoms, in four patients a secondary surgical procedure was performed, three patients underwent a subtalar fusion, and in one patient, a pantalar fusion was performed. In one case, the primary surgical intervention was a subtalar fusion, and in five cases, fixation of the bony fragment was performed. Due to the variety of presentations and limited descriptions on the specific treatment, a profound comparison of the outcomes was not possible. An overview of the published cases is presented in Table 1.
Over the last 15 years, three patients with a symptomatic talus bipartitus were identified in our institution and one had a bilateral talus bipartitus.

Case descriptions

Case 1
A 26-year-old female presented with pain in both ankles for over one year. History revealed recurrent bilateral ankle sprains. Pain was mainly triggered by ankle plantar flexion during walking, specifically when wearing high heels. There were no complaints of instability or swelling after activity. She did not perform any sports activities. Physical examination revealed recognizable tenderness on palpation, especially on the medial and posterolateral aspect of both ankles. Some crepitus was felt over the flexor hallucis longus (FHL) tendon at the level of the ankle joint. The hyper plantar flexion test was positive bilaterally. Weight-bearing radiographs and the computed tomography (CT) showed a talus bipartitus

in both ankles, with early degenerative changes in the subtalar joint, especially at the posterior facet. (Figure 1)

Conservative treatment by means of physiotherapy was unsuccessful. Since the left ankle was most symptomatic, in close correspondence with the patient, it was decided to treat the left ankle surgically by means of an arthroscopic excision of the fragment through the two-portal hindfoot approach[15 16].

The procedure was carried out in our outpatient clinic under general anaesthesia with the patient in the prone position. Standard posterolateral and medial portals were used. With the arthroscope in the posterolateral portal, the FHL tendon was identified. The posterior bony fragment was released from its surrounding tissues, being the posterior talofibular, talocalcaneal and tibiotalar ligaments and the flexor retinaculum (Figure 2). Subsequently, the fragment was split into a posteromedial and posterolateral part by means of a chisel to ease extraction through the portals.

Postoperatively, the patient was allowed full weight bearing as tolerated. At 6-week follow-up, the patient was free of symptoms and she was able to perform all normal daily activities without discomfort considering the operated ankle; however, the right ankle remained symptomatic. The portals had healed uneventfully and no transient or permanent neurovascular compromises were noticed. At one year following surgery, the patient was satisfied with the results (NRS 10/10) and AOFAS score had improved from 36 preoperatively to 90. The radiographs showed no signs of progressive degeneration at the level of the subtalar joint, as compared to the preoperative situation. (Figure 3) Due to the ongoing symptomatic right ankle, she was keen on having a similar arthroscopic surgical intervention. Two years following the second arthroscopic procedure, she had no pain and was not restricted in any of her activities. At final follow-up, ten years postoperatively, she was satisfied with the result for both her ankles (NRS 10/10), there were no pain issues (NRS 0/10) and she rated her ankle function as being 'normal'.

Case 2

An 18-year-old male presented with posterior ankle pain for 18 months without a preceding trauma. Pain aggravated during physical activity and prevented his participation in rugby. On examination, the right ankle was swollen and was specifically tender posterolaterally. Plantar flexion was restricted by 20 degrees, as compared to the contralateral unaffected ankle. The hyper-plantar flexion test was positive. Standard weight-bearing radiographs and the CT scan revealed a talus bipartitus. (Figure 4) Conservative treatment consisted of physiotherapy, a single corticosteroid injection and immobilization in a cast for 6 weeks.

Table 1. Overview of published cases. FU, Time to Follow-up; F, female; M, male; (F) ROM, (Full) Range of Motion; TCJ, Talocrural Joint; STJ, Subtalar Joint; TB, Talus Bipartitus; mo, months; y, years; ADL, Activities of Daily Living; RTW, Return to Work; AOFAS, American Orthopeadic Foot and Ankle Society- score. Age, Duration and FU in years.

Study	Year	Age	Sex	Side	Complaints	Phys. exam	Traumatic
Strehle [1]	1928	14	F	Left	Pain during walking	-	No
Weinstein [10]	1975	13	M	Right	Increasing pain lateral malleolus, radiating anteriorly	Restricted ROM TCJ and STJ	No
Schreiber [7]	1985	15	F	Left	Dull ankle pain over medial malleolus after exercise	Restricted. Dorsal flexion TCR, restr. ROM STJ, pain	-
Blauth [4]	1987	18	F	Left	Pain during activity	Restricted ROM AJ	No
Griffet [6]	2003	15	F	Left	Intermittent ankle pain during activity	Normal	No
Eichenbaum [11]	2010	18	M	Right	Increasing hindfoot pain	FROM TCJ, painful restricted ROM STJ	No
		16	M	Right	Ankle pain and instability	Increased ROM STJ, instability	Sprain
Thiel [9]	2010	12	M	Right	Intermittent dull ankle pain after heavy exercise	FROM, tenderness on palpation talus	No
Mann [12]	2010	14	M	-	Ankle pain	25% restricted ROM TCJ	No
		13	F	-	Ankle pain	25% restricted ROM TCJ	No
		15	F	-	Ankle pain	-	No
		16	M	-	Ankle pain during activities	50% restricted ROM TCJ, 50% increased ROM STJ	No
		15	M	-	Ankle pain during activities	25% restricted ROM TCJ	No
Rammelt [13]	2012	31	F	Right	Occasional ankle pain	Restricted ROM	Repetitve sprains
		25	M	Right	Intermittent ankle pain during activity	Restricted ROM	No

Duration	Imaging		Size	Treatment	Outcome	Follow-Up
8	X-ray	TB, incongruent joints	-	-	-	-
0. 4	X-ray	TB	2. 5x2x2cm, 100% STJ	Excision	-	-
4	X-ray, arthro-graph	TB, flattened talar dome	Both joints involved	-	-	-
2	X-ray	TB, sclerotic, congruent	1/ 3 talar dome, both joints involved	-	-	-
1	X-ray, MRI	TB, incongruent frag-ments both joints, degenerative, aberrant aspect calcaneus	posterior 1/3 of talar body	Subtalar arthrodesis	Decrease pain, recurrence after 2 y, conservatively treated	2
4	X-ray, CT	TB, degenerative changes	4x 2x1,5 cm, 50% post STJ	Excision + subtalar arthrodesis	Pain-free activity	1
1. 2	X-ray, CT, MRI	TB, sclerotic irregular margins	2, 8x1,1x0,8 cm	Excision	Pain and instability improved	0. 5
2	CT, MRI	TB, cystic, sclerotic areas, BME	posterior 1/3	Fixation, 1 screw	Asymptomatic, participating in sports	0. 75
-	CT	TB	20- 25% post STJ	Excision	Functional recovery after 4 mo	2
-	CT	TB	20- 25% post STJ	Excision	Limited recovery after 9 mo, no sports	1. 5
-	CT	TB, flattened talar dome	20- 25% post STJ	Excision	Functional recovery after 4 mo	5
-	CT	TB	20- 25% post STJ	Excision	Functional recovery after 6 mo	3
-	CT	TB	20- 25% post STJ	Excision	Excercise-induced pain	2
1. 2	CT, MRI	TB, displaced fragment	1/ 3 talar dome, both joints involved	Fixation, 2 screws	Pain-free ADL, FROM	3
3	CT, MRI	TB, irregular shape, degenerative arthritis	Posteromedial 1/3 talar body	Excision	Mild pain during exercise, unable to play soccer, no functional restric-tion	2

Table 1. Overview of published cases. FU, Time to Follow-up; F, female; M, male; (F) ROM, (Full) Range of Motion; TCJ, Talocrural Joint; STJ, Subtalar Joint; TB, Talus Bipartitus; mo, months; y, years; ADL, Activities of Daily Living; RTW, Return to Work; AOFAS, American Orthopeadic Foot and Ankle Society- score. Age, Duration and FU in years. (continued)

Study	Year	Age	Sex	Side	Complaints	Phys. exam	Traumatic
		27	F	-	Evaluation ankle sprain	-	Sprain
		22	F	Left	Increasing ankle pain	-	No
Chandoga [5]	2012	30	M	Right	Evaluation after sprain	Swelling	NR
Rose [14]	2012	11	M	Right	Ankle pain	Restricted ROM STJ, Cavovarus deformity	No
		15		Left	Ankle pain	-	No
		19	M	Left	Ankle pain	Subtalar complaints	No
		55	M	Right	Severe ankle pain	Painful and restricted ankle and subtalar motion	No
		26	M	Right	Severe hindfoot pain	Stiffness, painful STJ	No
Serrato [8]	2013	14	M	Left	Pain after sprain	No ROM STJ, pain plantar flexion	Sprain

Duration	Imaging		Size	Treatment	Outcome	Follow-Up
0. 2	MRI	TB	Both joints involved	Conservative	Minimal symptoms	3
2	CT, MRI	TB, incongruent both joints, degenerative arthritis	-	Excision	No pain ADL, mild pain activity, no progression arthritis	1
0	X-ray, CT, MRI	TB	-	-	-	-
0. 5	CT, MRI	TB, congruent joints	25% STJ	Fixation , 2 screws	FROM, pain-free, AOFAS 100	4. 2
-	X-ray, CT	TB, congruent joints	15 % STJ	Fixation , 2 screws	FROM, pain-free, non-union (broken screw), AOFAS 100	2. 3
Several years	X-ray, CT	TB, degenerative changes STJ	25% STJ	Excision + subtalar arthodesis	RTW, mild pain, AOFAS 75	4. 2
-	X-ray, CT	TB, oblique separation line, degenerative changes both joints	25% STJ	Excision + pantalar fusion, hind-foot nail	Generalized hind and mid-foot pain requiring analgesia, limited ADL. AOFAS 53	5. 6
-	X-ray, CT	TB, degenerative changes STJ	20% STJ	Excision + subtalar arthodesis	Clinical and radiographical fusion	0. 3
	X-ray, CT	TB,horizontal talar fracture	Both joints involved	Fixation, 1 screw	No pain	1

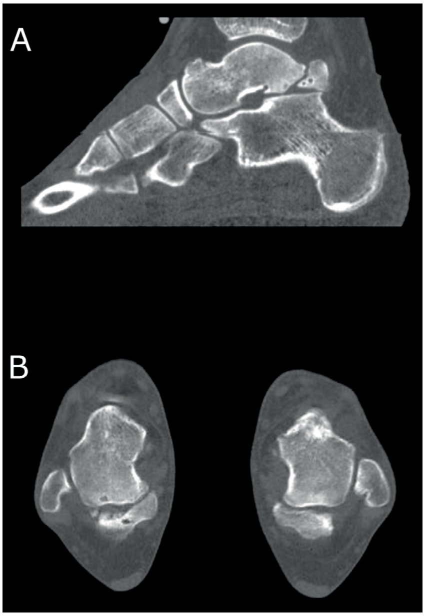


Figure 1. CT scan case 1. A. Sagittal view of the left ankle showing a talus bipartitus. B. Axial view showing a bilateral talus bipartitus.

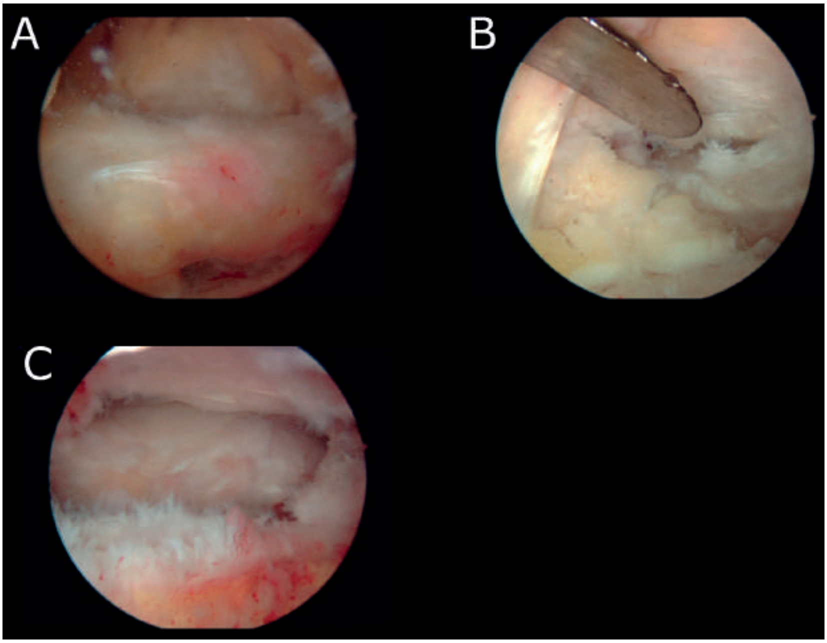


Figure 2. Endoscopic view. A. Posterior fragment is identified. B. Release of the soft tissues surrounding the bony fragment with the periosteal elevator C. End-result after removal of the posterior fragment.

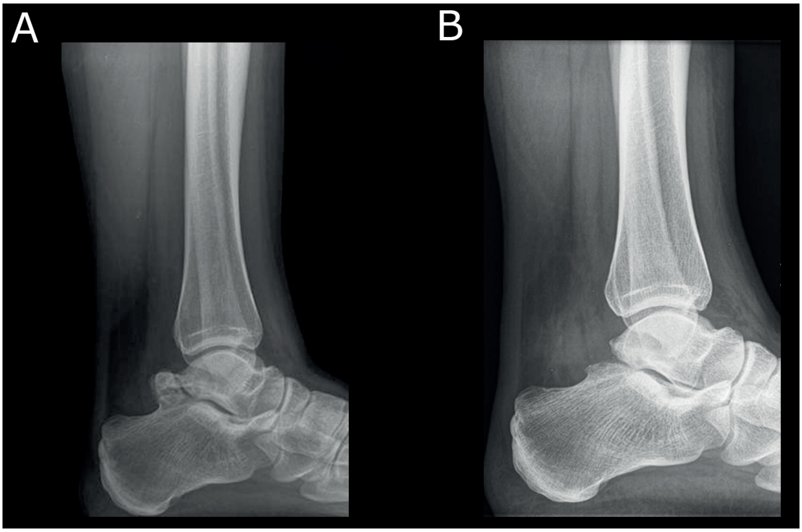


Figure 3. Lateral radiographs case 1. A. Preoperative radiograph showing talus bipartitus. B. Radiograph one year following surgery.

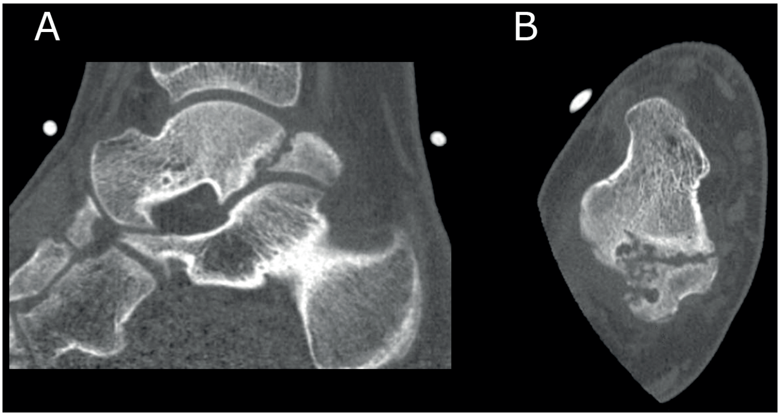


Figure 4. CT scan case 2. A. Sagittal view indicating talus bipartitus with degenerative changes. B Axial view of the right ankle.

Despite these conservative measures, symptoms persisted with a significant impact on patient' quality of life and therefore surgery was initiated. Since there was a considerable sized bony fragment, affecting a significant portion of the subtalar joint, it was decided to fix the fragment onto the talar body by means of a screw. Minimal interference with the periosteal tissue during the fixation was achieved by an arthroscopically assisted surgical technique. A standard two-portal hindfoot endoscopy was performed. The fragment was detached by means of a small fragment curved periosteal elevator. The pseudoarthrosis tissue was debrided by means of a curette and shaver. In order to stimulate bone healing, the fragment and talar body were microfractured with a dedicated probe. After adequate repositioning the fragment, fixation was obtained by two small fragment cannulated partially threaded cancellous screws. Postoperatively, the ankle was immobilized in a lower leg cast for 12 weeks, 6-week non-weight bearing and 6-week weight bearing and prophylactic dosages of low molecular weight heparin were given during the entire immobilization period. (Figure 5)

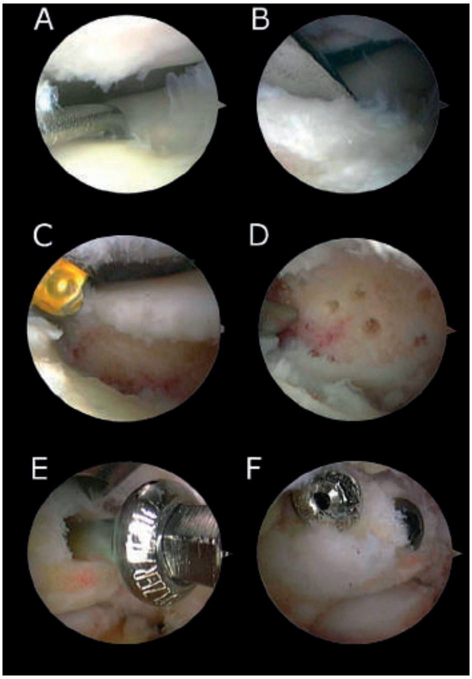


Figure 5. Endoscopic view case 2. A. Distinction made between fragments using arthroscopic hook. B. Splitting of the fragments with periosteal elevator. C. Debridement of the surface between the fragments. D. Arthroscopic image following microfracturing of the surfaces E. Fragment stabilization performed using two cannulated partially threaded cancellous screws F. Endoscopic view at the end of the surgical procedure.

At three-month follow-up, the weight-bearing radiographs showed a good position of the fixed fragment with early signs of union. The patient was allowed full weight bearing as tolerated and physiotherapy was initiated. At 6-month follow-up, the patient had no pain and a full range of motion on physical examination. Patient was allowed to resume his rugby activities as tolerated. At one year after surgery, the patient was persistently free of symptoms and had fully resumed rugby activities. The AOFAS score had improved from 24 preoperative to 91. Patient satisfaction was maximal (NRS 10/10). At final follow-up, 8 years after the surgery, he was still satisfied with the result (NRS 7/10), had occasionally pain after activity (NRS 4/10) and rated his ankle function as 'nearly normal'.

Case 3

A 30-year-old male presented with intermittent but progressive pain of the right ankle during activity without ankle swelling or laxity. There was a history of congenital bilateral clubfeet, for which he was treated conservatively in lower leg casts. Physical examination revealed a stiff hindfoot in varus at both sides and a flatfoot deformity. The weight-bearing radiographs showed a flattened talus. On CT scan, besides the extensive degeneration of both the ankle and subtalar joint, a strongly deformed talus bipartitus was detected. (Figure 6) Due to the limited impact of the complaints on his daily life, it was decided to start with steroid infiltrations in the subtalar joint. These injections were effective, and the ankle remained asymptomatic for several months. Injections were repeated occasionally if the pain aggravated. At final follow-up, 15 years following the onset of symptoms, he was still treated conservatively.

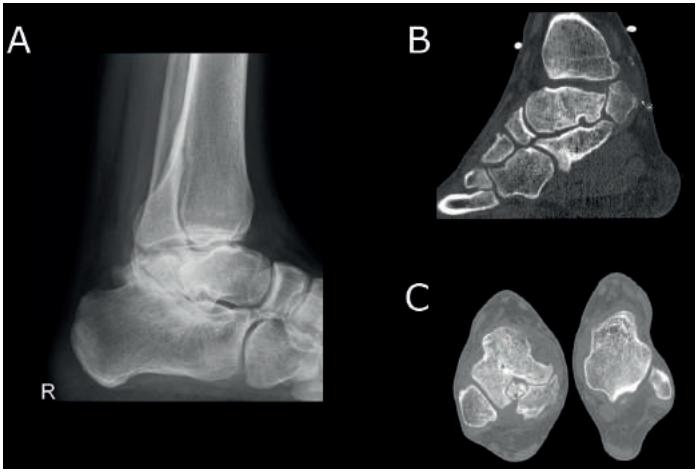


Figure 6. Radiographic images case 3. A. Weight bearing lateral radiograph showing a deformed talus and osteoarthritic changes in the subtalar joint. B. Sagittal CT image showing a flattened talar dome and talus bipartitus. C. Axial CT image showing a talus bipartitus at the right side. The left talus reveals a normal morphology.

DISCUSSION

Most important finding of this study was the wide variety in presentation of patients with symptomatic talus bipartitus. The presented manuscript provides an overview of the available literature on talus bipartitus. Patients with a symptomatic talus bipartitus predominantly develop nonspecific ankle pain on activity. A limited range of motion was noticed in half of the patients. This condition can remain asymptomatic for at least a couple of years, and two cases were detected coincidently after the follow-up of an ankle sprain. There was a wide variety in shape and size of the posterior fragment.

In 38% of the patients, signs of degenerative changes were present, and the extent of these changes depended on the congruency of the fragments in both the ankle and subtalar joints. In the reviewed literature, patients had a median age of 14 years, with a single patient aged 55 years as an outlier. The youngest patient was 11 years old. This is in accordance with the age at which the development of a second talar ossification centre was completed.[2]

In the literature, talus bipartitus is also known as 'talus bipartita', 'talus partitus' or 'frontal split of the talus'.[4 7] It is a rare congenital anomaly, in contrast to the more common and well-known os trigonum. The symptomatic os trigonum often can successfully be treated by arthroscopic resection.[17] The os trigonum is located at the posterolateral tubercle of the posterior process, whereas a true talus bipartitus involves both the posterolateral and posteromedial tubercles. In addition, in contrast to an os trigonum, the talus bipartitus can also extent into the ankle joint. This extension of the fragment makes it a different entity, in terms of clinical presentation, treatment and prognosis.

The prevalence of talus bipartitus is unknown. Pfitzner investigated 841 feet and reported on the prevalence of anomalies. He did not mention a single case of talus bipartitus.[18] Also Tsaruta et al., in their radiological study on 3460 ankles, did not find a case of talus bipartitus.[19] Together with the three cases presented in this study, we identified 26 patients with a talus bipartitus. Of them, only two had a bilateral talus bipartitus. In addition, Rammelt et al. reported also on imaging of a case in a book chapter.[13 20] This concerned a 13-year-old boy with ankle pain for more than a year. In this case, excision of the dorsal fragment was performed. Because of the persistence of complaints, a subtalar fusion was performed as a secondary procedure. However, this case was never published separately.

The majority of the cases have been published over the last decade. This was possibly due to advancements in additional diagnostics. CT and MRI are more sensitive to detect a talus bipartitus in comparison with conventional radiographs. Especially in case of the oblique running cleft, it might be missed on plain radiographs. Probably talus bipartitus is underreported in the literature, as it might be mistaken for a non-union of a talar fracture. A thorough history taking should, however, distinguish already between a talus bipartitus and a talar fracture.

Excision and fixation can both be considered while treating talus bipartitus surgically. The surgical preference depends on the size of the fragment and its involvement in surface area of both the talocrural and or subtalar joint. Two authors previously proposed a treatment algorithm. According to Rammelt et al., observation was indicated for asymptomatic patients, for symptomatic patients fixation was preferred in case of congruent fragments, and resection for incongruent fragments.[13] Joint fusion was indicated when signs of progressive osteoarthritis were present. Rose et al. proposed excision of the fragment when less than 20% of the subtalar articular surface was involved and fixation if the fragment exceeded 20%.[14] However, they did not mention how this should be measured. In our opinion, fixation is recommended when the fragment involves the joint surface of both the ankle and subtalar joint. Excision in those circumstances will lead to a decreased joint surface area which might lead to progressive osteoarthritis. In case the talus bipartitus only involves the subtalar joint, the decision to excise or fix is more challenging. Fixation is theoretically preferred over excision; however, the outcome depends on the size of the fragment, surgical skills and preexisting osteoarthritic changes. In our cases, more than 50% of the posterior subtalar joint was involved, as measured in the sagittal plane. The first presented patient was treated with excision, whereas in the second one the fragment was stabilized. Both patients had good short and long-term outcomes. Therefore, optimal treatment has to be tailored to the patient and depends on severity of complaints, activities of the patient, size of the fragment, joint involvements and the presence of degenerative changes at presentation.

Two cases were presented in which both fixation and excision were performed using an arthroscopic technique. To our knowledge, this is the first surgical description on the arthroscopic-assisted treatment of talus bipartitus. Arthroscopic treatment is preferable over open surgery because of the advantage of shortened hospital stay, rapid rehabilitation and smaller scars. Posterior ankle arthroscopy has been proven to be a safe and effective treatment option for several hindfoot problems.[17] Although we described only two cases, it seems that the two-portal hindfoot approach is also appropriate and safe for the treatment of symptomatic talus bipartitus. In this study, the first long-term outcomes are reported.

The talus ossifies from two ossification centres.[2,21] Based on a literature study and a histological study about the chondrification of tarsal primordia in human embryos and fetuses, Cihak concluded that the talus is formed out of the tibiale and intermedium. The tibiale forms the corpus tali and the intermedium will develop into the posterior process.[22] In case of independent ossification or failure of fusion, this part is responsible for the os trigonum, or possibly also for a talus bipartitus.

A direct traumatic injury is not likely to cause a bipartition of the talus. Eichenbaum hypothesized partition of the talus as a result of traumatic injury during osseous immaturity.[11] However, talar fractures only occur in high energy trauma, especially in children even higher forces are needed to cause a talar fracture. Therefore, absence of significant trauma rules out a fracture by definition. A possible alternative theory could be that the fusion of the secondary ossification centre with the talar body is prevented by a single or repetitive trauma during adolescence.[2] In addition to the ontogenetic and traumatic causes, also endocrine factors have to be excluded, since an association between hypothyroid epiphyseal dysgenesis and bipartition of hand and foot bones was described.[12]

In the third case, the talus was severely deformed as a result of a congenital clubfoot. This patient had bilateral clubfeet, with a talus bipartitus at the right ankle which became symptomatic later on in life. It is unknown whether there is a direct relation between the talus bipartitus and clubfeet.

This study has several limitations. Due to the rarity of talus bipartitus, only case reports and small cases series were included. The level of evidence is therefore low; however, this review provides the most comprehensive overview of the available evidence. Only two patients that underwent arthroscopic-assisted treatment for symptomatic talus bipartitus were included. Therefore, it was not possible to compare the results of the arthroscopic approach with results of open surgery.

CONCLUSION

Talus bipartitus is a rare anatomical anomaly. Symptoms are characterized by pain and restriction of subtalar motion in young patients. Surgical treatment can consist of excision or fixation of the fragment. We presented two cases of arthroscopically treated cases of talus bipartitus with excellent short- and long-term outcomes.

LITERATURE

1. Strehle E. Über Abnormitäten im Bereich der Tarsalknochen und ihre klinische Bedeutung: mit besonderer Berücksichtigung eines selbst beobachteten Falles einer Talusmißbildung: Oberreuter 1928.
2. McDougall A. The os trigonum. *J Bone Joint Surg Br* 1955;37-b(2):257-65. [published Online First: 1955/05/01]
3. Cedell CA. Rupture of the posterior talotibial ligament with the avulsion of a bone fragment from the talus. *Acta Orthop Scand* 1974;45(3):454-61. [published Online First: 1974/01/01]
4. Blauth W, Harten K, Kirgis A. [Frontal talus cleft--talus bipartitus]. *Zeitschrift fur Orthopadie und ihre Grenzgebiete* 1986;125(3):302-07.
5. Chandoga I, Vajcziková S. Talus partitus. Kazuistika. *Acta Chir Orthop Traumat Czechoslov* 2012;79(1):80-83.
6. Griffet J, Habre J, Abou-Daher A, et al. Talus bipartitus. *Revue de chirurgie orthopedique et reparatrice de l'appareil moteur* 2004;90(4):369-71. doi: 10.1016/s0035-1040(04)70134-8 [published Online First: 2004/06/24]
7. Schreiber A, Differding P, Zollinger H. Talus partitus. A case report. *Journal of Bone & Joint Surgery, British Volume* 1985;67(3):430-31.
8. Serrato J, Bennett J. Adolescent fracture of the talus associated with talus partitus. *Journal of surgical orthopaedic advances* 2012;22(2):164-67.
9. Thiel E, Feibel J, Chorey N, et al. Bipartite talus: a case report. *Foot & ankle international* 2010;31(6):552-55.
10. Weinstein SL, Bonfiglio M. Unusual accessory (bipartite) talus simulating fracture. A case report. *J Bone Joint Surg Am* 1975;57(8):1161-63.
11. Eichenbaum MD, Austin LS, Raikin SM. Chronic ankle pain secondary to talus partitus: two case reports. *Foot & ankle international* 2010;31(3):247-50.
12. Mann HA, Myerson MS. Treatment of posterior ankle pain by excision of a bipartite talar fragment. *J Bone Joint Surg Br* 2010;92(7):954-7. doi: 10.1302/0301-620X.92B7.23465
13. Rammelt S, Zwipp H, Prescher A. Talus Bipartitus: A Rare Skeletal Variation. *JBJS Case Connector* 2011(6):e21.
14. Rose B, Southgate C, Louette L. Bipartite talus: a case series and algorithm for treatment. *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2013;19(2):96-102. doi: 10.1016/j.fas.2012.11.011 [published Online First: 2013/04/04]
15. van Dijk CN, de Leeuw PA, Scholten PE. Hindfoot endoscopy for posterior ankle impingement. Surgical technique. *J Bone Joint Surg Am* 2009;91 Suppl 2:287-98. doi: 91/Supplement_2/287 [pii];10.2106/JBJS.I.00445 [doi]
16. van Dijk CN, Scholten PE, Krips R. A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2000;16(8):871-76.
17. Scholten PE, Sierevelt IN, van Dijk CN. Hindfoot endoscopy for posterior ankle impingement. *J Bone Joint Surg Am* 2008;90(12):2665-72.
18. Pfitzner W. Beiträge zur Kenntniss der Missbildungen des menschlichen Extremitätenskelets. In: Schwalbe, ed. Morph Arb. Jena1896:245 - 528.

19. Tsuruta T, Shiokawa Y, Kato A, et al. [Radiological study of the accessory skeletal elements in the foot and ankle (author's transl)]. *Nihon Seikeigeka Gakkai zasshi* 1981;55(4):357-70. [published Online First: 1981/04/01]
20. Hamel J, Braun A. Bildgebende Diagnostik am Fuss. *Fuss: Erkrankungen und Verletzungen Darmstadt, Germany: Steinkopff* 1998:14-22.
21. Hoerr NL, Pyle SI, Francis CC. Radiographic Atlas of Skeletal Development of the Foot and Ankle; A Standard of Reference. Springfield, Illinois: Charles C Thomas 1962.
22. Čihák R. Ontogenesis and Homologies of Human Carpal and Tarsal Components. Ontogenesis of the Skeleton and Intrinsic Muscles of the Human Hand and Foot: Springer 1972:12-59.

CHAPTER 9

A RARE CASE OF LATERAL ANKLE PAIN; A SYMPTOMATIC TALUS SECUNDARIUS

R. Zwiers
P.A.J. de Leeuw
G.M.M.J. Kerkhoffs
C.N. van Dijk

Foot Ankle Surg 2017

ABSTRACT

The talus secundarius is one of the rarest accessory tarsal bones, being present in 0.01% of all ankles. It is located at the lateral side of the talus, distally to the tip of the fibula. Hitherto, only five cases of a symptomatic talus secundarius have been described in literature. We presented a case of bilateral symptomatic talus secundarius in a young gymnast. There was a difference in size of the two accessory bones. The large talus secundarius in the left ankle was fixated, in the right ankle the fragment was excised. Both excision and fixation in the presented patient led to satisfactory results, both in the short and long term outcome.

INTRODUCTION

The os trigonum and the os tibiale externum are the most common accessory bones in the foot and ankle. The talus secundarius is generally less known. It is located at the lateral side of the talus, distally to the tip of the fibula and is one of the rarest accessory ankle bones, being present in 0.01% of all ankles.[1] Up to present only five cases of a symptomatic talus secundarius have been described in literature.[2-5] We performed a literature review on this rare accessory bone and present a case of bilateral symptomatic talus secundarius in a high-level athlete.

CASE REPORT

A fourteen years old high-level gymnast presented with increasing pain at the lateral aspect of both ankles mainly during jumping exercises. The patient could not recall any trauma preceding his current complaints. With normal daily activities no limitations were reported. Past medical history did not reveal any other foot and ankle pathologies. On physical examination there was a normal hindfoot alignment, the range of motion of both the tibiotalar and talocalcaneal joints were symmetric, being 20° of dorsiflexion and 40° of plantar flexion and 20° of both inversion and eversion in the talocalcaneal joint. There was recognizable tenderness on palpation at the anterolateral aspect of both talar bones, specifically 1 cm distally to the anterolateral ligament complex. Both the anterolateral ankle ligaments and the syndesmosis were stable. In addition, there was tenderness over the distal aspect of the peroneal tendons, just distally to the tip of the lateral malleolus. However, peroneal tendon resistance tests did not reveal abnormalities. Based on the patient' complaints and the physical examination the differential diagnosis included a stress fracture, peroneal tendon instability, or a subtalar coalition.

The computed tomography (CT) scan of the right ankle showed a small rounded fragment (7 x 5 x 2 mm) lateral to the talus at the level of the subtalar joint, forming a synchondrosis with the talus. At the same location in the left ankle a larger osseous fragment was found (17 x 15 x 10 mm), with small cysts at the level of the synchondrosis. (Figure 1) In both ankles the superomedial aspect of the calcaneus showed an atypical aspect. In addition magnetic resonance imaging (MRI) showed bilateral bone marrow edema of the talus at the level of the fragments. (Figure 2)

The patient was diagnosed with a bilateral symptomatic talus secundarius. Initially, he was treated nonoperatively for a period of 6 weeks predominantly with rest and immobilization in a Walker boot. On follow-up there was no improvement and therefore it was decided to surgically address the pathology.

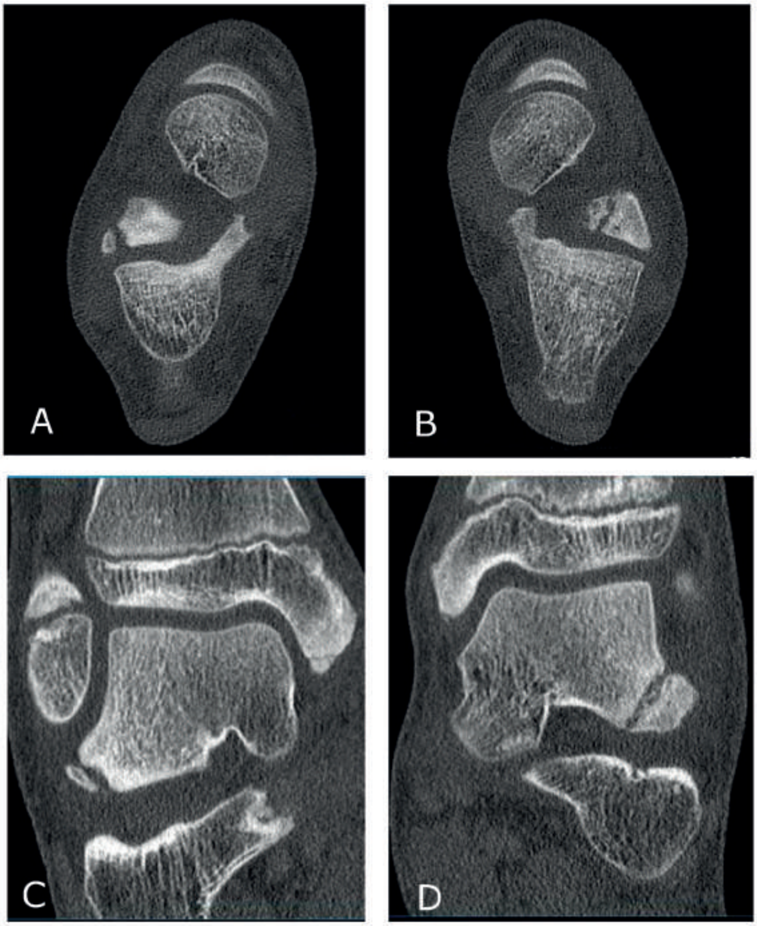


Figure 1. Computed tomography of both ankles showed a bilateral talus secundarius. A and C. right ankle small rounded ossicle (7 x 5 x2 mm). B and D. large fragment (17 x 15 x 10 mm) with small cyst at the level of synchondrosis.

The patient underwent the surgical procedure for both ankles in a single session, under spinal anesthesia in the daycare unit. Patient was positioned supine with a tourniquet around both upper legs and prophylactic antibiotics (cefuroxime iv) were given according to the local protocol. At the right side the bony fragment was removed through a mini-open surgical approach, just distally from the tip of the lateral malleolus. The anterior talofibular ligament and the talocalcaneal ligament remained undisturbed. At the left side it was decided to rigidly fixate the talus secundarius onto the talar body because of its significant contribution to the talocalcaneal surface area. A similar surgical approach was performed as in the right ankle and both the surface of the bony fragment and the talus were debrided, without the need to release the anterolateral ankle ligaments. Compression and fixation were achieved by means of two small fragment lag screws (26 mm 2.5mm).

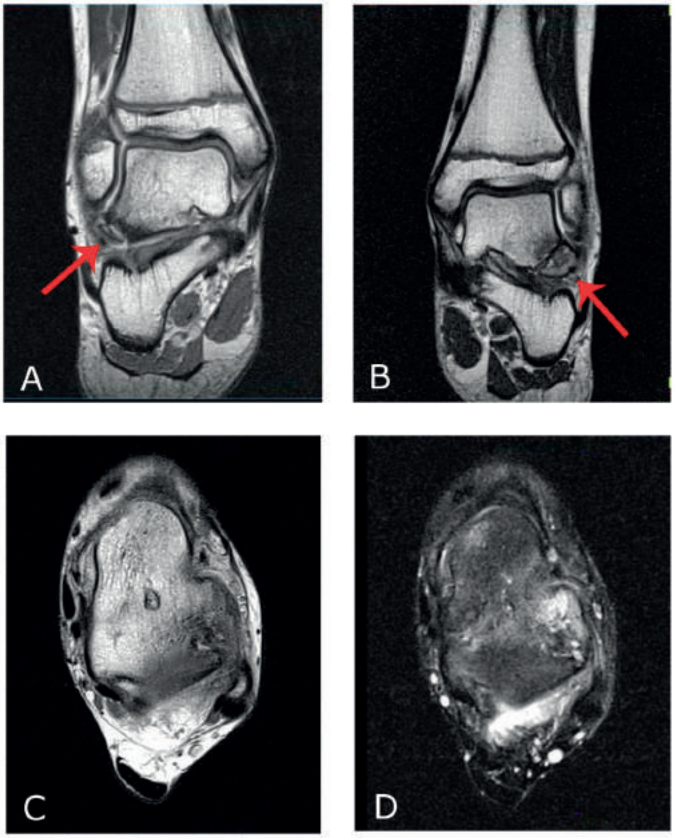


Figure 2. Magnetic resonance imaging of both ankles. A and C. right ankle, small talus secundarius fragment (red arrow) with bone marrow edema at the level of the fragment. B and D. left ankle, talus secundarius (red arrow) with bone marrow edema at the level of the bony fragment.

Postoperative management for both ankles consisted of non-weight bearing below knee casts for 2 weeks. At two weeks follow up the right side was allowed weight bearing as tolerated without immobilization. The left ankle was immobilized for another eight weeks, consisting of a four weeks below knee weight bearing cast and four weeks with a Walker. A prophylactic dose of low molecular weight heparin was prescribed for 6 weeks to prevent thromboembolic events.

At three months follow up, the right ankle had fully healed, whereas the left ankle was still tender on palpation over the anterolateral talus. The wound on both ankles healed uneventfully and there was no injury to the neurovascular structures. Both ankles had a full range of motion, and the patient was allowed to resume sporting activities as tolerated under the supervision of the sports physician and physiotherapist. Postoperative weight bearing radiographs of the left ankle showed signs of consolidation. (Figure 3) At one year follow up there was occasionally some tenderness in the left ankle during intensive activity, which however did not prevent him from performing at high level gymnastics. At two years follow up he was free of pain during all activities (numeric rating scale (NRS) for pain 0 / 10) and his function was equal to the pre-injured situation(NRS function 10 / 10; FAOS scores: symptoms 88, pain 100, activity 100, sport 100, quality of life 100). At final follow-up, seven years postoperatively, his condition was unchanged. Patient was satisfied with the result of both surgeries (NRS satisfaction 8 /10) and declared he would undergo the same surgery again in similar circumstances.

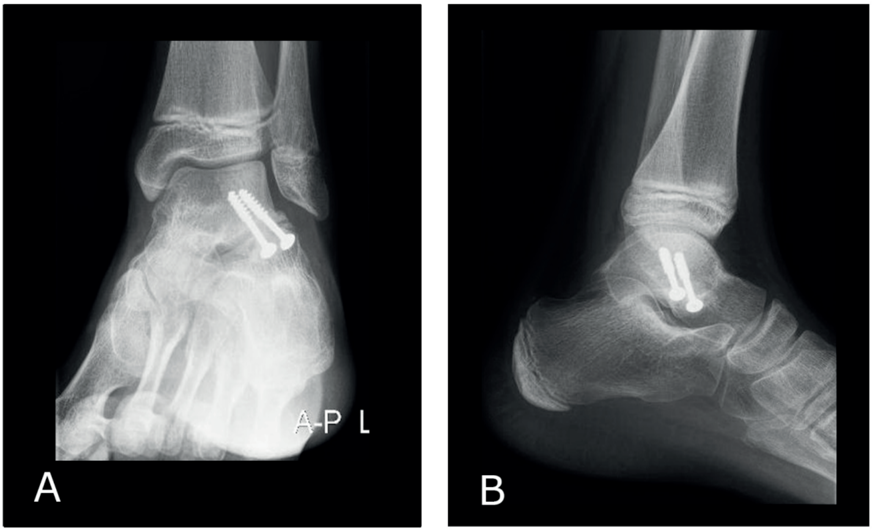


Figure 3. Postoperative weight bearing radiographs of the left ankle, AP (A) and lateral (B), three months after surgery, showed adequate position of the screws and early signs of consolidation.

DISCUSSION

Talus secundarius is very rarely a symptomatic pathology needing (surgical) treatment. In this study we present a case of bilateral symptomatic talus secundarius. Both excision and fixation in the presented patient led to satisfactory results, both in the short and long term outcome. The term talus secundarius was firstly used by Gruber in 1864.[6] He mentioned the accessory bone posterior to the talus, already described by Rosenmüller in 1804, which currently is known as the os trigonum.[7] Pfitzner was first to describe an accessory bone lateral to the lateral process of the talus and considered it as the result of an unhealed fracture.[8] After Bardeleben introduced the term 'os trigonum' for the posterior fragment[9], the name 'talus secundarius' was available for the lateral located fragment, as described by Pfitzner.[8] In literature the term 'talus secundarius' is still sometimes erroneously used when referring to the os trigonum or the talus accessorius. The talus accessorius is located at the medial side of the talus.[8] The term 'talus secundarius' is also used for other accessory ossicles as well, like the os supratalare or the os subtibiale.[10 11] Radiologically the talus secundarius can be confused with the os subfibulare, an accessory bone that is located distally to the fibula.[2] Furthermore, it must be distinguished from a lateral talar process fracture (Figure 4).[12]

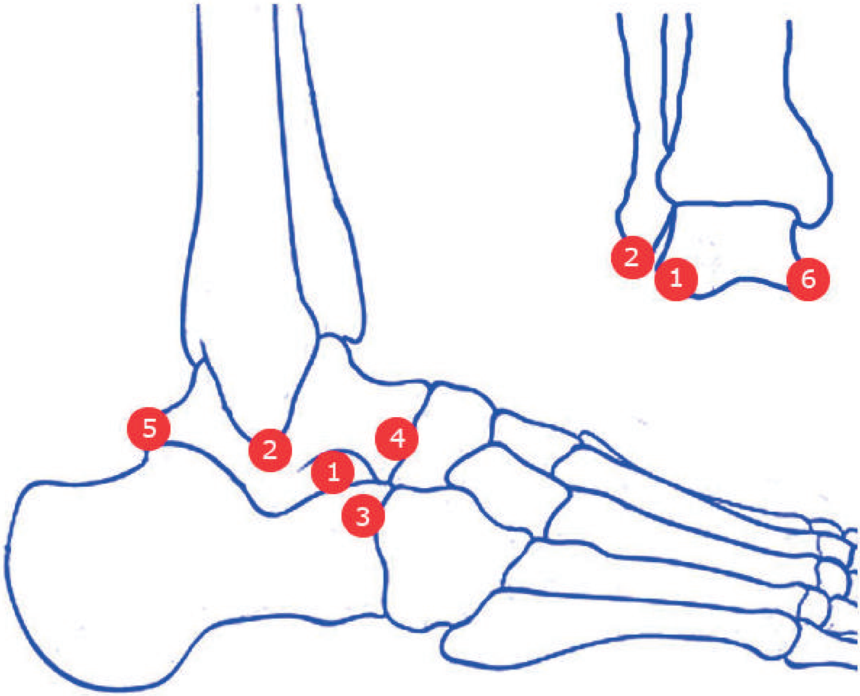


Figure 4. Accessory bones around the ankle, according to Pfitzner.[8] 1, os talus secundarius; 2, os subfibulare; 3, calcaneus secundarius; 4, os supratalare; 5, os trigonum; 6, os talus accessorius.

The talus secundarius is one of the rarest accessory bones of the foot. In a large Japanese study, three ankles with a talus secundarius were detected, resulting in a prevalence 0.01%.[1] The first cases of symptomatic talus secundarius have been described in 1952 by Schluter.[4] She described two cases of symptomatic talus in young patients after an ankle sprain. Since then only three additional cases have been published.[2 3 5] Patients aged from 12 to 31 years old. In these published cases five out of six patients were males, whereas in the radiological study symptomatic cases a clear injury occurred prior to the onset of symptoms. Only one other case of bilateral talus secundarius was found.[5] The bilateral prevalence is unknown. Four of the published cases underwent excision of the fragment, all with good results (Table 1)

Table 1. Overview of published cases of symptomatic talus secundarius. F, female; M, male.

Study	Age	Sex	Side	Symptoms	Physical Exam	Etiology	Connection Talus	Treatment
Schluter (1952) [4]	12	F	Right			Ankle sprain	Synchondrosis	Resection
	16	M	Left			Ankle Sprain	Synchondrosis	Resection
Hahn (1978) [3]	25	M	Right	Lateral ankle pain on uneven ground	Tenderness fibula tip, normal peroneal tendon function.	No trauma	Synostosis	Resection
Viana (2007) [2]	31	M	Right	Lateral ankle pain aggravated by walking and standing			Synostosis	
Oliviera(2012) [5]	18	M	Bilateral	Ankle pain aggravated by sports	Tender point just distal to both fibular malleoli	No trauma	Synchondrosis	Resection

The origin of the talus secundarius is unclear. Following the current literature the talus ossifies from two ossification centers, the main talar body and the posterior process. There is no literature on the existence of other ossification centers.[13] It is however hypothesized that accessory bones are the result of remnants of elements that arise during the ontogenesis of the talus.[14] There has been several theories on the development of the tarsal bones, of which a commonly used theory is that the tarsal bones are formed out of the different “canonical elements”, as described by Gegenbaur. These consists of the tibiale, fibulare, intermedium and the centralia I-IV.[15] According to embryological studies in mammals, the talus is developed out of the fusion of the tibiale (the corpus tali), the intermedium (posterior process) and the centrale I (at the location of the future lateral process).[16 17] During further development the centrale I is reduced and is replaced by an expansion and chondrification of the main talar body. It is hypothesized that accessory bones near the lateral tubercle of the talus are the results of rudiments of the centralia. The talus secundarius could be the result of the remnants of centrale III that is not incorporated in the navicular bone.[14] Schlutzer suggested that the talus secundarius center usually fuses with the talus during adolescence and that therefore it is rarely observed. This hypothesis is supported by the fact that presence of the talus secundarius is only reported in a young population. In addition, in two cases in which the patients were older the talus secundarius formed a synostosis with the talus, were in the other cases the fragments were completely separated from the talus or formed a synchondrosis.

Symptoms mainly involve pain and can cause limitation of the subtalar range of motion. In the presented case tenderness was the main issue without any limitation in the range of motion, possibly due to the relatively limited involvements of these accessory bones to the talocalcaneal joint. The MRI of the left ankle showed fragments and small cysts at the location of the synchondrosis. Possibly the pain was due to micromovement between the fragment and the talus.

There was a large difference in size between the two fragments, 7 x 5 x 2 mm and 17 x 15 x10 mm. The size of the talus secundarius and its involvement in the subtalar joint made that fixation was chosen over excision. Treatment strategies mirrors those for lateral tubercle fractures.[18]

The talus secundarius is one of the rarest accessory tarsal bones, located at the lateral side of the talus, varying in shape and size and thereby in its contribution to the talocalcaneal joint surface area. Symptomatic patients may suffer from lateral ankle pain during activity. Depending on the size of the fragment and involvement of the subtalar joint, either excision or fixation of the fragment can be performed. In the presented case both interventions have led to satisfactory results both in the short- and long term.

LITERATURE

1. Tsuruta T, Shiokawa Y, Kato A, et al. [Radiological study of the accessory skeletal elements in the foot and ankle (author's transl)]. *Nihon Seikeigeka Gakkai zasshi* 1981;55(4):357-70. [published Online First: 1981/04/01]
2. Viana S, Fernandes J, Mendonca J, et al. Painful os talus secundarius: A case report and imaging findings. *Foot & ankle international* 2007;28(5):624-25.
3. Hahn J. Surgical excision of an os talus secundarius: a case report. *The Journal of foot surgery* 1977;17(3):129-31.
4. Schluter A. [Two cases of talus secundarius in adolescents.]. *Archiv fur orthopadische und Unfall-Chirurgie* 1952;45(6):624-28.
5. Oliveira F, Serrano P, Faísca J, et al. Symptomatic os talus secundarius: a case report. *European Orthopaedics and Traumatology* 2012;3(4):261-62.
6. Gruber W. Vorläufige mittheilung über die secundären fusswurzelknochen des menschen. *Archiv für Anatomie Physiologie Wissenschaftliche Medizin* 1864;31:286-90.
7. Rosenmuller J. De mon nullis musculorum corpus humani varietatibus. *Leipzig* 1804;8
8. Pfitzner W. Beiträge zur Kenntniss der Missbildungen des menschlichen Extremitätenskelets. In: Schwalbe, ed. Morph Arb. Jena1896:245 - 528.
9. Bardeleben K. Das intermedium tarsi beim menschen und saugethieren. *J Anat Physiol* 1885;19:509.
10. O'Rahilly R. A survey of carpal and tarsal anomalies. *J Bone Joint Surg* 1953;35(3):626-42.
11. Coughlin MJ, Saltzman CL, Mann RA. Mann's Surgery of the Foot and Ankle: Expert Consult-Online: Elsevier Health Sciences 2013.
12. Williams H. Normal anatomical variants and other mimics of skeletal trauma. Imaging in Pediatric Skeletal Trauma: Springer 2008:91-118.
13. Hoerr NL, Pyle SI, Francis CC. Radiographic Atlas of Skeletal Development of the Foot and Ankle; A Standard of Reference. Springfield, Illinois: Charles C Thomas 1962.
14. Čihák R. Ontogenesis and Homologies of Human Carpal and Tarsal Components. Ontogenesis of the Skeleton and Intrinsic Muscles of the Human Hand and Foot: Springer 1972:12-59.
15. Gegenbaur C. Untersuchung zur vergleichenden Anatomie der Wirbeltiere. I. *Carpus und Tarsus Leipzig, Germany: Engelmann* 1864
16. Holmgren N. An embryological analysis of the mammalian carpus and its bearing upon the question of the origin of the tetrapod limb. *Acta Zoologica* 1952;33(1-2):1-115.
17. Steiner H. Der Aufbau des Säugetier-Carpus und-Tarsus nach neueren embryologischen Untersuchungen. *Rev Suisse Zool* 1942;49(13):217-23.
18. Perera A, Baker JF, Lui DF, et al. The management and outcome of lateral process fracture of the talus. *Foot and Ankle Surgery*;16(1):15-20. doi: 10.1016/j.fas.2009.03.004

CHAPTER 10

GENERAL DISCUSSION

GENERAL DISCUSSION

Part I - The os trigonum

The os trigonum is known as one of the most common accessory bones of the foot and ankle and is often associated with of posterior ankle impingement. [1 2] However since the first descriptions of the os trigonum by Rosenmuller there has been no consensus about its occurrence. [3] A wide variation of prevalences, 1.7% - 12.7%, has been reported to date.[1 4-12] In chapter 2 the prevalence of the os trigonum was found to be 30.3% in a asymptomatic population, remarkably higher than hitherto reported in the literature. Patients with posterior ankle complaints were more likely to have an os trigonum. Probably patient selection, the detection tool used and also definition play a role in the large variation. One of the reasons could be that in this study CT scans were used, whereas in other studies conventional radiographs were used of which it is known that they do not have high sensitivity for detecting an os trigonum.[13] The high prevalence of the os trigonum in the asymptomatic population supports the conclusion that it is usually an asymptomatic condition and underlines it should be considered as a normal anatomical variant. Remarkably it seems to appear as often as unilateral and as bilateral. Additionally, size and shape differ between left and right. Ethnicity was found to be related to prevalence of the os trigonum, Caribbean/Surinamese/African origin was associated with a lower rate of occurrence of os trigonum. It would be of interest to study why in some patients the os trigonum fails to fuse to the rest of the talus. One hypothesis is that the os trigonum does not fuse in case children are involved in activities that require frequent plantar flexion movements during the ossification period.[14] In our study only a few children were included and we were not able to retrieve information about activity. To study this hypothesis one could compare the prevalence of the os trigonum in the dominant leg in soccer players in comparison with their non-dominant leg. However, the prevalence in a study on ballet dancers showed to be similar to the prevalence found in our study, and so it is questionable whether the prevalence amongst ballet dancers is really higher, than the normal population.[14]

Since the presence of an os trigonum is common and only a very small portion becomes symptomatic, the question is which factors play a role in development of complaints. One could imagine an os trigonum to be become symptomatic after a traumatic event. Patients with repetitive plantar flexion movements are more likely to develop complaints due to overuse.[15] But it is unknown whether size and location of the bony impediment play a role. Therefore in Chapter 3 the geometrical characteristics of bilateral ossa trigona in patients with only unilateral complaints were compared. An association with size was found as well as with the presence of calcifications, the latter indicating repetitive impingement of soft tissue. Despite the shortcomings of this study we can conclude that there seems to be a relation between size and complaints. We hypothesized that the space between os trigonum and posterior aspect of tibia would show a relation with impingement symptoms. In our study we were not able to find a relation, but probably our sample size was too small to detect a difference. One of the possible causes of pain is impingement of the intermalleolar ligament or posterior capsule.[16] Chance of entrapment is likely to be higher when there is less space. The calcifications found around the os trigonum could be the result of the effect on the tissue of repetitive entrapment of these soft tissues.

With the determination of the high prevalence and the relation of size of the os trigonum with development of complaints we found some answers about the role of the os trigonum in the posterior ankle impingement syndrome. However there are still ambiguities to resolve. Like what is the exact source of pain? Further research could use new technologies like advanced MR imaging tools like 4D scans to perform more dynamic evaluation of the posterior ankle to help us to get better understanding of posterior impingement.

Part II – Conventional imaging for detecting osseous impediment

In part II the conventional imaging in the diagnostic work up of posterior ankle impingement was evaluated. Essentially, the diagnosis is made clinically, based on the recognizable pain provoked with the hyperplantar flexion test.[15] However, imaging is used to confirm the hypothesized diagnosis, rule out other pathology. Imaging can also be used as a tool for preoperative planning.

A previous study showed the PIM- view to be superior in detecting an os trigonum compared to the standard lateral view.[13] This view was set at an angle of 25 degrees without any scientific rationale of the effectiveness of this angle. In Chapter 4 we systematically assessed a wide range of direction views to find the projection angle with the best diagnostic value. Our study confirmed that exorotated views in a range from 15°-25° have a clear additional value in detecting an osseous impediment in comparison with the standard lateral view.

Advanced imaging modalities like CT and MRI are used more frequently and have their own advantages. CT scans gives the opportunity to assess the bony structures, relations between bones, calcifications and other degenerative changes like subchondral cysts. MRI allows us to detect bone marrow edema and is superior in imaging the soft tissue structures like tendons and ligaments involved in the posterior ankle. [17]

Despite these evident advantages of CT and MRI and the increasing use of these modalities in diagnosis of posterior ankle pain now and in the future, conventional imaging will still have a role in the work-up of patients with posterior ankle impingement. The advantages of radiography are that it is widely available, fast, easy to use, cheap and allows weight-bearing during imaging. [18-22] Conventional imaging has a function as screenings tool, and is usually used as first imaging step. The addition of the 25°degree exorotated view will provide a better view of the posterolateral aspect of the ankle and with a negative predictive value of 96% the presence of an os trigonum can be ruled out.

Radiological technology is continuously evolving. In the near future, weight-bearing CT and dynamic new MRI techniques will gain ground. [23 24]

Part III - Surgical treatment for posterior impingement

Although there is only little literature on conservative treatment options for posterior ankle impingement, non- surgical options are recommended as initial treatment.[16 25] When these options fail or do not lead to satisfactory outcome, surgical intervention is indicated. Surgical treatment consists of removal of osseous impediments and/or soft tissue, either using an open or endoscopic approach. [16]

At the start of this thesis we performed a systematic literature review on the surgical treatment of posterior impingement. [26] From this review we concluded that the overall level of evidence was low, based on small retrospective case series. For both open and endoscopic surgery where the osseous impediment and/or interposing soft tissue is removed, good outcomes were described. The available literature was lacking large series, randomized trails and studies reporting long-term outcomes and recurrence rates.

Hence, we studied the long term results of a cohort of patients that underwent endoscopic treatment using the two-portal hindfoot approach. In this series the patient satisfaction was good at the long term. There was a low recurrence rate and type or level of sport did not influence the long term outcome. This study showed that the satisfactory outcome previously described on the short term in the same patient group maintained over time. We found the presence of FHL tendinopathy to be associated with worse outcome. In contrast with earlier studies there was no difference in outcome between overuse and acute type of impingement.[27]

Over the last years several large series [28-30] and a randomized trial [31] were published. In chapter 6 we updated the systematic review and meta-analysis of the outcome of open and endoscopic treatment. From this study it can be concluded that there is no clinical relevant difference in postoperative AOFAS score, patient satisfaction and return to pre-injury level of activity between open and endoscopic techniques. Complication rates were lower with endoscopic treatment in the ‘fair’ and ‘good’ methodological quality studies. The only randomized trial performed found similar outcome between endoscopic and open surgery. However, in that study there was a significant difference in recovery time favoring endoscopic treatment.[31] There is a large heterogeneity in in the included studies in terms of population, surgical technique and rehabilitation protocol. We were not able to compare different endoscopic techniques. For fair comparison between techniques or determine the effect of rehabilitation protocol more high quality comparative studies are needed. Most orthopedic surgeons or institutions have a preferred technique. The use of other techniques often comes with a learning curve. Therefore in studies evaluating different techniques an expertise-based randomized design would maybe considered. [32 33]

Part IV – Related osseous hindfoot anomalies

The talus bipartitus has probably the same origin as the extensively discussed os trigonum. The two main ossification centers fail to fuse, however in the case of the talus bipartitus the separation is more anterior, resulting in a separated posterior talar process. The Cedell fracture, or posteromedial tubercle fracture, results in a fragment posterior to the posterior talar process and can therefore be mistaken for the os trigonum or a posterolateral tubercle fracture (or Shepherd’s fracture). The talus secundarius is a fragment that failed to fuse to the lateral tubercle of the talus. The name talus secundarius was initially used for the os trigonum.

In chapter 7 the current literature on talus bipartitus was summarized. In comparison with symptomatic ossa trigona, the talus bipartitus has a wide range of symptom presentations. There are also asymptomatic cases described. The size and extent of joint involvement varied widely among the cases. Therefore the treatment is often tailored to the case and not only depends on the size of the fragment or joint involvement, but also the presence of degenerative changes, severity of complaints and activity level.

The posteromedial talar process fracture is often referred to as the Cedell fracture. However the fracture as described by Cedell [34], an avulsion of the insertion of the posterior talotibial ligament, is only one of several different fracture types. In the systematic review in chapter 8, 33% of the cases were involved in high velocity incidents and 12.5% reported a direct impact during sports. Most important is that in these cases the fracture is recognized and the injury is not be mistaken for a simple ankle sprain. 73% of the cases in the literature underwent an open surgical intervention, either excision of the fragment or internal fixation. We presented an endoscopic technique using the two-portal hindfoot technique [35] as alternative to open surgery. Results of the small retrospective case series showed this technique to be a safe and effective treatment option.

In contrast with the os trigonum, the talus secundarius is one of the rarest accessory tarsal bones as discussed in chapter 9.[1] Our literature search yielded only five symptomatic cases, all presenting with lateral ankle pain during activity. A case report of an athlete with bilateral symptomatic talus secundarius was described, showing that both fixation and excision, depending on size and subtalar joint involvement, can result in satisfactory outcome. Recently two case reports[36 37] and a small case series[38] were published. In all symptomatic cases excision of the fragment was performed.

All three diagnoses, i.e. the talus bipartitus, the avulsion of the insertion of the posterior talotibial ligament and, the talus secundarius, are rare. The relevant literature is scarce, consisting of case reports and small case series only. However for decision making for treatment of rare diagnoses, reviews of case reports and small case series can help by summarizing the treatment options and their outcome, even though the limited conclusions that can be drawn. More knowledge of these rare pathologies and infrequent accessory bones will help to recognize them as cause of symptoms in the clinical setting.

In conclusion, the os trigonum should be considered as normal anatomical variant with a high prevalence in the population. Generally, its presence is an asymptomatic condition, however, it can become symptomatic after a hyperplantarflexion trauma of repetitive plantar flexion movements. Probably, larger ossa trigona cause more often symptoms. Diagnosis is based on physical examination supported by imaging. The diagnostic value of conventional radiographs is improved when an exorotated view is added to the standard lateral view. Endoscopic treatment provides good long-term outcome with a low recurrence rate. Both open surgical techniques as well as endoscopic techniques result in high patient satisfaction, good functional outcome, however the complication rate of endoscopic treatment seems to be lower. Related pathologies like talus bipartitus and posteromedial tubercle fractures should be distinguished from a symptomatic os trigonum. These pathologies can be surgically treated with an endoscopic approach as alternative to an open procedure.

LITERATURE

1. Tsuruta T, Shiokawa Y, Kato A, et al. [Radiological study of the accessory skeletal elements in the foot and ankle (author's transl)]. *Nihon Seikeigeka Gakkai Zasshi* 1981;55(4):357-70.
2. Keles-Celik N, Kose O, Sekerci R, et al. Accessory ossicles of the foot and ankle: disorders and a review of the literature. *Cureus* 2017;9(11)
3. Rosenmuller J. De mon nullis musculorum corpus humani varietatibus. *Leipzig* 1804;8
4. Thompson A. Report of the committee of collective investigation of the Anatomical Society of Great Britain and Ireland for the year 1889-1890. *J Anat* 1891;25:89-101.
5. Pfitzner W. Beiträge zur Kenntniss der Missbildungen des menschlichen Extremitätenskelets. In: Schwalbe, ed. Morph Arb. Jena1896:245 - 528.
6. Stieda CHL. Ueber secundare fusswurzelknochen. *Arch Physiol Wissensch Med* 1869:108-11.
7. Sewell RS. A study of the astragalus. *Journal of anatomy and physiology* 1904;38(Pt 3):233.
8. Burman M, Lapidus PW. The functional disturbances caused by the inconstant bones and sesamoids of the foot. *Archives of Surgery* 1931;22(6):936-75.
9. Agur AM, Dalley AF. Grant's atlas of anatomy: Lippincott Williams & Wilkins 2013:475.
10. Mann R, Owsley D. Os trigonum. Variation of a common accessory ossicle of the talus. *Journal of the American Podiatric Medical Association* 1990;80(10):536-39.
11. Cilli F, Akçaoğlu M. [The incidence of accessory bones of the foot and their clinical significance]. *Acta orthopaedica et traumatologica turcica* 2004;39(3):243-46.
12. Coskun N, Yuksel M, Cevener M, et al. Incidence of accessory ossicles and sesamoid bones in the feet: a radiographic study of the Turkish subjects. *Surgical and radiologic anatomy* 2009;31(1):19-24.
13. Wiegerinck JI, Vroemen JC, van Dongen TH, et al. The posterior impingement view: an alternative conventional projection to detect bony posterior ankle impingement. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2014;30(10):1311-6. doi: 10.1016/j.arthro.2014.05.006 [published Online First: 2014/07/16]
14. McDougall A. The os trigonum. *J Bone Joint Surg Br* 1955;37-b(2):257-65. [published Online First: 1955/05/01]
15. van Dijk CN. Anterior and posterior ankle impingement. *Foot Ankle Clin* 2006;11(3):663-83.
16. Ribbans WJ, Ribbans HA, Cruickshank JA, et al. The management of posterior ankle impingement syndrome in sport: a review. *Foot and ankle surgery : official journal of the European Society of Foot and Ankle Surgeons* 2015;21(1):1-10. doi: 10.1016/j.fas.2014.08.006 [published Online First: 2015/02/16]
17. Hayashi D, Roemer FW, D'Hooghe P, et al. Posterior ankle impingement in athletes: pathogenesis, imaging features and differential diagnoses. *European journal of radiology* 2015;84(11):2231-41.
18. Ebraheim NA, Karkare N, Gehling DJ, et al. Use of a 30-degree external rotation view for posteromedial tubercle fractures of the talus. *J Orthop Trauma* 2007;21(8):579-82. doi: 10.1097/BOT.0b013e31804ea0d9 [doi];00005131-200709000-00010 [pii]

19. Ebraheim NA, Mekhail AO, Haman SP. External rotation-lateral view of the ankle in the assessment of the posterior malleolus. *Foot & ankle international* 1999;20(6):379-83.
20. Ebraheim NA, Patil V, Frisch NC, et al. Diagnosis of medial tubercle fractures of the talar posterior process using oblique views. *Injury* 2007;38(11):1313-17. doi: S0020-1383(07)00193-3 [pii];10.1016/j.injury.2007.04.025 [doi]
21. van Dijk CN, Wessel RN, Tol JL, et al. Oblique radiograph for the detection of bone spurs in anterior ankle impingement. *Skeletal radiology* 2002;31(4):214-21.
22. Tol JL, Verhagen RA, Krips R, et al. The anterior ankle impingement syndrome: diagnostic value of oblique radiographs. *Foot & ankle international* 2004;25(2):63-68.
23. Bae WC, Ruangchaijatuporn T, Chung CB. New techniques in MR imaging of the ankle and foot. *Magnetic Resonance Imaging Clinics* 2017;25(1):211-25.
24. Siriwanarangsun P, Bae WC, Statum S, et al. Advanced MRI techniques for the ankle. *American Journal of Roentgenology* 2017;209(3):511-24.
25. Robinson P, Bollen SR. Posterior ankle impingement in professional soccer players: effectiveness of sonographically guided therapy. *American Journal of Roentgenology* 2006;187(1):W53-W58.
26. Zwiers R, Wiegerinck JI, Murawski CD, et al. Surgical treatment for posterior ankle impingement. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2013;29(7):1263-70. doi: 10.1016/j.arthro.2013.01.029 [published Online First: 2013/04/02]
27. Scholten PE, Sierevelt IN, van Dijk CN. Hindfoot endoscopy for posterior ankle impingement. *J Bone Joint Surg Am* 2008;90(12):2665-72.
28. Rietveld A, Haitjema S. Posterior Ankle Impingement Syndrome and M. Flexor Hallucis Longus Tendinopathy in Dancers Results of Open Surgery. *Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science* 2018;22(1):3-10. doi: 10.12678/1089-313x.22.1.3 [published Online First: 2018/03/08]
29. Miyamoto W, Miki S, Kawano H, et al. Surgical outcome of posterior ankle impingement syndrome with concomitant ankle disorders treated simultaneously in patient engaged in athletic activity. *Journal of orthopaedic science : official journal of the Japanese Orthopaedic Association* 2017;22(3):463-67. doi: 10.1016/j.jos.2016.12.017 [published Online First: 2017/01/15]
30. Zwiers R, Baltes TPA, Wiegerinck JI, et al. Endoscopic treatment for posterior ankle impingement: High patient satisfaction and low recurrence rate at long-term follow-up. *Journal of ISAKOS* 2018;3(5):269-73. doi: http://dx.doi.org/10.1136/jisakos-2017-000175
31. Georgiannos D, Bisbinas I. Endoscopic Versus Open Excision of Os Trigonum for the Treatment of Posterior Ankle Impingement Syndrome in an Athletic Population: A Randomized Controlled Study With 5-Year Follow-up. *The American journal of sports medicine* 2017;45(6):1388-94. doi: 10.1177/0363546516682498 [published Online First: 2017/01/24]
32. Scholtes VA, Nijman TH, van Beers L, et al. Emerging designs in orthopaedics: expertise-based randomized controlled trials. *JBJS* 2012;94(Supplement_1):24-28.
33. Cook JA, Campbell MK, Gillies K, et al. Surgeons' and methodologists' perceptions of utilising an expertise-based randomised controlled trial design: a qualitative study. *Trials* 2018;19(1):478.
34. Cedell CA. Rupture of the posterior talotibial ligament with the avulsion of a bone fragment from the talus. *Acta Orthop Scand* 1974;45(3):454-61.

35. van Dijk CN, Scholten PE, Krips R. A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 2000;16(8):871-76.
36. Kose O, May H, Acar B, et al. Symptomatic os talus secundarius: a case report and review of the literature. *Skeletal radiology* 2018;47(4):553-62. doi: 10.1007/s00256-017-2803-6 [published Online First: 2017/11/04]
37. Madi S, Pandey V, Senthil V, et al. An annoyance from an anomalous OS. *Case Reports* 2016;2016:bcr2016214540.
38. Rammelt S, Manke E, Prescher A. Talus Secundarius: Case Series. *Foot & Ankle International* 2020:1071100720903298.

CHAPTER 11

SUMMARY / SAMENVATTING

SUMMARY

Posterior ankle impingement is an uncommon cause of posterior ankle pain during plantar flexion. It is associated with the presence of bony anomalies like the os trigonum. However, the presence of an os trigonum usually is an asymptomatic condition. Aim of this thesis is to provide more insight in the epidemiologic and geometric characteristics of the os trigonum, the role of conventional radiographs, and surgical treatment of posterior ankle impingement and the long term outcomes. In addition, related osseous pathologies will be addressed, as well as new insights on their treatment.

In chapter 2 the prevalence of the os trigonum is determined in an asymptomatic population. With a prevalence of 30.3% in patients without posterior ankle complaints, the prevalence is higher than hitherto reported. The os trigonum was found to be as often unilateral as bilateral. As expected the prevalence in patients with posterior impingement was higher.

To study the differences between symptomatic and asymptomatic ossa trigona, the geometrical characteristics of symptomatic and symptomatic ankles were compared in chapter 3. Of patients with a bilateral os trigonum in which only one ankle was symptomatic, the size, distance between bones and presence of degenerative changes were compared. The symptomatic ossa trigona were larger and calcifications were more often seen in the symptomatic side.

In chapter 4 different projection angles were systematically compared using DRR to find the optimal radiographic views to detect an osseous impediment. Views with the foot in 25-35 degrees of exorotation were found to have the highest sensitivity for detecting an os trigonum or hypertrophic posterior talar process and showed highest interobserver reliability.

In chapter 5 a large retrospective case series showed endoscopic treatment of posterior ankle impingement to yield good long term outcome with a low recurrence rate. In this study no difference in outcome between bony and pure soft tissue impingement was found. In addition, the results for acute onset and overuse type impingement were similar. Additional flexor hallucis longus tendinopathy showed to result in lower patient satisfaction and higher recurrence rate.

In a meta-analysis in chapter 6 the outcome of open and endoscopic surgery were compared. No clinical relevant difference in postoperative AOFAS score, patient satisfaction and return to pre-injury level of activity between open and endoscopic techniques were found. Complication rates were lower with endoscopic treatment in the ‘fair’ and ‘good’ methodological quality studies. In the only randomized trial there was also a significant difference in recovery time favoring endoscopic treatment.

In chapter 7 the literature on talus bipartitus is discussed. Symptoms are characterized by pain and restricted subtalar motion in young patients. Surgical treatment is either focused on fixation or excision of the bony fragment. Our cases show an endoscopic approach can be a safe and effective treatment option.

According to the literature review in chapter 8, there is not one type of the posteromedial tubercle fracture with a typical trauma mechanism. Treatment consist of immobilization, excision of the fragment or fixation in case of large fragments. Based on the available literature no conclusions can be made on which treatment option is superior. Our case series show endoscopic excision of the fragment as a safe and effective alternative for open surgical treatment.

In chapter 9 a case of a bilateral symptomatic talus secundarius was discussed. This ossicle is considered as one of the rarest accessory tarsal bones, located at the lateral process of the talus. When symptomatic, depending on the size of the fragment and involvement of the subtalar joint, either excision or fixation of the fragment can be performed. In the presented case both interventions have led to satisfactory results both in the short- and long term.

NEDERLANDSE SAMENVATTING

Posterieure enkel impingement is een oorzaak van posterieure enkelpijn tijdens plantairflexie. Het wordt geassocieerd met ossale afwijkingen zoals het os trigonum. Echter, de aanwezigheid van een os trigonum is normaal gesproken geen reden voor klachten. Het doel van deze thesis is om meer inzicht te verkrijgen in de epidemiologie en geometrische karakteristieken van het os trigonum, de rol van conventionele beeldvorming en operatieve behandeling van posterieure enkel impingement. Daarnaast worden de presentatie en behandeling van gerelateerde ossale pathologie besproken.

In hoofdstuk 2 werd de prevalentie van het os trigonum in een asymptomatische populatie onderzocht. Met een prevalentie van 30.3% in de groep zonder posterieure enkelklachten was de prevalentie hoger dan tot nu toe beschreven. Het os trigonum werd even vaak unilateraal als bilateraal gevonden. Zoals verwacht was de prevalentie hoger in de groeppatiënten met posterieure enkel impingement.

Om de verschillen tussen symptomatische en asymptomatische ossa trigona te bestuderen, werden de geometrische karakteristieken van symptomatische en asymptomatische enkels vergeleken in hoofdstuk 3. Van de patiënten met een bilateraal os trigonum waarvan slechts één zijde symptomatisch was, werden de grootte, afstand tot omliggende botten en de aanwezigheid van degeneratieve veranderingen vergeleken. De symptomatische ossa trigona waren groter en er werden vaker calcificaties rond het os trigonum gezien aan de symptomatische zijde.

In hoofdstuk 4 werden verschillende projectiehoeken systematisch vergeleken met behulp van DDR om de optimale röntgenopname voor het vaststellen van een ossaal impediment te bepalen. Opnames met de voet 25-35 graden in exorotatie hadden de hoogste sensitiviteit voor detectie van een os trigonum of hypertrofisch posterieur process van de talus en hadden daarnaast ook de hoogste intraobserver betrouwbaarheid.

In hoofdstuk 5 liet een grote retrospectieve case serie goede lange-termijn uitkomsten zien voor de endoscopische behandeling van posterieure enkel impingement, met een laag recidiefpercentage. Er werd geen verschil gevonden in uitkomst tussen ossaal of uitsluitend weke delen impingement en ook de resultaten van patiënten met een acuut begin van klachten en patiënten met het chronische type waren gelijk. Als er sprake was van additioneel flexor hallucis longus tendinopathie was de patiënttevredenheid lager en het recidiefpercentage hoger.

In een meta-analyse in hoofdstuk 6 werden de uitkomsten van open en endoscopische chirurgie vergeleken. Er werd geen verschil gevonden in postoperatieve AOFAS score, patiënttevredenheid en tijd tot terugkeer naar volledige activiteit.

Het percentage complicaties was lager in de endoscopie groep als alleen de studies met ‘gemiddelde’ en ‘goede’ methodologische kwaliteit werden meegenomen in de analyse. De enige gerandomiseerde studie liet een kortere hersteltijd zien in de endoscopisch behandelde groep.

In hoofdstuk 7 werd de literatuur over de talus bipartita besproken. Symptomen bestaan uit pijn en beperkte bewegelijkheid van het subtalaire gewricht bij jonge patiënten. Chirurgische behandeling bestaat uit fixatie of excisie van het fragment. Er werden cases gepresenteerd waarin een endoscopische excisie van de fragmenten een veilig en een effectief alternatief bleken voor open chirurgie.

Naar aanleiding van een review van de literatuur in hoofdstuk 8 kunnen we concluderen dat er niet één type fractuur van het posteromediale tuberkel is met een typisch trauma mechanisme. Behandeling bestaat uit immobilisatie, verwijdering van het fragment of fixatie van het fragment. Gebaseerd op de beschikbare literatuur kunnen er geen conclusies worden getrokken ten aanzien van de optimale behandeling. Onze case serie van endoscopisch behandelde patiënten laat zien dat dit een veilig en effectief alternatief kan zijn voor de open chirurgische behandeling.

In hoofdstuk 9 werd een casus besproken van een bilateraal symptomatische talus secundarius. De talus secundarius wordt gezien als een van de zeldzaamste accessoire tarsale botkernen, gelokaliseerd ter hoogte van het laterale proces van de talus. Afhankelijk van de grootte en betrokkenheid van het subtalaire gewricht kan indien symptomatisch, excisie of fixatie van het fragment overwogen worden. In de gepresenteerde casus leidden beide interventies tot een goede uitkomst op korte en lange termijn.

ADDENDUM

PhD Portfolio

Curriculum Vitae

Dankwoord

PHD PORTFOLIO

Ruben Zwiers
2013-2020
Promotores: prof. dr. C.N. van Dijk / dr.ir. L. Blankevoort

PhD Training

General courses

AMC Graduate School		
Practical Biostatistics	2013	1 ECTS
Clinical Epidemiology	2013	1 ECTS
Scientific Writing in English for Publication	2013	1 ECTS
Basiscursus Regelgeving en Organisatie voor Klinisch onderzoekers	2013	1.5 ECTS
Evidence based practice – University of Amsterdam:		
Epidemiology and Evidence Based Practice: concepts	2014	9 ECTS
Epidemiology and Evidence Based Practice: designs	2015	11 ECTS
Biostatistics - elementary analysis	2015	8 ECTS
Systematic Reviews and Clinical Guidelines	2015	6 ECTS
Biostatistics & Advanced Epidemiology	2015	9 ECTS
Clinimetrics	2016	7 ECTS
Health Economics	2016	6 ECTS
Health Care Policy Evaluation	2016	7 ECTS
Capita Selecta	2016	6 ECTS
Master thesis EBP	2017	24 ECTS

Podium presentations

Sterfte op hoge leeftijd onder voormalig olympisch atleten.
Bessensap, Wetenschap ontmoet Pers, 2012

De volgende stap in de diagnostiek van posterieure enkel impingement
3e Verstoord Bewegen Symposium, AMC Amsterdam, 2013

Achilles Tendon Disorder a Comprehensive overview of Diagnosis and Treatment
ICL Achilles tendon, 16th ESSKA Congress Amsterdam, 2014

Long-term outcome after arthroscopic treatment for posterior ankle impingement
17th ESSKA Congress, Barcelona, 2016

Quality of life in patients with foot and ankle injuries: Athletes versus non-athletes
17th ESSKA Congress, Barcelona, 2016

Het gebruik van PROM's in voet en enkel aandoeningen: Een survey onder voet en enkel chirurgen
NOV Najaarscongres 2017, Veldhoven

The syndesmotic injury – Football-specific treatment and return to play
18t h ESSKA Congress, Glasgow, 2018

Poster presentations
Postoperative appearance of pre-Achilles fat pad; still a useful diagnostic tool?
9th European Foot and Ankle Society (EFAS) Congress, Noordwijk, 2013

Betrouwbaarheid en validiteit van Nederlandse versie ATRS
NVA Jaarcongres, Den Bosch 2016

Optimal radiographic view for detecting os trigonum in patients with posterior ankle impingement complaints
17th ESSKA Congress, Barcelona, 2016

Good functional outcome and high patient satisfaction after endoscopic treatment in patients with midportion tendinopathy: a follow-up study
17th ESSKA Congress, Barcelona, 2016

Preoperative factors associated with patient satisfaction and functional outcome one year following ankle arthroscopy
18th ESSKA Congress, Glasgow, 2018

Placement of blind injections for Flexor Hallucis Longus Tendinitis: a cadaveric study
18th ESSKA Congress, Glasgow, 2018

High patient satisfaction and good functional outcome after endoscopic calcaneoplasty in patients with retrocalcaneal bursitis: a long-term follow-up study.
18th ESSKA Congress, Glasgow, 2018

Fracturen posteromediale tuberkel van de talus
NVA Jaarcongres, Nieuwegein, 2019

(Inter)national conferences

Nederlandse Orthopaedische Vereniging, jaar-, voorjaars, en najaarsvergaderingen	2011-heden
Vereniging Orthopaedisch Chirurgische Assistenten, jaarcongressen	2016-heden
Bessensap 2012: Wetenschap ontmoet Pers, Den Haag	2012
9th ISAKOS Congress, Toronto, Canada	2013
16th ESSKA Congress Amsterdam	2014
17th ESSKA Congress Barcelona	2016
18th ESSKA Congress Glasgow	2018

Peer-reviewing

Journal of Science and Medicine in Sport
Clinical Orthopaedics and Related Research
American Journal of Sports Medicine
Knee Surgery, Sports Traumatology, Arthroscopy
Journal of ISAKOS
Case Reports in Medicine
Sport & Geneeskunde

Teaching

Supervising bachelor and master students

T.P.A. Baltes	Prevalence of the os trigonum
T.P.A. Baltes	Surgical treatment for midportion Achilles tendinopathy
G. Vuurberg	Prognostic value of anterior ankle impingement classifications
D. Azim	Translation and validation of the Dutch Foot and Ankle Ability Measure
J.I. Jansen	Translation and validation of the Dutch PODCI questionnaire
J.H.F. Oosterhoff	Diagnostic accuracy of MRI and ultrasound for identifying pathology in clinically suspected midportion Achilles tendinopathy
R. Fakkert	Effects of ankle support on balance in the prevention of ankle sprains in athletes
T.N. Miedema	Surgical treatment of posterior ankle impingement

Publications

Peer reviewed publications

Mortality in former Olympic athletes: retrospective cohort analysis
Zwiers, R., Zantvoord F. W., Engelaer F. M., van Bodegom D., van der Ouderaa F. J., Westendorp R. G. (2012). BMJ 13; 345, e7456

Arthroscopic treatment of osteochondral talar defects
van Bergen, C. J., Zwiers, R., van Dijk, C. N. (2013). JBJS Essential Surgical Techniques, 3(2), e10.

Kickbokser met een acuut compartiment syndroom van het bovenbeen
Zwiers R., de Leeuw P.A.J., Bramer J.A.M., Kerkhoffs G.M.M.J. (2013) Nederlands Tijdschrift voor Traumatologie, 21(5), 134-137

Surgical treatment for posterior ankle impingement
Zwiers, R., Wiegerinck J. I., Murawski C. D., Smyth N. A., Kennedy J. G., van Dijk C. N. (2013) Arthroscopy, 29, 1263-70.

Posterior hindfoot arthroscopy: a review
Smyth, N. A., Zwiers R., Wiegerinck J. I., Hannon C. P., Murawski C. D., van Dijk C. N., Kennedy J. G. (2014) Am J Sports Med, 42, 225-34

Long term effect of glass remnants in the heel — a case report
Zwiers R., de Leeuw P.A.J., Kerkhoffs G.M.M.J. (2014) ESSKA Newsletter May 2014, p35

The appearance of the pre-Achilles fat pad after endoscopic calcaneoplasty
Wiegerinck J. I., Zwiers R., van Sterkenburg M.N., Maas M.M., van Dijk C.N. (2014) Knee Surg Sports Traumatol Arthrosc. 23(8):2400-2405

Treatment of midportion Achilles tendinopathy: an evidence-based overview
Zwiers R., Wiegerinck J.I., van Dijk C.N. (2014) Knee Surg Sports Traumatol Arthrosc. 24(7):2103-11

Validity and reliability of a Dutch version of the Foot and Ankle Ability Measure
Weel H., Zwiers R., Azim D., Sierevelt I. N., Haverkamp D., van Dijk C.N., Kerkhoffs G.M.M.J. (2014) Knee Surg Sports Traumatol Arthrosc. 24(4):1348-54

Arthroscopic Treatment for Anterior Ankle Impingement: A Systematic Review of the Current Literature
Zwiers, R., Wiegerinck J.I., Murawski C.D., Fraser E.J., Kennedy J.G., van Dijk C.N. (2015) Arthroscopy. 31(8):1585-96.

Treatment of Calcaneal Apophysitis: Wait and See Versus Orthotic Device Versus Physical Therapy: A Pragmatic Therapeutic Randomized Clinical Trial
Wiegerinck J. I., Zwiers, R., Sierevelt, I. N., van Weert, H. C., van Dijk, C. N., Struijs, P. A. (2015) J Pediatric Orthopaedics. 36(2):152-7

Nederlandse Patiënt-gerapporteerde Uitkomstmaten voor patiënten met Voet- en Enkelblessures: systematisch overzicht
Weel H., Zwiers R., Sierevelt I.N.,Haverkamp D., van Dijk C.N., Kerkhoffs G.M.M.J. (2015) Nederlands Tijdschrift voor Geneeskunde. 2015;159:A8831

Current Concepts Review: Arthroscopic Treatment of Anterior Ankle Impingement
Ross K.A., Murawski C.D., Smyth N.A., Zwiers R, Wiegerinck J.I., van Bergen C.J.A., van Dijk C.N., Kennedy J.G. (2016) Foot Ankle Surg, 23(1), 1-8.

Surgical treatment for midportion Achilles tendinopathy: a systematic review
Baltes T. P. A., Zwiers R., Wiegerinck J. I., Van Dijk, C. N. (2016). Knee Surgery, Sports Traumatology, Arthroscopy, 25(6), 1817-1838.

Reliability and validation of the Dutch Achilles tendon Total Rupture Score
Opdam K. T. M., Zwiers R., Wiegerinck J. I., Kleipool A. E. B., Haverlag R., Goslings J. C., van Dijk, C. N. (2016). Knee Surgery, Sports Traumatology, Arthroscopy, 1-7.

Taping and bracing in the prevention of ankle sprains: current concepts
Zwiers R., Vuurberg G., Blankevoort L., Kerkhoffs G. M. M. J. (2016). JISAKOS 1(6) 304-310

Large variation in use of patient-reported outcome measures: A survey of 188 foot and ankle surgeons
Zwiers R., Weel H., Mallee W. H., Kerkhoffs G. M. M. J., van Dijk, C. N. (2017). Foot Ankle Surg. 24(3):246-251.

A rare cause of lateral ankle pain: A symptomatic talus secundarius
Zwiers R., de Leeuw P. A., Kerkhoffs G. M., van Dijk, C. N. (2017). Foot Ankle Surg, 23(4), e20-e24.

Talus bipartitus: a systematic review and report of two cases with arthroscopic treatment
Zwiers R., de Leeuw P. A., Kerkhoffs G. M., van Dijk C. N. (2017). Knee Surgery, Sports Traumatology, Arthroscopy, 26(7):2131-2141.

Pain Relief After Operative Treatment of an Extremity Fracture: A Noninferiority Randomized Controlled Trial
Helmerhorst G. T., Zwiers R., Ring D., Kloen P. (2017). J Bone Joint Surg, 99(22), 1908-1915.

Prevalence of Os Trigonum on CT Imaging
Zwiers R, Baltes TPA, Opdam KTM, Wiegerinck JI, van Dijk CN. (2018) Foot Ankle Int, 39(3):338-342.

Endoscopic Treatment of Mid-Portion Achilles Tendinopathy: A Retrospective Case Series of Patient Satisfaction and Functional Outcome at a 2- to 8-Year Follow-up
Opdam KTM, Baltes TPA, Zwiers R, Wiegerinck JI, van Dijk CN. (2018) Arthroscopy, 34(1):264-269.

Measurement properties of the most commonly used Foot- and Ankle-Specific Questionnaires: the FFI, FAOS and FAAM. A systematic review
Sierevelt IN, Zwiers R, Schats W, Haverkamp D, Terwee CB, Nolte PA, Kerkhoffs GMMJ. (2018) Knee Surg Sports Traumatol Arthrosc, 26(7):2059-2073.

Endoscopic treatment for posterior ankle impingement: high patient satisfaction and low recurrence rate at long-term follow-up
Zwiers, R., Baltes, T. P., Wiegerinck, J. I., Kerkhoffs, G. M. M. J., van Dijk, C. N. (2018). JISAKOS, 3(5), 269-273.

Surgical treatment for posteromedial talar process fractures
Zwiers R, de Leeuw PAJ, Wiegerinck EMA, van Dijk CN. (2019) Foot Ankle Surg. 27. pii: S1268-7731(19)30223-1.

The accuracy of an injection technique for Flexor hallucis longus tendon sheath: A cadaveric study
Opdam KTM, Madirolas X, Zwiers R, Terra MP, Reina F, van Dijk CN. (2019) Foot Ankle Surg. 2019 Apr 16. pii: S1268-7731(19)30058-X.

Exorotated radiographic views have additional diagnostic value in detecting an osseous impediment in patients with posterior ankle impingement
Zwiers, R., Dobbe, J. G., Streekstra, G. J., Blankevoort, L., Wiegerinck, J. I., Maas, M., van Dijk, C. N. (2019). JISAKOS, 4(4), 181-187.

Corticosteroid Injections in Posterior Ankle Impingement Syndrome: A Survey amongst Professional Ballet Dancers
Opdam. K.T.M., van Loon J., Zwiers R., Kuijer P.P.F.M., van Dijk C.N. (2020) J Dance Med Sci, 2021 Mar 15;25(1):24-29.

Geometrical characteristics of the symptomatic and non-symptomatic ossa trigona
Zwiers R. Görgec B, van Dijk C.N., Blankevoort L. (2020) Foot Ankle Surg. 2020 Aug 25;S1268-7731(20)30174-0

Increasing consensus on terminology of Achilles tendon-related disorders
Opdam KTM, Zwiers R, Wiegerinck JI, van Dijk CN; Ankleplatform Study Collaborative –Science of Variation Group. Knee Surg Sports Traumatol Arthrosc. 2021 May 15. doi: 10.1007/s00167-021-06566-z

High patient satisfaction and good long-term functional outcome after endoscopic calcaneoplasty in patients with retrocalcaneal bursitis
Opdam KTM, Zwiers R, Vroemen J, Sierevelt IN, Wiegerinck JI, van Dijk CN. Knee Surg Sports Traumatol Arthrosc. 2021 May;29(5):1494-1501.

Open versus Endoscopic Surgical Treatment of Posterior Ankle Impingement; a Meta-analysis
Zwiers R., Miedema, T.N., Wiegerinck J.I., Blankevoort L, van Dijk C.N. (2020) Am J Sports Med, *2021 May; doi:10.1177/03635465211004977*

Book chapters

Terminology for Achilles Tendon Disorders
Wiegerinck J.I., Zwiers R., Karlsson J., Maffuli N., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment” – Golden edition. DJO Publications, Guildford, UK 2014

Endoscopic Surgery Insertional Achilles tendinopathy

Wiegerinck J.I., Zwiers R., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Endoscopic Surgery Midportion Achilles tendinopathy
Thermann H., Becker C., Zwiers R., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Current Concepts: Treatment for Insertional Achilles Tendinopathy and Retrocalcaneal Bursitis
Wiegerinck J.I., Zwiers R., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Current Concepts: Treatment Midportion Achilles tendinopathy
Zwiers R., Wiegerinck J.I., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Current Concepts: Treatment Achilles tendon ruptures
Zwiers R., Wiegerinck J.I., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Imaging of the Achilles Tendon
Zwiers R., van Sterkenburg M.N., van Dijk C.NAchilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Injection Treatment in Patients with Achilles Tendinopathy
Zwiers R., van Sterkenburg M.N., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Activity Resumption after Achilles Tendon Disorders
Zwiers R., van Sterkenburg M.N., van Dijk C.N. Achilles Tendon Disorders – A Comprehensive Overview of diagnosis and treatment" – Golden edition. DJO Publications, Guildford, UK 2014

Taping Techniques and Braces in Football
Zwiers R., Blankevoort L., Swier C.W., Verheul A.C.M., Kerkhoffs G.M.M.J. The Ankle in Football (pp. 287-310). Springer Paris 2014.

Achilles tendon rupture – Open Surgical Treatment
Zwiers R., Wiegerinck J.I., van Dijk C.N. Athletic Injuries of the Ankle (dvd). TIMEO editore srl, Bologna, Italy 2014

Tibialis Posterior Tendon Disorders
Pereira H., Zwiers R., D'Hooghe P., Ripoll P.L, Kerkhoffs G.M.M.J. , Espregueira-Mendes J.D, van Dijk C.N. Athletic Injuries of the Ankle (dvd). TIMEO editore srl, Bologna, Italy 2014

Tendoscopic Treatment of Recurrent Peroneal Tendon Dislocation
De Leeuw P.A.J., Zwiers R., van Dijk C.N.. Athletic Injuries of the Ankle (dvd). TIMEO editore srl, Bologna, Italy 2014

Surgical management of Osteochondral Lesions of the Talus
Van Bergen C.A.J., Zwiers R., van Dijk C.N. Athletic Injuries of the Ankle (dvd). TIMEO editore srl, Bologna, Italy 2014

Anterior Ankle Impingement
Pereira H., Zwiers R., D'Hooghe P., Ripoll P.L, Kerkhoffs G.M.M.J. , Espregueira-Mendes J.D, van Dijk C.N. Athletic Injuries of the Ankle (dvd). TIMEO editore srl, Bologna, Italy 2014

Posterior Ankle Disorders
Zwiers R., Wiegerinck J.I., van Dijk C.N. Athletic Injuries of the Ankle (dvd). TIMEO editore srl, Bologna, Italy 2014

Posterior ankle impingement
Zwiers R., van Dijk C.N. The Foot and Ankle: AANA Advanced Arthroscopic Surgical Techniques. Saunders/Elsevier, Philadelphia, 2015

Tendinoscopy
Zwiers R., van Dijk C.N. The Foot and Ankle: AANA Advanced Arthroscopic Surgical Techniques. Saunders/Elsevier, Philadelphia, 2015

Tendinoskopie
Zwiers R, de Leeuw P.A.J., van Dijk C.N. Arthroskopie an Sprunggelenk und Fuß: Das Praxisbuch der Techniken und Indikationen. Schattauer Verlag, 2016

Endoscopic Calcaneoplasty
Zwiers R., Wiegerinck JI., van Dijk CN. Arthroscopy. Springer, Berlin, Heidelberg, 2016.

Anterior Ankle Impingement
Zwiers R., Opdam KTM., van Dijk CN. Arthroscopy. Springer, Berlin, Heidelberg, 2016.

Anterior Ankle Arthroscopy: General Setup and Portal Options
Opdam KTM, Zwiers R, van Dijk CN. Arthroscopy. Springer, Berlin, Heidelberg, 2016.

Posterior Ankle Arthroscopy: General Setup and Portal Options
Opdam KTM., Zwiers R., van Dijk CN. Arthroscopy. Springer, Berlin, Heidelberg, 2016.

CURRICULUM VITAE

Ruben Zwiers was born in Purmerend, the Netherlands, on the 17th of June 1989. After graduating from high school in 2007 (VWO, Bernard Nieuwentijt College, Amsterdam), he studied Medicine at the University of Amsterdam. Clinical rotations were paused in 2012 to start a PhD-research project and work for two years as research felllow at the department of orthopaedic surgery at the Academic Medical Center in Amsterdam (prof. dr. C.N. van Dijk), which eventually resulted in this thesis. After finishing medical school in 2016 he started his orthopaedic surgery training at the department of general surgery at the Westfriesgasthuis in Hoorn (dr. D.J.A. Sonneveld). During the same period he started the master study Clinical Epidemiology at the University of Amsterdam, from which he graduated in 2017. He continued his orthopaedic residency at the departments of orthopaedic surgery of the Tergooi hospitals, Hilversum (dr. A.M.J.S. Vervest) and Academic Medical Center (prof. dr. G.M.M.J. Kerkhoffs and dr. M.U. Schafroth). He will finish his orthopaedic surgery training in 2023.

DANKWOORD

Tot slot wil ik iedereen bedanken die geholpen heeft bij het tot stand komen van dit proefschrift. Zonder jullie hulp, begeleiding, steun en inspiratie was het niet gelukt.

Prof. dr. C.N. van Dijk, beste prof, het begon met een wetenschappelijke stage en leidde uiteindelijk tot dit proefschrift. Door de geboden kansen heb ik mezelf kunnen ontwikkelen en de orthopedie kunnen ontdekken. Naast de begeleiding van het onderzoek, kreeg ik als jonge onderzoeker de mogelijkheid op vele vlakken ervaring op te doen door onder andere samen te werken in de ATSG, congres en fietstocht te organiseren. Dank voor het vertrouwen en de geboden kansen.

Dr. ir. L. Blankevoort, beste Leendert, vanaf de eerste dag in de kweekvijver heb ik ontzettend veel van je geleerd. Je hebt ervoor gezorgd dat ik een betere onderzoeker ben geworden. Als promotor heb je met jouw kritische blik, scherpe opmerkingen en oog voor detail een belangrijke bijdrage gehad aan dit proefschrift, dank daarvoor.

Overige leden van de promotiecommissie, prof. dr. M. Maas, prof. dr. R.J. Oostra, prof. dr. C. Lucas, prof. dr. M.P.J. van den Bekerom en prof. dr. S.K. Bulstra, hartelijk dank voor het beoordelen van het manuscript.

Prof. dr. G.M.M.J. Kerkhoffs, beste Gino, je was betrokken bij een deel van dit boekje, maar nog veel meer dank voor het voorbeeld dat je geeft in je rol als opleider, orthopeed en als persoon. Je gedrevenheid en persoonlijke benadering zijn inspirerend en uniek. Ik hoop in de toekomst nog veel van je te mogen leren.

Dr. J.I. Wiegerinck, beste Jan Joost, via jou kwam ik binnen op G4 als onwetende student. Je maakte me wegwijs in de wereld van de kweekvijver, de ATSG, onderzoek en de orthopedie. Dank daarvoor en voor je bijdrage aan dit proefschrift.

Dr. P.A.J. de Leeuw, beste Peter, kweekvijver oude garde. Je had ‘nog wel wat ideetjes liggen’ toen ik begon. Onze samenwerking leverde uiteindelijk met drie artikelen over zeldzame botfragmenten een fraaie bijdrage aan dit boekje, waarvoor dank.

Dr. K.T.M. Opdam, beste Kim, op de valreep ben je toch nog eerder gepromoveerd! Als opvolgster in de ankleplatform-lijn hebben we veel samengewerkt, je enthousiasme is aanstekelijk. Dank voor de mooie periode op G4 en ook zeker erna. Samen artikelen geschreven, congressen bezocht en georganiseerd. Nu onze boekjes klaar zijn, hebben we nog meer tijd voor gezelligheid!

Co-auteurs, Thomas Baltes, Burak Görgec, dr. J.G.G. Dobbe, dr. ir. G.J. Streekstra, Thymen Miedema, Esther Wiegerinck, bedankt voor jullie bijdrage aan dit proefschrift.

Prof. dr. D. van Bodegom, beste David, en dr. F.M. Engelaer, beste Frouke, door de samenwerking met jullie werd mijn enthousiasme voor onderzoek aangewakkerd. Jullie lieten zien hoe leuk onderzoek kan zijn. Wat begon met de vraag of marathon lopen wel goed voor je was, eindigde met een publicatie in de kersteditie van de BMJ.

Secretariaat van de orthopedie, Rosalie van der Sandt, Marga Lammerts, Tineke Nagel, Ellen Rolleman, Veerle Montes Klaver, Cynthia Thesing en Tugba Ulucay, heel veel dank voor jullie ondersteuning van de eerste tot de laatste dag.

Dr. H. Weel, beste Hanneke, naast onze promotieonderzoeken hebben we ons samen gestort op de PROMs, het heeft even stil gelegen, maar nu is er straks weer tijd om het op te pakken. Dank voor de mooie samenwerking.

De kweekvijver op G4, Arthur, Gijs, Inge, Aimee, Wouter, Joy, Rogier, Thijs, Jonah en Gwen dank voor de mooie tijd, alle congressen, gezelligheid en Dumpert sessies.

Paranimfen, wat is het ontzettend leuk om dit met jullie te doen. Guido, al sinds ik me kan herrineren zijn we een goed team. Ik kan altijd op je rekenen, daarom ben ik blij dat je me ook nu bij zult staan. Wessel, je bent m’n broer en vriend. We hebben een heel ander pad gekozen, maar we hebben meer gemeen dan we soms denken. Ik heb heel veel respect voor wat je allemaal doet. Nu dit proefschrift af is heb ik meer tijd om samen door te brengen.

Pap en Mam, dank voor alles. Dank voor jullie onvoorwaardelijke steun, voor alle mogelijkheden die jullie mij hebben geboden en voor het goede voorbeeld dat jullie altijd hebben gegeven. Ik ben heel blij met jullie.

Lieve Marith, sinds jij in m’n leven bent, maak je me elke dag gelukkig, met jou is alles zoveel leuker. Dank voor je steun en je positieve instelling. Dank voor je geduld en dat je me af en toe aanspoorde dit langdurige project nou eens af te ronden. Ik zie uit naar onze toekomst samen!