Ankle arthroscopy under the scope

de Leeuw, P.A.J.

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Ankle Arthroscopy under the Scope

Peter AJ de Leeuw
Colophon

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Ankle Arthroscopy under the Scope

ACADEMISCH PROEFSCHRIFT

der 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
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General introduction
General introduction
The current oath every doctor swears at the beginning of his or her career, includes the sentence that he or she should not do harm to a patient.¹ This statement originates from Hippocrates, our ancient father of medicine. Surgery in itself could be seen as harming a patient. On the other hand it can be a useful tool to assist patients in obtaining or sustaining an acceptable quality of life level. Patients with ankle pathology frequently suffer from pain, which can result in less mobility and thereby reduce their quality of life. Ideally these pathologies are treated non-operatively, having the least risk of harming the patient. However if conservative treatment fails or leads to a suboptimal situation for a patient, surgery should be considered. Over the last decades minimally invasive surgery has been introduced for a variety of ankle pathologies. The aim of this technique is to reduce the surgery-related risks to a patient and provide an overall quicker recovery, when compared to open surgical approaches.²-⁶ Minimally invasive surgery could therefore be regarded as being directly in line with the oath.
Ankle arthroscopy is a form of minimally invasive surgery. The first attempt to visualize the anterior ankle joint was performed by Burman in 1931.⁷ At that time it was thought the ankle joint was unsuitable for arthroscopy due to its narrow intraarticular access. This brings us to another profound aspect of the ability to safely perform surgery, being the knowledge of the anatomy. Human anatomy is the key element to any surgical intervention.⁸-¹⁰ Anatomy dictates the safe surgical approach and the skilled surgeon is dependent on the available instruments to reach and treat the
pathology. The anatomy books in general do not provide us with the surgical anatomy, however the ankle anatomy can be considered fixed, a constant factor not subject to changes in surgical strategies. The instruments provided to the surgeons following the improved industrial knowledge and skills did however open doors to treat more and more pathological conditions surgically within the boundaries of (constant) anatomy. One of these instruments was the arthroscope, offering the possibility to perform an ankle arthroscopy. The first patient-series was published by Watanabe in 1972. Understanding and properly explaining the surgical (ankle) anatomy could assist surgeons in daily practise, possibly resulting in less surgical related complications. Furthermore it may push industries to the limit to assist in and to improve surgical practice.

One of the elements enabling Watanabe to perform anterior ankle arthroscopy was the use of joint distraction. For a long period it was believed that continuous distraction was required to obtain a sufficient intraarticular arthroscopic view and working area. In 1997 van Dijk and Scholte introduced the dorsiflexion method. Nowadays anterior ankle arthroscopy is performed either by continuous-fixed distraction or by the dorsiflexion technique. Whether either of these techniques is safer or otherwise advantageous over the other is subject to debate, anatomy by itself may provide the answer.

Historically, numerous routes to gain arthroscopic access to the anterior ankle joint were introduced in literature. Some seemed to be inappropriately proven by the relatively high number of complications caused by the location of the portal itself. Again, if
reviewing the basic ankle anatomy, that could have been predicted. Knowledge of and respecting the anatomy could have prevented surgical harm to these patients.²¹ Nowadays the routine anterior ankle portals for arthroscopy are the anteromedial- and anterolateral portals.²² The anteromedial portal, if created just medial to the anterior tibial tendon can be regarded as safe in relation to potential injury to relevant anatomical structures. The closest structure potentially at risk is the great saphenous vein and saphenous nerve.¹⁵,²³

The anterolateral ankle arthroscopic portal, although regarded as one of the standard portals, is close to relevant anatomical structures and therefore potentially prone in introducing iatrogenic complications. The most frequently reported complication in relation to this portal is iatrogenic damage to the superficial peroneal nerve, or to the intermediate dorsal cutaneous branch in case the nerve has bifurcated proximally to the level of the portal.⁸,¹⁵,¹⁹,²⁴ Techniques have been introduced to allow for the identification of this nerve clinically through the patient’ skin.¹⁵,²⁰,²⁵-²⁹ Despite this unique ability²⁹, iatrogenic superficial peroneal nerve damage is the most frequently reported complication in relation to the anterolateral arthroscopic ankle portal.⁸,¹²,¹⁸ In which percentage of patients the nerve can be identified and which determinants prohibit its identification is unknown. Furthermore, it would be interesting to assess what happens to this anatomical structure when different foot and ankle positions are used. This may provide insight and could possibly explain the reported complication rates in relation to the superficial
peroneal nerve and furthermore provide ways to prevent these in future.
Less than two decades ago, the ability to treat posterior ankle pathology, arthroscopically, was introduced by van Dijk et al.\textsuperscript{30} As compared to open surgery, this minimally invasive technique could potentially reduce the risk of harming patients if dealing with posterior ankle pathology. The technique was developed and performed on human (cadaveric) specimens first. The location of the portals was dictated by the posterior ankle anatomy. This common-sense approach presumably is the key factor for introducing a safe and reliable surgical technique with good clinical outcomes.\textsuperscript{5,31-38} It is possible for these reasons, that the technique has not been modified since its introduction in 2000. The original report was, however, mostly written in plain text, which seemed to be difficult for colleagues to understand. A step-by-step visual report of the technique in combination with the demonstration of the surgical posterior ankle anatomy could add in safely executing this ankle arthroscopic technique by others.
Peroneal tendon instability is a rare but disabling pathological condition, initially described by Monteggi in the early 19\textsuperscript{th} century.\textsuperscript{39} Patients suffering from chronic peroneal tendon instability frequently need surgery, since conservative treatment is associated with unpredictable results and high recurrence rates.\textsuperscript{40-42} Attempts have been made to minimize surgical risks by introducing minimally invasive techniques to stabilize the tendons. However, these techniques were suboptimal both due to the inability to treat all forms of instability and its restricted surgical working space.\textsuperscript{43,44} Following
the initial description of the posterior ankle arthroscopic technique, the peroneal tendons can be visualized and inspected.\textsuperscript{30} Since posterior ankle arthroscopy in itself is a safe a reproducible technique, it would be worthwhile to use this technique and evaluate the anatomy for the possibility to add an additional portal, thereby obtaining a minimally invasive technique to stabilize the peroneal tendons. Another disabling pathological condition, significantly affecting patient’s quality of life, is ankle osteoarthritis.\textsuperscript{4,45} There are multiple conditions, which could eventually result in ankle osteoarthritis. Posttraumatic ankle disorders are an important cause of ankle osteoarthritis.\textsuperscript{46} Significant pain, both in rest and during activity, with a subsequent limited range of motion of the ankle, not responding to conservative treatment, can adequately be treated with an ankle joint fusion. The ankle joint fusion is nowadays frequently performed in a minimally invasive way.\textsuperscript{4,47,48} Again, in line with our oath, minimizing surgery-related complications is the main goal. Anterior ankle arthroscopic techniques to fuse the joint have been introduced.\textsuperscript{2,49-52} Unfortunately, although improved results were obtained, as compared to open surgery, still significant complications were reported, mainly non-unions and/or infections.\textsuperscript{49,52} It can be debated, to which extent these complications are purely surgery related and to what extent patient factors play a role. The question is whether improvement is possible. Well it would be worthwhile to explore a new concept to minimally invasively fuse the ankle in patients with disabling posttraumatic ankle osteoarthritis aiming at the reduction of complication rates. One of the important principles for bones to unite
is to obtain bone-to-bone contact without interference of cartilage. Complete cartilage removal, in combination with forces to allow for optimal compression, within optimal biological circumstances, are believed to be the most important principles for obtaining a joint fusion.\textsuperscript{4,53} To assess whether posterior ankle arthroscopy was safe and suitable for complete ankle joint debridement, an anatomical study was performed. It was concluded that up to 96\% of the cartilage could be debrided by this technique.\textsuperscript{54} If needed, the ‘safe’ anteromedial portal was used to assist in the joint debridement and/or was used for instruments to amplify joint distraction. Anatomical dissections following the joint debridements were performed. Neurovascular or tendon damage was not observed in any of the specimens.\textsuperscript{54} Whether the posterior ankle arthroscopic technique to fuse the ankle in posttraumatic ankle osteoarthritis results in less complications, as compared to the existing minimally invasive and open techniques, would be an interesting topic to assess.

**Outline of the thesis**
This thesis aims at providing answers to the previously questioned topics but certainly will raise other exciting questions to the surgical and anatomical ankle topics. The aim of this thesis is to contribute to the reduction of complication rates in ankle arthroscopy, mainly by providing and improving the knowledge of surgical anatomy. **Chapter 2** provides a general overview of both the anterior- and posterior ankle arthroscopic techniques to understand the surgical principles of treating ankle pathology minimally invasive.
To be able to properly perform (ankle) surgery one should understand the surgical anatomy. Basic anatomy books are not providing this knowledge which is however fundamental for reducing surgical complication rates. Chapter 3 describes the detailed anatomy mainly relevant for ankle arthroscopy. Apart from knowledge of anatomy also the technique to perform an ankle arthroscopy is important. As different techniques in anterior ankle arthroscopy are available, it is interesting to compare these, in relation to their potential for introducing surgical complications. Therefore in Chapter 4 the continuous joint distraction as compared to the ankle dorsiflexion technique are assessed. The anterolateral portal is one of the two standard portals in anterior ankle arthroscopy. This portal is responsible for the most reported neurological complications in anterior ankle arthroscopy, being damage to the superficial peroneal nerve. However this nerve is the only clinically observable nerve through the skin. Which identification technique and in how many potential patients this nerve can be identified at the aim of reducing complications is subject of Chapter 5. Furthermore it would be interesting to assess whether the visually apparent superficial peroneal nerves actually change position while changing the orientation of the foot and ankle. This is evaluated in Chapter 6.

Understanding and coping with new surgical techniques, introduced as plain text in the journals, may be difficult. Repetition and visual support throughout all the important surgical steps may increase confidence to safely cope with new surgical techniques. Chapter 7
aims to introduce a step-by-step surgical approach to address posteriorly located ankle pathology. Many (open) surgical techniques are available for the treatment of peroneal tendon dislocations, all with good to excellent clinical results. Whether minimally invasive surgery can be used to treat this pathology is the subject in Chapter 8. Despite available minimally invasive surgical techniques to fuse an osteoarthritic ankle joint, complication rates remain relatively high. A novel minimally invasive arthroscopic technique was therefore introduced in 2015.52

In Chapter 9 the midterm results following a posterior ankle arthroscopic approach to fuse the ankle joint are described and compared to the existing complication rates as reported in literature.

References


Arthroscopy and Endoscopy of the Ankle and Hindfoot

Peter AJ de Leeuw, Maayke N van Sterkenburg, C Niek van Dijk

*Sports Med Arthrosc Rev 2009;17:175-184*
Abstract
Ankle arthroscopy provides the surgeon with a minimally invasive treatment option for a wide variety of indications such as impingement, osteochondral defects, loose bodies, ossicles, synovitis, adhesions, and instability. Posterior ankle pathology can be treated using endoscopic hindfoot portals. These posteromedial and lateral hindfoot portals provide excellent access to the posterior aspect of the ankle and subtalar joint. Also extraarticular structures in the hindfoot, for instance recurrent peroneal tendon dislocation, can be treated by creating an additional portal. The endoscopic hindfoot portals are safe and reliable, both anatomically and clinically. It compares favorably to open surgery with regard to less morbidity and a quicker recovery.
Introduction
Ankle arthroscopy has been developed and improved over the last decades. The first orthopedic surgeon attempting ankle joint arthroscopy was Burman in 1931. He concluded this joint not to be suitable for arthroscopy, with respect to its narrow interarticular access. Because of the technical improvements, such as smaller diameter arthroscopes and joint distraction methods, Watanabe was the first to report on a series of 28 ankle arthroscopies in 1972. From the 1980s on several publications followed. Main indications for anterior ankle arthroscopy are the treatment of anterior impingement syndrome, talar osteochondral defects, removal of loose bodies, ossicles, adhesions, and synovitis. Arthroscopy of the subtalar joint was first described by Parisien in 1985. Van Dijk et al were the first to describe endoscopic access to the tendons by tendoscopy. These included tendoscopy of the posterior tibial tendon, the peroneal tendons, and Achilles tendon, which was followed by endoscopic treatment for retrocalcaneal bursitis, called endoscopic calcaneoplasty. Subsequently he introduced a 2 portal endoscopic hindfoot approach. This surgical technique provides access to the posterior aspect of the ankle and subtalar joint. Also extra-articular structures of the hindfoot such as the os trigonum, flexor hallucis longus (FHL), and the deep portion of the deltoid ligament can be assessed. On the basis of these portals, recently a minimally invasive groove deepening technique for recurrent peroneal tendon dislocation was introduced.
Contraindication/indications of the procedures
For each of the described endoscopic/arthroscopic procedures in this manuscript, there are no absolute contraindications. Caution must be taken into consideration with patients suffering from vascular diseases, such as diabetics. The different indications can be categorized according to the location of the pathology.

Articular pathology
Anterior Compartment
The main indications include soft tissue and bony impingement, loose bodies, avulsion fragments, and ossicles. For chronic lateral ankle instability an anterior ankle arthroscopy with thermal capsular shrinkage can be performed. Soft tissue impingement can be produced by the anterior inferior tibiofibular ligament, the anterior talofibular ligament, and the medial collateral ligaments. Bony impingement is caused by tibial and talar osteophytes. In anterior ankle impingement recognizable pain on palpation is pathognomonic. The patient typically presents with anterior ankle pain, swelling after activity, and limited dorsiflexion. Recognizable local tenderness on palpation is present anteriorly and osteophytes may be noticed with the ankle in slight plantarflexion. In the anterior ankle impingement syndrome the osteophyte itself does not cause the pain, but does the inflamed soft tissue being caught in between the osteophytes. Differentiation between an anteromedial and an anterolateral impingement is based on the location of the recognizable tenderness on palpation.
Central Compartment
Indications for arthroscopy of the central compartment include talar or tibial osteochondral defects with or without secondary cyst formation. Patients typically experience intermittent or persistent deep ankle pain during or after activity, sometimes accompanied by swelling and a limited range of motion. On physical examination, there can be some swelling or a slight restriction in the range of motion, but in most patients the physical examination does not show any abnormalities. Syndesmotic problems, which can be subdivided into loose bodies and/or soft tissue impingement, can be assessed through anterior ankle arthroscopy. Another indication is osteoarthritis. If patients present with recognizable tenderness over anteriorly located osteophytes, these can be removed. An arthroscopic arthrodesis can be performed in case of incapacitating complaints, which have failed conservative management.

Posterior Compartment Ankle Joint
The main indications include removal of loose bodies, ossicles, posttraumatic calcifications, avulsion fragments, resection of posterior tibial rim osteophytes, treatment of chondromatosis, and/or chronic synovitis. Also debridement and drilling of a posterior located osteochondral defect in the ankle joint is an important consideration, as in some cases it is technically not possible to approach these by means of anterior ankle arthroscopy.
Posterior Compartment Subtalar Joint  
The main indications are removal of osteophytes, treatment of degenerative changes in the subtalar joint including talar cystic lesions, loose body removal and a subtalar arthrodesis in case of osteoarthritis. Intraosseous talar ganglions can also be treated arthroscopically.

Periarticular pathology  
Posterior Ankle Impingement  
Posterior ankle impingement syndrome is by definition a pain syndrome. The pain is mainly present in the hindfoot during forced plantarflexion. The mechanism to produce this syndrome can be divided into an overuse and a trauma group. The overuse group is mainly exists from ballet dancers, downhill runners and soccer players. In professional ballet the specific dancing steps force the ankle in hyper plantarflexion. The anatomic structures in between the calcaneus and the posterior part of the distal tibia thereby become compressed. Through exercise the dancer will attempt to increase the range of motion and joint mobility, ultimately decreasing the distance between the calcaneus and talus. The anatomic structures at the back of the ankle joint hereby can become compressed. During downhill running, the ankle is repetitively forced into plantarflexion, resulting in repetitive stress on the anatomic structures in this posterior area. A hyper plantarflexion trauma and supination trauma can cause damage to these structures and can finally lead to a chronic posterior ankle impingement syndrome. A differentiation must be made between the 2 groups, as overuse trauma seems to have a better
prognosis\textsuperscript{35} and patients are more satisfied after arthroscopic treatment.\textsuperscript{36} Congenital anatomic anomalies such as a prominent posterior talar process, an os trigonum or a talus bipartitus\textsuperscript{37} can facilitate the occurrence of the syndrome. An os trigonum is estimated to be present in 1.7\% to 7\% and occurs bilateral in 1.4\% people.\textsuperscript{38–40} These congenital anomalies in combination with a traumatic or overuse injury facilitate the occurrence of symptoms.\textsuperscript{33,41–43} During plantarflexion the soft tissue structures such as synovium, posterior ankle capsule, or one of the posterior ligamentous structures can get pinched and compressed, eventually resulting in swelling, partial rupture, or fibrosis.

The diagnosis is clinical. The forced passive hyper plantarflexion test is positive when the patient complains of recognizable pain during the test (Fig. 1). A negative test rules out the posterior ankle impingement syndrome. A positive test is followed by a diagnostic infiltration with Xylocaine (AstraZenica, Zoetermeer, The Netherlands). Disappearance of pain after infiltration confirms the diagnosis.
Fig. 1 The forced hyperplantarflexion test is performed with patient sitting with the knee flexed in 90 degrees. The test should be performed with repetitive quick passive hyper plantarflexion movements. The test can be repeated in slight external rotation or slight internal rotation of the foot relative to the tibia. The investigator can apply to this rotational movement on the point of maximal plantar flexion, thereby “grinding” the posterior talar process/os trigonum between tibia and calcaneus.

**Deep Portion of the Deltoid Ligament/Cedell Fracture**
Hyper dorsiflexion or eversion trauma can result in avulsed fragments, posttraumatic calcifications, or ossicles in the deep portion of the deltoid ligament. The patient typically presents with posteromedial ankle pain, which is aggravated by running and walking on uneven grounds. Ligament avulsion of the deep portion of the deltoid ligament was first described by Cedell.44

**Flexor Hallucis Longus**
Posterior ankle impingement syndrome is often accompanied by a tendinopathy of the tendon of the FHL. The patient experiences posteromedial ankle pain. On physical examination the tendon can be palpated behind the medial malleolus. By asking the patient to
repetitively flex the big toe, whereas the ankle is in 10 to 20 degrees plantarflexion, the FHL tendon can be easily identified in its gliding channel, in between the medial and lateral talar process. In patients with tendinopathy or paratendinopathy, crepitus, and recognizable pain can be provoked by the examiner putting the palpat ing/compressing finger just behind the medial malleolus. In some patients, a painful nodule in the tendon can be palpated.

_Achilles Tendon and Retrocalcaneal Bursa_
A symptomatic inflammation of the retrocalcaneal bursa is caused by repetitive impingement of the bursa between the anterior aspect of the Achilles tendon and a bony postero-superior calcaneal prominence (Fig. 2). A prominent postero-superior calcaneal rim in combination with retrocalcaneal bursitis was first described by Haglund in 1928. Physical examination reveals swelling on both sides of the Achilles tendon at the level of the posterosuperior calcaneal prominence. Pain is aggravated by palpating this swelling just medial and lateral to the Achilles tendon.

Retrocalcaneal bursitis can be accompanied by midportion and/or insertional tendinopathy. In case of insertional tendinopathy, there is pain at the bone-tendon junction, which gets worse after exercise. Patients with tendinopathy or paratendinopathy of the main body of the Achilles tendon report pain and stiffness. A thick nodule is present 2 to 6cm proximal to the insertion, which is tender on palpation.
Fig. 2 The 27-year-old female patient with pain and swelling at the level of her right heel. **A** Lateral x-ray of the right ankle showing a hypertrophic postero-superior calcaneal aspect. **B** Endoscopic picture of her right ankle with the arthroscope in the posterolateral portal showing the inflamed retrocalcaneal bursa (I= Achilles tendon, II= inflamed retrocalcaneal bursa, and III= superior border calcaneus after partial resection). **C** Endoscopic picture after complete removal of the inflamed retrocalcaneal bursa with the full radius resector (I= Achilles tendon, II= removed retrocalcaneal bursa, and III= superior border calcaneus after partial resection).

**Neurovascular Bundle**
Entrapment of the posterior tibial nerve within the tarsal tunnel is commonly known as a tarsal tunnel syndrome. Clinical examination should be sufficient to differentiate these disorders from an isolated posterior tibial tendon disorder.

**Peroneal Tendons**
Peroneal tendon disorders are an uncommon, underrecognized source of posterolateral hindfoot pain and dysfunction. Pathology of the peroneal tendons is often overlooked because it is sometimes difficult to distinguish them from lateral ankle ligament disorders. Instability and dislocation are pathologies associated with the peroneal tendons and are often provoked by sports related injuries. In 1803, Monteggia was the first describing peroneal instability in a ballet
dancer. There are 2 factors, which can cause the tendons to dislocate. First of all the superior peroneal tendon retinaculum can be too lax or disrupted. The retinaculum normally tightly covers the peroneal tendons at the posterior distal fibula, maintaining the tendons at their anatomical site. In case of trauma this function can be impaired. The second mechanism is a (congenital) flat/non concave configuration of the posterior distal part of the fibula with or without an inadequate amount of cartilaginous rim. In the normal situation this part of the fibula is concave with a cartilaginous rim at the most distal part, nurturing the peroneal tendons behind the lateral malleolus. Superior peroneal retinacular dysfunction and an inadequate fibular groove often exist together in recurrent peroneal tendon dislocation. Patients typically complain of a recurrent painful and snapping sensation at the lateral aspect of the ankle with a perception of ankle instability, especially when walking on uneven grounds. The pain and dislocation can be provoked by combined dorsiflexion and eversion of the foot during physical examination.

**Preoperative planning**
After history taking and physical examination the diagnosis can be confirmed or rejected based upon different available imaging techniques. In case history taking and physical examination do not reveal abnormalities, additional diagnostics can be used to search for a clue or to rule out pathology, that is, medico-legal reasons. Close consultation between the orthopaedic surgeon and the radiologist is necessary to decide upon optimal radiographic diagnostics.
Always start with routine weightbearing radiographs in an anteroposterior and lateral directions. In case of anteromedial impingement and negative weightbearing views, an oblique radiograph is indicated. Anteromedial located tibial or talar osteophytes may be over-projected by the anterolateral border of the distal tibia or by the lateral part of the talar neck and body in the standard radiographs. In the oblique anteromedial impingement view, the beam is tilted in a 45 degrees Craniocaudal direction with the leg in 30 degrees external rotation and the foot in plantarflexion in relation to the standard lateral radiograph position\(^5\) (Fig. 3). In patients with an osteochondral defect the standard weightbearing radiographs may show an area of detached bone, surrounded by radiolucency. Initially the defect might be too small to be visualized. A heel rise mortise view may reveal a posteriorly located osteochondral defect.\(^6\) For further diagnostic evaluation computed tomography (CT) and magnetic resonance imaging have demonstrated similar accuracy.\(^6\) A multislice helical CT scan is preferred to determine the extent of the defect and also to decide upon anterior or posterior arthroscopic approach for debridement and bone marrow stimulation.\(^6\)

In patients with a posterior ankle impingement the anteroposterior ankle view typically does not show abnormalities. Osteophytes, calcifications, loose bodies, chondromatosis, and hypertrophy of the postero-superior calcaneal border can often be detected by the lateral ankle radiograph. In case of doubt for the differentiation between hypertrophy of the posterior talar process or an os trigonum, we recommend a lateral radiograph view with the foot in 25 degrees exorotation in relation to the standard lateral radiograph. Especially

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in posttraumatic cases, a spiral CT scan can be important to ascertain the extent of the injury and the exact location of calcifications or fragments. In general, soft tissue pathology consequently can be visualized best using a magnetic resonance imaging scan. Ultrasonography seems to be a good and relatively cheap alternative, with a positive predictive value of 100% for peroneal tendon dislocation.\textsuperscript{57,58}

![Fig. 3 The 36-year-old male patient presenting with anteromedial right ankle pain. A The weightbearing anteroposterior x-ray does not clearly show the ankle pathology. B The anteromedial impingement view (AMI-view) reveals osteophytes at the level of the medial malleolus (blue arrow) and at the anteromedial talus (red arrow). C Arthroscopic image showing osteophytes at the tip of the medial malleolus (blue arrow) and the anterior talus (red arrow). The osteophytes are visualized through the scope positioned in the anterolateral portal.}

**Operative techniques**

**Anterior Ankle Arthroscopy**

Anterior ankle arthroscopy is carried out as an outpatient procedure under general or spinal anesthesia. The patient is placed in the supine position with slight elevation of the ipsilateral buttock. The heel of the affected ankle in placed at the very end of the operating table (Fig. 4). In this way the surgeon can fully dorsiflex the ankle by leaning against the foot sole. Routine anterior portals used are the anteromedial and
anterolateral portal. A softtissue distraction device can be used when indicated (Fig. 5). Accessory portals are located just in front of the tip of the medial or lateral malleolus. The anteromedial portal is made first with the ankle in slight dorsiflexion. After the skin incision has been made just medial to the anterior tibial tendon, the subcutaneous layer is bluntly dissected with a hemostat at the level of the ankle joint. Routinely, a 4.0mm 30 degrees angled arthroscope is introduced, whereas the ankle is in full dorsiflexion. Hereby the talar cartilage is covered and thus protected by the tibial cartilage. For irrigation normal saline is used, and flow is obtained by gravity. By looking laterally the location of the anterolateral portal is determined. A spinal needle is introduced just lateral to the peroneus tertius tendon. A vertical skin incision is made with special attention to not damage the superficial peroneal nerve. The subcutaneous layers are bluntly dissected with a hemostat and the desired instrument can be introduced.

Fig. 4 Patient position on the operating table in case of anterior ankle arthroscopy. The heel of the affected ankle is placed at the very end of the operating table, with the patient in the supine position.
The contour of the anterior tibia is identified and in case of an osteophyte, soft tissue superior from this osteophyte is removed with a shaver. The extent of the osteophyte is determined and the osteophyte is subsequently removed using a 4mm chisel and/or shaver. When an osteophyte is located on the medial distal tibial rim or the front of the medial malleolus, the arthroscope is moved to the anterolateral portal and the instruments are introduced through the anteromedial portal. Osteophytes at the tip of the medial malleolus and ossicles or avulsion fragments in this area can be removed in a similar manner. It can be helpful to create an accessory portal in front of the tip of the medial malleolus. In case of osteophytes at the tip of the medial malleolus, usually overcorrection of the tip is feasible using a bonecutter shaver.

To prevent sinus formation, at the end of the procedure the skin incisions are sutured with 3.0 Ethilon. The incisions and surrounding skin are injected with 10mL of a 0.5% bupivacaine/morfine solution. A sterile compressive dressing is applied (Klinigrip, Medeco BV, Oud Beijerland, The Netherlands). Prophylactic antibiotics are not routinely given.
Posterior Ankle Arthroscopy

The procedure is carried out as outpatient surgery under general anesthesia or spinal anesthesia. The patient is placed in a prone position. The involved leg is marked by the patient with an arrow to avoid wrong side surgery, with a tourniquet inflated around the thigh. A small support is placed under the lower leg, making it possible to move the ankle freely (Fig. 6). We use a soft-tissue distraction device when indicated.\textsuperscript{59}

For irrigation normal saline is used, however, ringers solution is also possible. A 4.0mm arthroscope with an inclination angle of 30° is routinely used for posterior ankle arthroscopy. Apart from the standard excisional and motorised instruments for treatment of osteophytes and ossicles, a 4mm chisel and periosteal elevator can be useful. The anatomic landmarks on the ankle are the lateral malleolus, medial, and lateral border of the Achilles tendon and the foot sole. The ankle is kept in a neutral position. A straight line is drawn from the tip of the
lateral malleolus to the Achilles tendon, parallel to the foot sole (Fig. 7A).

The posterolateral portal is made directly in front of the Achilles tendon just proximal of this line. After making a vertical stab incision, the subcutaneous layer is split by a mosquito clamp. The mosquito clamp is directed anteriorly, pointing towards the interdigital webspace, in between the first and second toe. When the tip of the clamp touches the bone, it is exchanged for a 4.5-mm arthroscopic shaft with the blunt trocar pointing in the same direction. By palpating the bone in the sagittal plane, the level of the ankle joint and subtalar joint can often be distinguished as the prominent posterior talar process or os trigonum can be felt as a posterior prominence in between the 2 joints. The trocar is situated extra-articularly at the level of the ankle joint. The trocar is exchanged for the 4mm arthroscope with the direction of view 30 degrees to the lateral side.

Fig. 6 For posterior ankle arthroscopy the patient is placed in a prone position. A tourniquet is applied around the upper leg and a small support is placed under the lower leg, making it possible to move the ankle freely.
The posteromedial portal is made at the same level, just above the line from the tip of the lateral malleolus, but just in front of the medial aspect of the Achilles tendon (Fig. 7B). After making a vertical stab incision, a mosquito clamp is introduced and directed towards the arthroscope shaft in a 90 degrees angle. When the mosquito clamp touches the shaft of the arthroscope, the shaft is used as a guide to “travel” anteriorly in the direction of the ankle joint, all the way down while contacting the arthroscope shaft until it reaches the bone. The arthroscope is now pulled slightly backward and slides over the mosquito clamp until the tip of the mosquito clamp comes to view. The clamp is used to spread the extra-articular soft tissue in front of the tip of the lens. In situations where scar tissue or adhesions are present, the mosquito clamp is exchanged for a 5mm full radius shaver. The tip of the shaver is directed in a lateral and slightly plantar direction towards the lateral aspect of the subtalar joint.

Fig. 7 A For marking the anatomic landmarks that are needed for portal placement the ankle is kept in a neutral position. A straight line is drawn from the tip of the lateral malleolus to the Achilles tendon, parallel to the foot sole. (A= Achilles tendon, B= lateral malleolus, and C= posterolateral portal). The posterolateral portal is made just above the line from the tip of the lateral malleolus to the Achilles tendon. B Macroscopic image of a right ankle. The posteromedial portal is located at the same level as the posterolateral portal, just in front of the medial aspect of the Achilles tendon. (M= Medial malleolus).
The joint capsule and fatty tissue can be removed. After removal of the very thin joint capsule of the subtalar joint, the posterior compartment of the subtalar joint can be inspected. At the level of the ankle joint, the posterior tibiotalar ligament is recognized and the posterior talofibular ligament. The posterior talar process can be freed from scar tissue and the FHL tendon is identified. This tendon should be located first, before addressing the pathology. The FHL tendon is an important safety landmark; as the neurovascular bundle runs just medial from this tendon. After removal of the thin joint capsule of the ankle joint, the intermalleolar and transverse ligament can be lifted to enter and inspect the ankle joint.

On the medial side, the tip of the medial malleolus can be visualized and the deep portion of the deltoid ligament. By opening the joint capsule from inside out at the level of the medial malleolus, the tendon sheath of the posterior tibial tendon can be opened when desired, and the arthroscope can be introduced into the tendon sheath. The posterior tibial tendon can be inspected. The same procedure can be carried out for the flexor digitorum longus tendon.

By applying manual distraction to the os calcis, the posterior compartment of the ankle opens up and the shaver can be introduced into the posterior ankle compartment. We prefer to apply a soft-tissue distractor at this point. A synovectomy and/or capsulectomy can be performed. The talar dome can be inspected over almost its entire surface and the complete tibial plafond. An osteochondral defect or subchondral cystic lesion can be identified, debrided, and drilled. The posterior syndesmotic ligaments are inspected and debrided if fibrotic or ruptured (Figs. 8A, B).
Removal of a symptomatic os trigonum, a nonunion of a fracture of the posterior talar process or a symptomatic large posterior talar prominence involves partial detachment of the posterior talofibular ligament and release of the flexor retinaculum, which both attach to the posterior talar prominence. Release of the FHL tendon involves detachment of the flexor retinaculum from the posterior talar process. The tendon sheath can now be entered with the scope, after the tendon under the medial malleolus and a further release can be performed. Bleeding is controlled by electrocautery at the end of the procedure. To prevent sinus formation, the skin incisions are sutured with 3.0 Ethilon. The incisions and surrounding skin are injected with 10mL of a 0.5% bupivacaine/morfine solution. A sterile compressive dressing is applied. Prophylactic antibiotics are not routinely given.

Fig. 8 The 43-year-old male patient with persisting deep right ankle pain. A Arthroscopic image showing fibrotic syndesmotic ligaments and a loose body. The syndesmotic ligaments are visualized with the arthroscope through the posteromedial portal. B Postoperative arthroscopic image showing the debrided syndesmotic ligaments.

**Endoscopic Groove Deepening for Recurrent Peroneal Tendon Dislocation**

The patient is positioned in the same way as in posterior ankle arthroscopy. Standard posteromedial and lateral portals are made as described above. A 30 degrees 4.0mm arthroscope is introduced
through the posterolateral portal while introducing a punch through the posteromedial portal. With the arthroscope at the level of the lateral part of the subtalar joint, looking 30 degrees to the lateral side, the peroneal tendon sheath can be identified. The peroneal tendon sheath can now be opened using the punch. The tendon sheath can subsequently be bluntly released with a probe, after which it is exchanged through the posteromedial portal for the punch and the peroneal tendons can be inspected.

The arthroscope is now removed from the posterolateral portal and is introduced through the posteromedial portal. A probe is introduced through the posterolateral portal. This probe is subsequently used to dislocate the peroneal tendons laterally and anteriorly over the lateral edge of the lateral malleolus, thus leaving the fibular groove empty. We sometimes introduce a second probe through the same posterolateral portal to dislocate the peroneal tendons, at a higher level thus exploring a larger portion of the groove. Now, 4cm proximal to the posterolateral ankle portal, a vertical stab incision is made. The subcutaneous tissue is split, with a mosquito clamp, until it is positioned into the fibular groove. Then a 5.5mm full radius bonecutter shaver is introduced, pointing inferiorly down to the level of the most distal part of the fibular bony groove (Figs. 9A–C). Subsequently, under direct arthroscopic view, the fibular groove can be deepened. As the outer diameter of this shaver is 5.5mm, the width and depth of the groove can be judged, aiming for 6 to 7mm and a depth of 5mm. After deepening and widening the groove, the potential sharp edges are smoothened. The probes and shaver are retracted and the peroneal tendons are positioned back into their newly created fibular groove. By manipulating the foot, the stability of the
peroneal tendons can be checked under direct arthroscopic examination.

To prevent sinus formation, at the end of the procedure the skin incisions are sutured with 3.0 Ethilon. The incisions and surrounding skin are injected with 10mL of a 0.5% bupivacaine/morphine solution. A sterile compressive dressing is applied. Prophylactic antibiotics are not routinely given.

![Image](image.png)

Fig. 9 A Macroscopic image of a left ankle indicating the portal placement for endoscopic groove deepening in case of peroneal tendon dislocation. Regular hindfoot portals are indicated; posterolateral\(^1\) and posteromedial portal.\(^2\) An accessory portal is positioned 4 cm proximal to the posterolateral portal (arrow). B Endoscopic image of a left ankle. By using a hook,\(^4\) introduced through the posterolateral portal the peroneal tendons are dislocated, freeing the nonconcave fibular groove.\(^3\) C A bonecutter shaver\(^5\) is introduced through the accessory portal to deepen the fibular groove.

**Postoperative management and rehabilitation**

*Anterior Ankle Arthroscopy*

The patient can be discharged the same day of surgery with a compression bandage applied around the affected ankle. Active range of motion exercises are encouraged and patients are instructed to repetitively dorsiflex the affected ankle several times an hour.
Dependent on the indication for anterior ankle arthroscopy the patient is instructed when full weightbearing is allowed. For instance larger osteochondral lesions (>1 cm) require partial weightbearing up to 6 weeks, whereas anterior ankle arthroscopy for an osteophyte allows the patient to fully bear weight after 5 days.

**Posterior Ankle Arthroscopy/Endoscopic Groove Deepening Technique**
The patient can be discharged the same day of surgery and weightbearing is allowed as tolerated. In case of an endoscopic groove deepening partial weightbearing is advised for 5 days. The patient is instructed to elevate the foot when not walking to prevent oedema. The dressing is removed 3 days postoperatively and the patient is permitted to shower. Performing active range of motion exercises for at least 3 times a day for 10 minutes each is encouraged. In case of an endoscopic groove deepening a soft brace is applied for 4 to 6 weeks with the permission to fully bear weight. With satisfaction of the surgeon and patient, no further outpatient department contact is necessary. Patients with limited range of motion are directed to a physiotherapist.

**Technical alternatives and pitfalls**

**Anterior Ankle Arthroscopy**
The saphenous nerve and great sapheneus vein are potentially at risk when making the anteromedial portal. The anteromedial portal is regarded to be relatively safe, nevertheless neurovascular complications have been reported. The superficial peroneal nerve is at risk when creating the anterolateral portal. In a number of patients
this nerve can be made visible when placing the foot in plantarflexion and inversion. Another possibility to visualize this nerve is by means of plantarflexion of the fourth toe.

Introduction of the instruments through the anteromedial and anterolateral portal must be performed with the ankle in dorsiflexion. In this position the nerves and vessels are not in tension, resulting in a minimal risk of iatrogenic damage. Osteophytes can be removed more easily in dorsiflexion, as it will increase the anterior working area in combination with the saline used for irrigation.

**Posterior Ankle Arthroscopy/Endoscopic Groove Deepening Technique**

In the hindfoot the crural fascia can be quite thick. This local thickening is called the ligament of Rouvière et al. This ligament needs to be at least partially excised of sectioned, using arthroscopic punch or scissors, to reach the level of the subtalar joint. The position of the arthroscope is important; the view should always be to the lateral side. Initially the arthroscope must be pointed in the direction between the first and second toe to be in a safe area. The FHL tendon is an important landmark. The working area is laterally with respect to the FHL tendon, as just medially the neurovascular bundle is situated. The FHL tendon can safely be identified by shaving on top of the posterior talar process, whereas the opening of the shaver is pointing towards the bone. Although staying in contact with the bone, the tip of the shaver should be moved slowly and slightly twisted to the medial side, so that the opening of the shaver is to the lateral side and thus the blunt back of the shaverblade is turned towards the FHL tendon.
The contour of the posterior talar process is followed until the shaver suddenly drops in between the posterior talar process and the FHL tendon. Shaving should be stopped at this moment and the FHL tendon must be identified. The FHL tendon can only be passed medially with a mosquito clamp in case a release of the neurovascular bundle is required (posttraumatic tarsal tunnel syndrome). If a hypertrophic posterior talar process is removed by using a chisel, care must be taken not to place the chisel too far anteriorly. Only the infero-posterior part of the process should be removed with the chisel. The remnant of the process can be taken away with a bonecutter shaver (Figs. 10A–C). If initially the chisel is placed too much anteriorly, it is hard to avoid taking away too much bone at the level of the subtalar joint.

Fig. 10 The 17-year-old male patient with right ankle pain mainly on plantarflexion. A Reconstructed computed tomography scan in the saggital plane indicating a prominent posterior talar process (arrow). B Arthroscopic image indicating the correct position of the chisel. Only the postero-superior edge of the talar process is removed with the chisel. Mind that the FHL tendon is located just medial to the talar process. C Postoperative arthroscopic image of the removed posterior talar process. The infero-posterior part of the talar process has been removed with a bone cutter, without disrupting the FHL tendon. FHL indicates flexor hallucis longus.
Loose bony particles can easily be created with the microfracture awl in case of puncturing the subchondral plate in osteochondral defects. They can become detached upon withdrawal of the awl. If the particles are not removed properly, they may act as loose bodies.\textsuperscript{66} Deepening the fibular groove can potentially damage the ligamentous structures. Medial from the groove the posterior syndesmotic ligaments and the posterior talofibular ligament are located. The contour of the groove must be followed from proximal to distal. The calcaneofibular ligament inserts more anteriorly in the most distal part of the lateral malleolus. The fibular groove must be deepened anteriorly and distally, whereas the shaver is directed medial from the calcaneofibular ligament insertion. The shaver blade must always stay in close contact to the bone to prevent sural nerve damage. The depth of the fibular groove needs to be sufficient to prevent redislocation of the peroneal tendons and should approximately be 5mm. At the end of the procedure, the ankle is manipulated to check whether sufficient bone is excised. Removing too much fibular bone could induce weakening, which could eventually result in a fracture of the remaining lateral rim. It is important to smoothen the created lateral edge of the groove to prevent it from causing peroneal tendon (length) ruptures.

The advantage of a 2-portal procedure\textsuperscript{20} and also of the 3-portal endoscopic groove deepening technique\textsuperscript{21} with the patient in the prone position, is the working space that can be created in between the Achilles tendon and the back of the ankle and subtalar joint. The position is ergonomic for the orthopaedic surgeon. Soft-tissue distraction can easily be applied.\textsuperscript{59}
Discussion/consideration
Arthroscopy has become an important operative technique in treating a wide variety of ankle pathology. It provides a minimally invasive approach as a good alternative to the existing open surgical approaches. The surgeon must be familiar with the anatomy and must try to use routine portals in ankle arthroscopy. Ideally these routine portals can be used to treat the vast majority of pathology, without the need for additional portals.

Reports of complications in ankle arthroscopy vary widely and rates from 9% to 17% have been reported. In the largest series, nearly 50% of these complications were neurologic.

Open and arthroscopic resection of osteophytes were compared by Scranton and McDermott. Arthroscopic resection is favorable as compared with open removal for both the length of hospitalization and time to recovery. Prospective studies report on success rates varying from 73% to 96%.

The authors feel that the posteromedial and lateral portal, as described in 2000 possess the criteria, as discussed above. Also portals must provide a safe access, as is anatomically demonstrated to be true for these posterior endoscopic portals.

Recently, a retrospective study has been published, in which 16 posterior ankle arthroscopies were evaluated. The patients all had a good functional and clinical outcome at a mean follow-up of 32 months. One patient had a temporary numbness in the region of the scar. Similar results are published in a prospective study by Scholten et al under supervision of the senior author. In total 55 posterior ankle arthroscopies for different pathologies have been assessed, resulting in
good functional and clinical outcome. Only one complication occurred, being a temporary sensational loss of the posteromedial heel. The 2-portal endoscopic hindfoot approach compares favorably to open surgery with regard to less morbidity and a quicker recovery. The technique has now expanded to other areas in the hindfoot. The endoscopic groove deepening technique for recurrent peroneal tendon dislocation, as described in this manuscript, is one of these new possibilities.

Other examples are the subtalar arthrodesis and the treatment of Cedell fractures and talus bipartitus.

References

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Anatomy of the ankle ligaments: a pictorial essay

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Abstract
Understanding the anatomy of the ankle ligaments is important for correct diagnosis and treatment. Ankle ligament injury is the most frequent cause of acute ankle pain. Chronic ankle pain often finds its cause in laxity of one of the ankle ligaments. In this pictorial essay, the ligaments around the ankle are grouped, depending on their anatomic orientation, and each of the ankle ligaments is discussed in detail.
Introduction
Despite the fact that the ankle ligaments are prone to injury during the fast majority of sports, literature focusing on the ankle ligaments is rare. Proper anatomic knowledge of the different ligaments is important for a correct diagnosis and subsequent treatment. The most common mechanism of injury to the ankle ligaments is inversion of the foot. With this mechanism of injury, the anterior talofibular ligament is the first or only ligament to sustain injury. A total rupture involves the calcaneofibular ligament and the posterior talofibular ligaments as well. An eversion injury will cause damage to the deltoid ligaments, while a hyperdorsiflexion trauma might cause an injury to the syndesmotic ligaments.

The ligaments around the ankle can be divided, depending on their anatomic position, into three groups: the lateral ligaments, the deltoid ligament on the medial side, and the ligaments of the tibiofibular syndesmosis that join the distal epiphyses of the bones of the leg (tibia and fibula).

In this review article, these three groups of ligaments are described separately, and in each section, the specific ligaments are described in detail.

The lateral and medial collateral ligaments
The lateral collateral ligament complex (LCL) consists of the anterior talofibular, the calcaneofibular, and the posterior talofibular ligaments. The medial collateral ligaments (MCL), also known as the deltoid ligament, are a multifascicular group of ligaments and can roughly be divided into a superficial and deep group of fibers.
Lateral collateral ligaments

*Anterior talofibular ligament*

The anterior talofibular ligament is the most frequently injured ligament of the ankle and is the most frequently observed injury in the emergency room\(^7\) (Fig. 1). This ligament plays an important role in limiting anterior displacement of the talus and plantar flexion of the ankle.\(^40\) This ligament is closely related to the ankle joint capsule and is typically composed of two separate bands (Fig. 2).\(^23\) The bands are separated by vascular branches from the perforating peroneal artery and its anastomosis with the lateral malleolar artery. In literature, numerous anatomic descriptions have been given, varying from a single up to three bands\(^9,10,12,23,24\); however, in our observation during ankle dissections, this ligament most commonly compromises a double-banded morphology, similar to the description by Sarrafian.\(^36\)

The anterior talofibular ligament originates at the anterior margin of the lateral malleolus. The centre is on average 10 mm proximal to the tip of the fibula as measured along the axis of the fibula.\(^10\) The overall width (6–10 mm) of the anterior tibiotalar ligament does not appear to vary greatly irrespective of the number of bands present, suggesting that the variations observed do not modify the ligament’s function (Figs. 3, 4).\(^40\)

From its origin, it runs anteromedially to the insertion on the talar body immediately anterior to the joint surface occupied by the lateral malleolus. The ligament is virtually horizontal to the ankle in the neutral position but inclines upward in dorsiflexion and downward in plantar flexion. It is only in the latter position that the ligament comes
under strain and is vulnerable to injury, particularly, when the foot is inverted. In plantar flexion, the inferior band of the ligament remains relaxed while the upper band becomes taut. In dorsiflexion, the upper band remains relaxed, and the inferior band becomes tight.

Fig. 1 Anterolateral view of the ankle. Anatomic dissection. 1 Anterior talofibular ligament; 2 anterior tibiofibular ligament; 3 fibular insertion of the calcaneofibular ligament; 4 superior extensor retinaculum; 5 inferior extensor retinaculum; 6 peroneus tertius tendon; 7 extensor digitorum longus tendons; 8 superior peroneal retinaculum; 9 inferior peroneal retinaculum; 10 peroneus brevis tendon; 11 peroneus longus tendon; 12 extensor digitorum brevis muscle.

Fig. 2 Osteoarticular anatomic dissection of the lateral ligaments of the foot and ankle joint. The anterior talofibular ligament is typically composed of two separate bands. 1 Tip of the lateral malleolus; 2 tibia; 3 anterior tibiofibular ligament; 4 distal fascicle of the anterior tibiofibular ligament; 5 superior band of the anterior talofibular ligament; 6 inferior band of the anterior talofibular ligament; 7 lateral articular surface of the talus; 8 neck of the talus; 9 head of the talus; 10 calcaneofibular ligament; 11 talocalcaneal interosseous ligament; 12 cervical ligament; 13 talonavicular ligament; 14 navicular.
Fig. 3 Anatomic dissection of the lateral region of the foot and ankle showing the morphology and relationship of the anterior talofibular with the calcaneofibular ligaments. 1 Fibula and tip of the fibula; 2 tibia (anterior tubercle with arrows); 3 anterior tibiofibular ligament; 4 distal fascicle of the tibiofibular ligament; 5 interosseous membrane; 6 foramen for the perforating branch of the peroneal artery; 7 talus; 8 anterior talofibular ligament; 9 calcaneofibular ligament; 10 talocalcaneal interosseous ligament; 11 inferior extensor retinaculum (cut); 12 talonavicular ligament; 13 bifurcate ligament; 14 peroneal tubercle (arrows showing the peroneal tendons sulcus); 15 peroneus longus tendon; 16 peroneus brevis tendon; 17 calcaneal tendon.
Fig. 4 Anatomic dissection of the lateral ankle ligaments showing the relationship of the calcaneofibular and lateral talocalcaneal ligaments with the morphology of the anterior talofibular ligament. Some authors describe a third band of the anterior talofibular ligament. We have never found this third band in our dissections. In the presented dissection, the superior band of the anterior talofibular ligament is smaller than usually. 1 Tip of the fibula; 2 superior and inferior bands of the anterior talofibular ligament; 3 calcaneofibular ligament; 4 lateral talocalcaneal ligament; 5 anterior tibiofibular ligament; 6 distal fascicle of the anterior tibiofibular ligament; 7 triangular region of the talus; 8 lateral articular surface of the talus; 9 dorsal articular surface of the talus; 10 talocalcaneal interosseous ligament; 11 cervical ligament; 12 talonavicular ligament; 13 navicular; 14 lateral calcaneocuboid ligament; 15 bifurcate ligament (calcaneonaviclar fascicle).

**Calcaneofibular ligament**
The calcaneofibular ligament originates from the anterior part of the lateral malleolus. It is anatomically positioned just below the lower band of the anterior talofibular ligament. Frequently, fibers connecting these ligaments can be observed (Fig. 3). In the neutral ankle position, the ligament runs obliquely downwards and backwards to attach to the posterior region of the lateral calcaneal surface (Fig. 5). This ligament is superficially crossed by the peroneal tendons and sheaths, which can leave a concavity over the ligament; only about 1 cm of the ligament is uncovered (Fig. 6). The anatomic variants of the calcaneofibular ligament and their relationship with the lateral talocalcaneal ligament have been the subject of study. In 35% of the cases, the calcaneofibular ligament is
reinforced by the lateral talocalcaneal ligament, attached by the former but diverging proximally or distally. In 23% of the cases, a lateral talocalcaneal ligament exists anteriorly and independent of the calcaneofibular ligament. In 42% of the cases, the lateral talocalcaneal is absent and is replaced by an anterior talocalcaneal ligament. In these cases, the calcaneofibular ligament acquires more functional significance in providing stability to the subtalar joint (Fig. 7). In cross-section, the ligament is rounded and has a diameter of 6–8 mm, and its length is about 20 mm. This ligament is separate from the ankle joint capsule, but it is intimately associated with the posteromedial part of the peroneal tendons sheath, covering almost the entire ligament. The calcaneofibular ligament is the only ligament bridging both the talocrural joint and subtalar joint. Insertion of this ligament and its axis of rotation point allow flexion and extension movements of the talocrural joint. Depending on its bi-articular characteristic, this ligament also permits subtalar movement.

Broström found that combined ruptures of the anterior talofibular and the calcaneofibular ligaments occurred in 20% of cases and that isolated rupture of the calcaneofibular ligament was very rare. The posterior talofibular ligament is usually not injured unless there is a frank dislocation of the ankle. Variants in its orientation of the calcaneofibular ligament were studied by Ruth. The calcaneofibular ligament becomes horizontal during extension and vertical in flexion, remaining tense throughout its entire arc of motion (Fig. 5). A valgus or varus position of the talus considerably changes the angle formed by the ligament and the
longitudinal axis of the fibula. The ligament is relaxed in the valgus position and tense in the varus position. This explains the potential for injury even without dorsiflexionplantar flexion movement in the ankle.

Fig. 5 Osteoarticular dissection of the calcaneofibular ligament during ankle movements. A Neutral position. B Dorsal flexion. C Plantar flexion. Calcaneofibular ligament becomes horizontal during plantar flexion and vertical in dorsal flexion, remaining tensed throughout the entire arc of motion of the ankle. 1 Calcaneofibular ligament; 2 tip of the fibula; 3 calcaneus; 4 peroneal tubercle; 5 subtalar joint; 6 anterior talofibular ligament; 7 neck of the talus; 8 talocalcaneal interosseous ligament; 9 anterior tubercle of the tibia; 10 anterior tibiotalar ligament; 11 posterior tubercle of the tibia; 12 lateral talar process; 13 calcaneocuboid joint; 14 lateral calcaneocuboid ligament; 15 talonavicular ligament; 16 cervical ligament; 17 navicular; 18 bifurcate ligament (calcaneonavicular fascicle); 19 long plantar ligament.
Fig. 6 Anatomic dissection showing the relationship of the calcaneofibular ligament with peroneal tendons. 1 Calcaneofibular ligament; 2 peroneus longus tendon; 3 peroneus brevis tendon; 4 fibula; 5 talofibular ligament; 6 calcaneus; 7 subtalar joint; 8 septum in the peroneal tubercle; 9 superior extensor retinaculum; 10 inferior extensor retinaculum; 11 extensor digitorum longus tendons; 12 peroneus tertius tendon; 13 extensor digitorum brevis; 14 extensor digitorum brevis tendon; 15 calcaneal tendon; 16 Kager’s fat pad; 17 tuberosity of the fifth metatarsal bone; 18 lateral plantar fascia; 19 abductor digiti minimi.
Posterior talofibular ligament
The posterior talofibular ligament originates from the malleolar fossa, located on the medial surface of the lateral malleolus, coursing almost horizontally to insert in the posterolateral talus. In plantar flexion and in the neutral ankle position, the ligament is relaxed, while in dorsiflexion, the ligament is tensed. Due to the multifascicular aspect of this ligament, it inserts not just in a specific area. Fibers insert in the posterior surface of the talus, in the lateral talar process or os trigonum, if present. Some fibers can contribute in forming the tunnel for the flexor hallucis longus tendon (Fig. 8). Moreover, a group of fibers fuse with the posterior intermalleolar ligament. The posterior intermalleolar ligament has been the subject of recent studies because of its involvement in the posterior soft tissue impingement syndrome of the ankle. Its prevalence of
occurrence both in radiological and in anatomic studies vary widely, ranging from 19% up to 100%.\textsuperscript{24,27,30} In our dissections, the intermalleolar ligament is a consistent finding.\textsuperscript{16} In the recent study of Oh et al.\textsuperscript{27} on the morphology of the posterior intermalleolar ligament and its correlation with MR images, the posterior intermalleolar ligament was observed in 81.8% of the specimens (63 of 77 specimens). In MRI study, the intermalleolar ligament was identified in all ankles (26 specimens) (Figs. 9, 10). These differences can probably be explained by its limited size and therefore difficult assessment during an ankle dissection, although Oh et al.\textsuperscript{27} propose the number of specimens used or interracial variations. In addition, the ligament may be divided into two or three different bands (20\%\textsuperscript{34} –100\%\textsuperscript{27}).

In the posterior view, the posterior intermalleolar ligament is situated between the transverse ligament and the posterior talofibular ligament and runs obliquely from lateral to medial and from downwards to upwards. The shape of the posterior intermalleolar ligament is variable. These variations depend on its medial arising sites, the number of composing fiber bundles, and the degree of the bundle compactness. The medial arising sites of the ligament included the lateral border of the medial malleolar sulcus, the medial border of the medial malleolar sulcus through the septum between the flexor digitorum longus and posterior tibial tendons, the posterior distal margin of the tibia, and the posterior process of the talus through the joint capsule (Fig. 10).\textsuperscript{27} The posterior intermalleolar ligament tenses during dorsiflexion and relaxes during plantar flexion, and therefore, trauma that causes forced dorsiflexion of the ankle can be assumed to
produce either injury or rupture of this ligament, or osteochondral avulsion. Plantar flexion would cause it to relax and become susceptible to trapping between the tibia and the talus, leading to impingement (Fig. 11).

Since the introduction of the posterior ankle arthroscopy by van Dijk et al.\textsuperscript{44,45} in 2000, the posterior ankle ligaments can clearly be visualized and treated in case of pathology.

![Fig. 8 Posterior view of the anatomic dissection of the ankle ligaments. 1 Tip of the fibula; 2 peroneal groove of the fibula; 3 tibia; 4 superficial component of the posterior tibiofibular ligament; 5 deep component of the posterior tibiofibular ligament or transverse ligament; 6 posterior calcaneofibular ligament; 7 lateral talar process; 8 medial talar process; 9 tunnel for flexor hallucis longus tendon; 10 flexor hallucis longus retinaculum; 11 calcaneofibular ligament; 12 subtalar joint; 13 posterior intermalleolar ligament; 14 flexor digitorum longus tendon (cut); 15 tibialis posterior tendon; 16 peroneal tendons.](image-url)
Fig. 9  a Posterior view of the ankle ligaments showing the relationships of the posterior intermalleolar ligament, posterior talofibular ligament and transverse ligament. A T1-weighted spin-echo MR imaging showing the correlation between MRI and the sagittal cuts in B 1 Posterior intermalleolar ligament; 2 superficial component of the tibiofibular ligament; 3 deep component of the tibiofibular ligament or transverse ligament; 4 posterior talofibular ligament; 5 lateral talar process; 6 tunnel for flexor hallucis longus tendon.
Fig. 10 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.
Medial collateral ligament
The anatomical descriptions of the MCL vary widely in the literature; however, in general most agree that it is composed of two layers; the superficial and deep.\textsuperscript{8,24,28,36}
Similar to the posterior talofibular ligament, the MCL is a multifascicular ligament, originating from the medial malleolus to insert in the talus, calcaneus, and navicular bone. The tendon sheath of the posterior tibial muscle covers the posterior and middle part of the deltoid ligament in much the same way as the peroneal tendon sheath is associated with the calcaneofibular ligament on the lateral side. The most commonly accepted description of the MCL is the one originally proposed by Milner and Soames.\textsuperscript{24} Six bands or components have been described for the MCL: three of them are always present (the tibiospring ligament, tibionavicular ligament, and deep posterior tibiotalar ligament), whereas the presence of the other three may vary (superficial posterior tibiotalar ligament, tibiocalcaneal ligament, and deep anterior tibiotalar ligament)\textsuperscript{8,24} (Table 1; Figs. 12, 13). Most of the MCL is covered by tendons as it extends down the leg to the bony insertions in the foot (Fig. 14). Although the description proposed by Milner and Soames has been accepted\textsuperscript{24}, the anatomy of this ligament and its components is still confusing. During our dissections, we found it rather difficult to determine each individual band, since most are continuous to one another, and therefore pointing out individual bands is artificial.
Fig. 11 Anatomic view of the posterior intermalleolar ligament (arrows) showing its involvement in the posterior soft tissue impingement of the ankle. From dorsiflexion (A) to plantar flexion (D), to dorsiflexion (F). 1 Superficial component of the posterior tibiofibular ligament; 2 deep component of the posterior tibiofibular ligament or transverse ligament; 3 posterior talofibular ligament; 4 lateral talar process; 5 medial talar process; 6 tunnel for the flexor hallucis longus tendon; 7 deep layer of the medial collateral ligament (deep posterior tibiotalar ligament).

<table>
<thead>
<tr>
<th>Milner and Soames</th>
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<td><strong>Superficial layer</strong></td>
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<td>Tibiospring ligament (major component)</td>
<td>Tibioligamentous fascicle</td>
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<td>Tibionavicicular ligament (major component)</td>
<td>Tibionavicicular fascicle and Anterior superficial tibiotalar fascicle</td>
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<td>Superficial tibiotalar ligament (additional band)</td>
<td>Superficial posterior tibiotalar ligament</td>
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<td>Tibiocalcaneal ligament (additional band)</td>
<td>Tibiocalcaneal ligament</td>
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<td><strong>Deep layer</strong></td>
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<td>Deep posterior tibiotalar ligament (major component)</td>
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<td>Anterior deep tibiotalar ligament (additional band)</td>
<td>Deep anterior tibiotalar ligament</td>
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Table 1 Comparison of the nomenclature used for the medial collateral components, as suggested by Sarrafian\(^{26}\) and Milner and Soames\(^{24}\).
Ligaments that join the distal epiphyses of the tibia and fibula
The talocrural joint consists of a fork-shaped dome formed by the
distal tibia and fibula and the talar trochlea enclosed by this mortise.
Cartilagenous areas of the ankle joint are not congruent in their
surface outlines. In the frontal plane, the talar dome has a slightly
concave profile. The planes of the tibial and fibular facets are not
parallel. The trochlea is wider anteriorly than posteriorly, and the
cartilage covered surfaces have slightly curved sides. The fibular facet
has a convex contour, whereas the tibial facet is concave.\textsuperscript{13}
It is a syndesmotic articulation that allows the tibiafibula as a whole to
adapt to the varying width of the upper articular surface of the talus
by slight ascending and medial rotation movements of the fibula
during extreme dorsiflexion (maximum width) and by inverse
movements during plantar flexion (minimum width).\textsuperscript{21}
The syndesmotic ligament complex ensures the stability between the
distal tibia and the fibula and resists the axial, rotational, and
translational forces that attempt to separate the tibia and fibula. The
three ligaments responsible are the anterior or anteroinferior
tibiofibular ligament, the posterior or posteroinferior tibiofibular
ligament, and the interosseous tibiofibular ligament. The inferior
segment of the interosseous membrane also helps stabilize the
tibiofibular syndesmosis. Distal to the insertion site of this ligament,
the remaining anterior surface corresponds to the tibiofibular
synovial recess of the ankle joint, and at the posterior surface, there is
a small bundle of adipose tissue called the fatty synovial fringe (Fig.
15). The synovial fringe lowers or rises during ankle movements,
retracting in dorsiflexion to rise and position itself between the tibia and fibula and descending in plantar flexion toward the ankle joint. This structure has been implicated as a cause of chronic pain following ankle sprain in the condition known as anterolateral soft tissue impingement or more specifically, syndesmotic impingement.

Fig. 12 Schematic representation of the main components of the medial collateral ligament found as frequently observed in our dissections. The morphology of the medial malleolus is helpful to understand the origins of the medial collateral ligament. In the medial view, two areas or segments (culliculi) can be seen, separated by the intercollicular groove. 1 Tibionaviculair ligament; 2 tibiospring ligament; 3 tibiocalcaneal ligament; 4 deep posterior tibiotalar ligament; 5 spring ligament complex (plantar and superomedial calcaneonaviculair ligaments); 6 anterior culliculus; 7 posterior culliculus; 8 intercullicular groove; 9 sustentaculum tali; 10 medial talar process; 11 lateral talar process; 12 navicular; 13 navicular tuberosity.
Anterior or anteroinferior tibiofibular ligament

The ligament originates in the anterior tubercle of the tibia (5 mm in average above the articular surface⁴¹, and its fibers extend in a distal and lateral direction to the insertion site in the anterior margin of the lateral malleolus, with increased length of the fibers distally. Upon examination, the ligament is seen to be divided into several fascicles, allowing the perforation branches from the peroneal artery (Figs. 16, 17). The most distal fibers of the ligament at its origin may be confused with those of the anterior talofibular ligament.¹,⁶,³⁶

The most distal fascicle of the anterior tibiofibular ligament appears to be independent from the rest of the structure (Fig. 16). It is separated by a septum of fibroadipose tissue and may be slightly deeper than the rest of the ligament. Pathology to this fascicle is
frequently described as being responsible for anterolateral soft tissue impingement.\(^1,2,5,32\) Excision of this distal fascicle through open or ankle arthroscopic approach frequently resolves the patient’s complaints, whereas the ankle stability is not compromised.\(^6,25,26,31\) Impingement of the distal fascicle of the anterior tibiofibular ligament appears to depend on changes in the ankle mechanics.\(^6\) An injury to the LCL (e.g., anterior talofibular ligament) would increase anteroposterior laxity of the ankle.\(^20\) This, in turn, would result in increased anterior extrusion of the talus and cause the distal fascicle to have greater contact and pressure on the talus.\(^6\) Another factor related to distal fascicle impingement is the level at which the anterior tibiofibular ligament is inserted in the fibula with respect to the joint line. More distal insertion of the ligament could lead to increased contact in the neutral position of the ankle and a higher potential for ligamentous pathology (Fig. 18). Knowledge of this configuration is important to understand the anatomic bases for anterolateral soft tissue impingement, since abrasion between the distal fascicle of the anterior tibiofibular ligament and the talus may lead to pain (Fig. 19). Our observations in the dissection room have allowed us to identify contact between the distal fascicle and the talus in the neutral position. This finding is frequently observed during ankle arthroscopy, and the surgeon should consider it a normal feature.\(^2\) This fact has been reported by other authors\(^1,19,22,26,32\), although in cases of anatomic variation or ankle instability, the feature may be pathological. Contact decreases with joint distraction\(^2\), which should be taken into account during arthroscopy. Akseki et al.\(^2\) observed that section of the anterior talofibular ligament does not alter the contact
when the ankle is in neutral position, although important changes are observed when the ankle is in movement. Therefore, ankle instability is one direct factor in anterior tibiofibular ligament pathology. A diagnosis of this type of ligamentous impingement should be considered in patients with chronic pain in the anterolateral area of the ankle following a sprain, with joint stability and a normal
Fig. 14 Medial view of the anatomic dissection of the medial collateral ligament. Most of the medial collateral ligament is covered by tendons (tibialis posterior and flexor digitorum longus tendons). In order to see the ligament, the tendon of flexor digitorum longus was removed. **A** Neutral position showing the relationship with the tibialis posterior tendon. **B** The posterior tibialis tendon was removed. **C** Plantar flexion. The components located anteriorly to the bimalleolar axis are tensed. **D** Dorsiflexion. The components located anteriorly to the bimalleolar axis are relaxed. 1 Medial malleolus; 2 lateral talar process; 3 sustentaculum tali; 4 navicular; 5 tibialis posterior tendon; 6 navicular tuberosity; 7 flexor hallucis longus (cut); 8 flexor hallucis longus retinaculum; 9 posterior talocalcaneal ligament; 10 calcaneal tendon (cut at the level of the insertion); 11 long plantar ligament; 12 spring ligament complex (superomedial calcaneonavicular ligament); 13 tibionavicular ligament; 14 tibiospring ligament; 15 tibiocalcaneal ligament; 16 deep posterior tibiotalar ligament.

![Medial view of the tibiofibular joint](image)

Fig. 15 Medial view of the tibiofibular joint (os talus previously removed). 1 Articular surface of the lateral malleolus; 2 distal articular surface of the tibia; 3 anterior tibiofibular ligament (distal fascicle); 4 superficial component of the posterior tibiofibular ligament; 5 deep component of the posterior tibiofibular ligament or transverse ligament; 6 fatty synovial fringe; 7 anterior talofibular ligament; 8 calcaneofibular ligament; 9 posterior talofibular ligament; 10 fibulotalocalcaneal ligament or Rouvière and Canela ligament.
Fig. 16 Anterosuperior view of talocrural joint and dorsum of the foot. 1 Anterior tibiofibular ligament; 2 anterior tubercle of the tibia.

**Posterior or posteroinferior tibiofibular ligament**

As is frequently observed, also for this rather strong compact syndesmotic ligament, numerous terminologies have been postulated\(^5\), which is particularly evident in the arthroscopic literature\(^16\).

This ligament is basically formed by two independent components, the superficial and deep component (Fig. 20).

The superficial component originates at the posterior edge of the lateral malleolus and directs proximally and medially to insert in the posterior tibial tubercle. This component would be homologous to the
anterior tibiofibular ligament. The term posterior or posteroinferior tibiofibular ligament is usually used to refer to the superficial component (Figs. 20, 21).

The deep component is cone shaped and originates in the proximal area of the malleolar fossa to insert in the posterior edge of the tibia. Its insertion is immediately posterior to the cartilaginous covering of the inferior tibial articular surface; the fibers may reach the medial malleolus (Fig. 21). This component is also known as the transverse ligament, forming a true labrum\(^{36}\) to provide talocrural joint stability and to prevent posterior talar translation.\(^{37}\)
Fig. 17 Anatomic view of the anterolateral part of the ankle showing the relationship between the anterior tibiofibular ligament and the perforating branch of the peroneal artery (arteries are filled with black latex). 1 Anterior tibiofibular ligament; 2 distal fascicle of the anterior tibiofibular ligament; 3 anterior tubercle of the tibia; 4 perforating branch of peroneal artery; 5 triangular region of the talus; 6 anterior malleolar artery; 7 lateral articular surface of the talus; 8 dorsal articular surface of the talus; 9 anterior talofibular ligament.

Fig. 18 Anatomic view of the anterior ligaments of the ankle. 1 Anterior tibiofibular ligament; 2 distal fascicle of the anterior tibiofibular ligament; 3 tibia (anterior tubercle indicated with arrows); 4 anterior talofibular ligament; 5 beveled triangular region of the talus; 6 deep layer of the medial collateral ligament; 7 superficial layer of the medial collateral ligament; 8 notch of Harty.
**Interosseous tibiofibular ligament**

The interosseous tibiofibular ligament is a dense mass of short fibers, which, together with adipose tissue and small branching vessels from the peroneal artery, span the tibia to the fibula. It can be considered a distal continuation of the interosseous membrane at the level of the tibiofibular syndesmosis.\(^{18,36,38}\) Some investigators have suggested that the interosseous ligament is mechanically insignificant, whereas others consider it the primary bond between the tibia and fibula.
Hoefnagels et al.\textsuperscript{18} suggest that the interosseous ligament plays an important role in the stability of the ankle.

![Anatomic dissection of the posterior ligaments of the ankle](image)

**Fig. 20** Anatomic dissection of the posterior ligaments of the ankle.
1 Lateral malleolus; 2 tip of the lateral malleolus; 3 peroneal groove; 4 tibia; 5 posterior tubercle of the tibia; 6 posterior tibiofibular ligament, superficial component; 7 posterior tibiofibular ligament, deep component or transverse ligament; 8 subtalar joint; 9 posterior talofibular ligament; 10 posterior intermalleolar ligament; 11 lateral talar process; 12 tunnel for flexor hallucis longus tendon (tendon was removed); 13 medial talar process; 14 calcaneofibular ligament; 15 flexor digitorum longus.
Fig. 21 Sagittal section of the ankle (lateral view). 1 Tibia; 2 talus; 3 calcaneus; 4 posterior tibiofibular ligament; 5 superficial component of the posterior tibiofibular ligament; 6 deep component of the posterior tibiofibular ligament or transverse ligament; 7 posterior talofibular ligament; 8 posterior intermalleolar ligament; 9 subtalar joint; 10 talocrural joint; 11 posterior capsular recess of the subtalar joint; 12 flexor hallucis longus muscle.
Conclusions
The ankle sprain injury is the most frequently observed injury in the emergency room.\textsuperscript{7} Up to 40\% of individuals with a history of an ankle ligament injury have been found to have residual complaints interfering with daily living.\textsuperscript{14,15} Adequate knowledge of the anatomy of the ankle ligaments provides a foundation for understanding the basic mechanism of injury, diagnosis, and treatment of these ankle sprains.
Soft tissue impingement syndromes of the ankle are usually preceded by an ankle sprain. Depending on the mechanism of injury, a specific ligament and/or ligaments can be injured.\textsuperscript{43} Injury to the anterior talofibular ligament is the most common injury following an ankle sprain. Most frequently, it is an isolated injury; however, in approximately 20\% of the patients, also the calcaneofibular ligament is injured.\textsuperscript{9}
An inversion sprain can result in injury to the capsule, lateral or medial collateral ligaments, or tibiofibular ligaments. The added influence of plantar or dorsiflexion on the injury mechanism will mean that the lesion is predominantly anterior or posterior, respectively, and could also lead to injury to other structures such as the posterior intermalleolar ligament, the osteochondral region of the neck of the talus, or the anteroinferior margin of the tibia.
The mechanism of foot eversion is more closely associated with injury to the medial capsular and ligamentous elements, although an inversion sprain can also produce a lesion to these structures. Medial injury is probably more influenced by the rotating component of the subtalar joint to which the capsule and the MCL are subject.
The aim of this pictorial review on the anatomy of the ankle ligaments is to provide a guide to those who are involved in diagnosing and treating ligament injury around the ankle.

References


Anterior ankle arthroscopy, distraction or dorsiflexion?

Peter AJ de Leeuw, Pau Golanó, Joan A Clavero, C Niek van Dijk

*Knee Surg Sports Traumatol Arthrosc* 2010;18:594–600
Abstract
Anterior ankle arthroscopy can be performed by two different methods; the dorsiflexion- or distraction method. The objective of this study was to determine the size of the anterior safe working area for both the dorsiflexion and distraction method. The anterior working area is anteriorly limited by the overlying anatomy which includes the neurovascular bundle. We hypothesize that in ankle dorsiflexion the anterior neurovascular bundle will move away anteriorly from the ankle joint, thus increasing the anterior working area, whereas in ankle distraction the anterior neurovascular bundle is pulled tight towards the joint, thereby decreasing the safe anterior working area. Six fresh frozen ankle specimens, amputated above the knee, were scanned with computed tomography. Prior to scanning the anterior tibial artery was injected with contrast fluid and subsequently each ankle was scanned both in ankle dorsiflexion and in distraction. A special device was developed to reproducibly obtain ankle dorsiflexion and distraction in the computed tomography scanner. The distance between the anterior border of the inferior tibial articular facet and the posterior border of the anterior tibial artery was measured.
The median distance from the anterior border of the inferior tibial articular facet to the posterior border of the anterior tibial artery in ankle dorsiflexion and distraction was 0.85 cm (range 0.7 – 1.5) and 0.65 cm (range 0.5 – 0.8) respectively. The distance in ankle dorsiflexion significantly exceeded the distance in ankle distraction (p=0.03).
The current study shows a significantly increased distance between the anterior distal tibia and the overlying anterior neurovascular bundle with the ankle in a slightly dorsiflexed position as compared to the distracted ankle position. We thereby conclude that the distracted ankle position puts the neurovascular structures at greater risk for iatrogenic damage when performing anterior ankle arthroscopy.
**Introduction**

The ankle joint or talocrural articulation at the proximal level is formed by the articular surfaces of the distal tibial and fibular epiphyses and distally by the talus in its superior, lateral and medial aspect (Fig. 1). The morphology of these surfaces forms a hinge-type synovial joint, with a single axis of movement (bimalleolar axis) that allows dorsiflexion (flexion) and plantar flexion (extension) of the ankle and foot in the sagittal plane. Because of this configuration and the fact that it is a load-bearing joint, the intraarticular space is very narrow. In 1931 Burman for this reason concluded that this joint was not suitable for arthroscopy. In the second half of the last century technical improvements have led to smaller diameter arthroscopes and improved instruments. These improvements have increased the popularity of the ankle joint arthroscopy. Currently an increasing amount of indications can be diagnosed and arthroscopically treated. Ankle arthroscopy is nowadays considered reliable and relatively safe and is therefore frequently used for treatment of a wide variety of ankle pathology.

Because of the high joint congruency, various methods have been developed to distract the ankle joint with the objective to improve visualization and to obtain access to the articular surface. Fixed joint distraction in combination with a 2.7 mm diameter arthroscope was popularized by Guhl (Fig. 2). Since the small diameter shaft does not allow for a high volume of water inflow an additional posterolateral portal is usually recommended. This three portal approach was advocated and used for diagnostic as well as therapeutic purposes. A 21-point diagram was introduced by Ferkel and
Fischer.\textsuperscript{11} This diagram was suggested being able to systematically and reproducibly exam the ankle by arthroscopy from a diagnostic point of view.

With the development and improvement of a variety of additional diagnostics like MRI, CT, and bone scans, the diagnostic use of ankle arthroscopy has been questioned.\textsuperscript{25} Especially in the ankle joint a variety of asymptomatic pathological changes, like spurs, ossicles, scar tissue and cartilage damage can coexist. The combination of history, physical examination and additional diagnostics are sufficient for a proper clinical diagnosis and to decide for the best surgical approach. A diagnostic arthroscopy has no added value. Anterior pathology, like impingement syndromes, ossicles, loose bodies and anterior located osteochondral defects can be treated by means of an anterior 2 portal approach.\textsuperscript{31} Posterior ankle pathology like the os trigonum, flexor hallucis longus tendinopathy or posterior located osteochondral defects can effectively be treated by a 2 portal hindfoot approach.\textsuperscript{30,32}

For the treatment of these lesions routine distraction is not indicated and can even provide a disadvantage since it could reduce the anterior and posterior working area.\textsuperscript{10,31} For this reason the senior author developed a non-distraction method to access the anterior ankle compartment by means of ankle arthroscopy.\textsuperscript{31} The key element in this method is to dorsiflex the ankle, thereby opening up the anterior working area, creating sufficient space to use a 4.0 mm arthroscope (Fig. 3). The large diameter arthroscope allows for an increased saline inflow as compared to the 2.7 mm arthroscope.

The anterior working area is anteriorly limited by the overlying anatomy which includes the neurovascular bundle (Fig. 4). We
hypothesize that in ankle dorsiflexion the anterior neurovascular bundle will move away anteriorly from the ankle joint, thereby increasing a safe anterior working area, whereas in ankle distraction the anterior neurovascular bundle is pulled tight towards the joint, thereby decreasing the safe anterior working area (Fig. 3). The objective of this study was to determine the size of the anterior working area for both the dorsiflexion and distraction method.

Fig. 1 Anatomic view of the anterior ligaments of the ankle. 1 Tibia and medial malleolus. 2 Lateral malleolus. 3 Talus. 4 Head of the talus. 5 Anterior tibiofibular ligament. 6 Distal fascicle of the anterior tibiofibular ligament. 7 Anterior talofibular ligament. 8 Superficial and deep layers of the medial collateral ligament.
Fig. 2 Invasive distractor for ankle arthroscopy.\textsuperscript{16}

Fig. 3 A Schematic view of the ankle joint in the neutral ankle position showing the anterior (1) and posterior working areas. B Interarticular work is possible when distraction (arrows) is used, but the capsular tension reduces the anterior and posterior working areas. C The anterior working area is opened in dorsiflexion of the foot; anterior ankle pathology can easily be treated.
Fig. 4 Sagittal section of the ankle showing the most relevant anatomical structures. 1 Tibia. 2 Talus. 3 Neck of the talus. 4 Head of the talus. 5 Tibiotalar working area. 6 Posterior subtalar joint. 7 Talonavicular joint. 8 Capsule. 9 Intracapsular but extrasynovial fatty tissue. 10 Anterior tibial artery and vein painted with Adobe Photoshop (the deep peroneal nerve has not been identified). 11 Extensor hallucis longus. 12 Deep layer of inferior extensor retinaculum. 13 Superficial layer of inferior extensor retinaculum.

**Materials and methods**

Six ankles from five female and one male fresh frozen specimen, amputated approximately 10 cm above the knee, from the Department of Pathology and Experimental Therapeutic Unit of Human Anatomy and Embryology in Barcelona, Spain, were examined. The specimens were from the Caucasian origin with a mean age of 81 years (range 79–89 years). Specimens were excluded in case of deformities or scars following ankle surgery and/or limited range of motion, and furthermore ankles with severe atherosclerosis were excluded based on a computed tomography (CT) scan with the arteries containing contrast fluid.
In order to visualize the anterior tibial artery contrast fluid was injected in the fresh frozen specimens and its orientation relatively to the anterior distal tibia was determined based on CT scans, both in ankle distraction and dorsiflexion. The contrast mix injected into the femoral artery consisted of 1 unity of Barium with 4 unities of commercially available latex and 2 drops of dimeglumine (Magnevist) for every 50 ml of solution. The femoral artery was located in the proximal part of the specimen and was separated from the femoral vein. Horizontal incisions in the first and fifth toe were made up to the level of the bone. The femoral artery was first injected with 50 ml water to assess possible vessel obstructions. Subsequently the femoral artery was injected, using a 60 ml filled syringe, with the contrast fluid, until the fluid leaked from the toe incisions. A special device was developed for reproducible ankle positioning inside the CT scanner (Fig. 5a, b).

The basis of the device is formed by two aluminium sliding arms (A) which are on the left side terminated by a methacrylate block (B). This block is used to fix the proximal part of the specimen to the device using a 12 mm aluminium pin (C). A movable clamp (D) is attached to the sliding arms and is used to adjust to lower leg length differences. A footplate (E), entirely composed of fibreglass, is attached both to the movable clamp (D) and to a calibrated spring (F). The spring on his turn is attached to another movable methacrylate block (G). Once a specimen correctly fits into the device and the movable clamp (E) is fixed to the aluminium sliding arms, the turning grip (H) is used to vary the distance between the footplate (E) and the aluminium block (G), thereby changing ankle positioning. By increasing this distance
the ankle is manipulated into plantar flexion and decreasing the
distance results in ankle dorsiflexion.
Furthermore the foot plate can be removed to attach the calibrated
spring (F) to a non-invasive foot distracting device. By moving the
aluminium block (G) away from the specimen, ankle distraction can
be obtained and the amount of force applied can be read from the
calibrated spring (Fig 6).
Each specimen was first scanned in slight ankle dorsiflexion followed
by ankle distraction, standardized at 100 N, in a sixteen-detector row
CT scanner (Aquilion 16; Toshiba Medical, Tokyo, Japan). Scanning
was performed using the following parameters, 1-s gantry rotation
speed, 0.5-mm slice thickness (x16), 7.5-mm table travel per rotation,
X-ray tube voltage was 120 kV and tube current was 150 mA.
The volumetric CT data were reconstructed with a slice width of 10.5
mm and a reconstruction interval of 0.4 mm. The multiplanar
reformatted images and 3-D volume-rendered images were generated
on a Vitrea computer workstation (Vitrea version 3.0.1., Vital Images,
MN).
The sagittal CT reconstructions were used to assess the anterior
working area for both the dorsiflexion and distraction ankle position. A
line parallel to the anterior and posterior most distal part of the tibia
was drawn to determine the position of the anterior border of the
inferior tibial articular facet (Figs. 7, 8). In the sagittal CT reconstruction
in which the anterior tibial artery had the widest diameter, the shortest
distance between the anterior border of the inferior tibial articular facet
and artery was measured using E-film (Figs. 7, 8). This distance was
regarded as the anterior working area.
Fig. 5 The device is formed by: A Aluminium sliding arm. B Methacrylate block. This block is used to fix the proximal part of the specimen to the device using a aluminium pin. C Aluminium pin. D Movable clamp used to adjust to lower leg length differences. E Fibreglass footplate. F Calibrated spring. G Methacrylate block. H Grip, used to vary the distance between the footplate (E) and the methacrylate block (G).
Statistical analysis
Each of the measurements was performed twice by two independent observers and inter- and intra-observer reliability was assessed by calculating the intraclass correlation coefficient (ICC). The reliability was considered good if the coefficient exceeded 0.8. Since the sample size was limited, data were presented as medians with accompanying ranges, and a non-parametric Wilcoxon Signed Rank test was performed to investigate whether the anterior working area for the ankle dorsiflexion differed significantly from the ankle distraction (P < 0.05).

The amount of dorsiflexion in each of the specimens was not standardized during the CT scanning process but was retrospectively measured by the angle of the footplate as compared to the neutral (90 degree) position. The correlation between the degrees of dorsiflexion applied and the anterior working area was assessed through a
Spearman correlation coefficient (r). The correlation was regarded strong if the Spearman coefficient exceeded 0.8.

Fig. 7 The sagittal CT reconstructions in the distracted ankle position. A line parallel to the anterior and posterior most distal part of the tibia was drawn to determine the position of the anterior border of the inferior tibial articular facet. The shortest distance between the anterior border of the inferior tibial articular facet and artery was measured using E-film. This distance was regarded as the anterior working area.

Fig. 8 The sagittal CT reconstructions in ankle dorsiflexion.
None of the specimens met the exclusion criteria, some revealed mild artherosclerosis of the popliteal artery, which however, did not interfere with the injected amount of contrast fluid. On average 43 ml contrast fluid was injected in each of the specimens (range 40–50 ml). Intra-observer reliability coefficient was 0.99 for both observers in the dorsiflexion position and 0.95 and 0.93 in ankle distraction. Inter-observer reliability coefficient was 0.99 for both measurements in ankle dorsiflexion and 0.79 and 0.94 in ankle distraction for the first and second measurement, respectively. The median distance from the anterior border of the inferior tibial articular facet to the posterior border of the anterior tibial artery (anterior working area) in ankle dorsiflexion and distraction was 0.9 cm (range 0.7–1.5) and 0.7 cm (range 0.5–0.8), respectively (Fig. 9). The anterior working area in ankle dorsiflexion significantly exceeded the area in ankle distraction (P = 0.03).

![Graph showing median distance from the anterior border of the inferior articular tibial facet to the anterior tibial artery (cm) in ankle dorsiflexion and distraction (N = 6).]
The correlation between the degrees of ankle dorsiflexion in each specimen and the median distance from the anterior tibial artery to the anterior border of the inferior tibial articular facet, is shown in Fig. 10. There was no significant correlation between the amount of ankle dorsiflexion and the distance of the anterior tibial artery to the anterior border of the distal tibial facet (r = 0.6, P = 0.26).

![Graph showing correlation](image)

Fig. 10 Correlation between the degrees of ankle dorsiflexion in each specimen and the median distance from the anterior tibial artery to the anterior border of the inferior tibial articular facet (N = 6).

**Discussion**

The most important finding of this study is that a significantly increased anterior safe working area is created when performing anterior ankle arthroscopy with the dorsiflexion method as compared to the distraction method. With an increased anterior working area, the chance of iatrogenic damage to the neurovascular structures during anterior ankle arthroscopy is decreased. This finding is supported by the reported complication rates for anterior ankle arthroscopy. In ankle arthroscopic series with fixed distraction the average complication rate varies between 8 and 17%\(^1, 4, 5, 9, 12-14, 17, 18, 20, 21, 24\) and is on average 10.7%. A series of 1,305 consecutive arthroscopic procedures with the
ankle dorsiflexion method has revealed a complication rate of 3.4%. This figure compares favorably to the distraction method rates. The increased working area with ankle dorsiflexion enables the use of a larger diameter arthroscope and arthroscopic instruments. Another advantage is that during ankle dorsiflexion the articular cartilage is protected against iatrogenic damage. The joint is locked in this position which prevents the transfer of loose bodies and/or detached bone fragments from the anterior ankle compartment to posterior. The main advantage of the distraction method is the direct access to the cartilage of the talar dome.

The ankle joint capsule is in close relation to the anterior neurovascular bundle. At the level of the ankle joint, the anterior neurovascular bundle is located just anteriorly to the joint capsule. This bundle is formed by the deep peroneal nerve and the anterior tibial artery or dorsalis pedis artery and veins, depending the level of consideration. We decided to use the anterior tibial artery as a landmark to determine the anterior safety zone.

One of the limitations of our research is that the examined specimens are not comparable to the age group that is normally operated by means of arthroscopy. The mean age at time of death in the examined specimens was 81 years old, whereas ankle arthroscopy is most frequently performed in patients between 18 and 40 years old. Probably with age soft tissue structures, including the anterior neurovascular bundle, become more rigid. The anterior neurovascular bundle will then not move easily with ankle dorsiflexion, resulting in an underestimated distance between the anterior border of the inferior tibial facet and the anterior tibial artery in our study.
Another limitation of the presented research is that during the CT scanning process the joint capsule was not filled with saline, as is during ankle arthroscopy. Saline in combination with ankle dorsiflexion will create a capsular recess, which is probably more prominent as compared to a joint capsule without saline. As the anterior neurovascular bundle will shift with the creation of a prominent capsular recess, in the present report presumably an underestimated safe distance is measured for the dorsiflexion ankle position.

**Conclusion**
The current study shows that while performing anterior ankle arthroscopy with the ankle in distraction, the anterior neurovascular structures are more at risk for iatrogenic damage, as compared to anterior ankle arthroscopy with the ankle in dorsiflexion.

**References**
Identification of the superficial peroneal nerve. - Anatomical study with surgical implications -

Peter AJ de Leeuw, Pau Golanó, Leendert Blankevoort, Inger N Sierevelt, C Niek van Dijk

Abstract
To prevent iatrogenic damage to the superficial peroneal nerve during ankle arthroscopy, it needs to be identified. The purpose of the present study was to determine which clinical test identified the superficial peroneal nerve most frequently and which determinants negatively affected the identification.
A total of 198 ankles (99 volunteers) were examined for identification of the superficial peroneal nerve. Race, gender, body mass index (BMI), shoe size and frequency of physical activity were collected. The best method to identify the superficial peroneal nerve was the maximal combined ankle plantar flexion and inversion test. In this position, the nerve was identified in 57 % of the ankles by palpation. BMI was the only independently influential factor in the identification of the superficial peroneal nerve.
Since in nearly six out of the ten ankles the superficial peroneal nerve can be identified, it is advised to assess its anatomy prior to portal placement. A higher BMI negatively influences the identification of the superficial peroneal nerve.
Introduction
Anterior ankle arthroscopy is routinely used as a minimally invasive surgical technique for the treatment of ankle pathology. Sine introduction, arthroscopic equipment has improved significantly, enabling surgeons to visualize and treat an increasing number and more complex pathologies.\textsuperscript{25, 26}
Complication rates for anterior ankle arthroscopy have been reported to be up to 17\%, of which more than 25\% was related to iatrogenic superficial peroneal nerve damage during anterolateral portal placement.\textsuperscript{2, 4, 6, 8, 10–13, 14, 16–18, 21, 27} The superficial peroneal nerve perforates the crural fascia at an average of 13 cm proximal to the level of the ankle joint.\textsuperscript{1} Subsequently, the nerve divides into its terminal branches: the medial dorsal cutaneous and the intermediate dorsal cutaneous nerves.\textsuperscript{14, 17} The level at which this nerve penetrates the fascia and the level at which the terminal branches originate has been studied extensively.\textsuperscript{1, 5, 15, 20, 24} The superficial peroneal nerve and the above-mentioned branches are the only nerves in the human body that can be visualized at clinical examination.\textsuperscript{22} Identification of the superficial peroneal nerve preoperatively may prevent iatrogenic damage.\textsuperscript{23} Literature is inconclusive with respect to which specific test identifies the superficial peroneal nerve most accurately. Furthermore, it is unknown which determinants influence nerve identification. Determinants which have a negative influence on the identification of the superficial peroneal nerve might account for an increased risk of superficial peroneal nerve damage following surgery.
The purpose of this study was to determine which specific clinical tests identify the superficial peroneal nerve most frequently and which determinants negatively affected its identification. We hypothesized that in the majority of the population the superficial peroneal nerve, or if divided, its terminating branches, can be identified by ankle plantar flexion and inversion.

**Materials and methods**
Inclusion criteria were volunteers between 18 and 40 years old, with the ability to understand and sign the informed consent form. Informed consent was obtained in all volunteers. Volunteers were excluded if they had a history of foot and/or ankle surgery. The investigator was trained on cadaveric specimens in the specific clinical examinations by an experienced anatomist (PG). The superficial peroneal nerve was distinguished from blood vessels by its subcutaneous colour and the fact that vessels, in contrast to nerves, can be compressed. Arteries are not located subcutaneously; thus, only veins were relevant in this examination. The subcutaneous colour of the nerve is white, while veins are coloured blue in the Caucasian and Asian people. Distinguishing the superficial peroneal nerve from the extensor tendons was done by flexion and extension of the toes. Superficial peroneal nerve visibility and palpability were assessed in different foot and ankle positions: the neutral (90°) position, same ankle position but with the addition of maximal plantar flexion of the fourth toe, and the forced combined maximal ankle plantar flexion and inversion position (Fig. 1).
Race, gender, and physical activity of the volunteer were determined. The height and weight of each volunteer were recorded, and the BMI was subsequently calculated. The European shoe sizes and the frequency of sport participation were recorded following a questionnaire. Institutional review board approval from the University of Amsterdam, the Netherlands, was obtained under registration number 08/053.

Fig. 1 Visible identification of the superficial peroneal nerve (white arrows) by combined ankle plantar flexion and inversion both in an ankle from the Caucasian and Negroid race.

**Statistical analysis**
Statistical analysis was performed using SPSS 19.0 (SPSS Inc., Chicago, Illinois, USA). Identification of the peroneal nerve in three positions (neutral, fourth toe flexion and combined plantar flexion/inversion) is presented as proportions (with 95 % CI) and pairwise tested using McNemar tests to determine which clinical test is most sensitive to identify the superficial peroneal nerve. Additionally, a post hoc power analysis was performed.

A mixed logistic regression analysis was performed to assess the influence of the determinants (gender, age, race, shoe size, and BMI) on the detectability of the superficial peroneal nerve. To account for dependency between left and right leg within the individual, the
variance–covariance structure “compound symmetry” was used. Odds ratios (with 95% CI) were calculated for the factors that were significantly \( p < 0.05 \) associated with the identification of the superficial peroneal nerve.

![Graph showing identification of nerves](image)

**Fig. 2** Percentage of the ankles in which the superficial peroneal nerve could be identified (with 95% CI) for the foot in the neutral position and for each of the clinical tests.

**Results**

We recruited 99 volunteers (39 men, 60 women), in whom both ankles were examined (with the ankle in the 90° position, the superficial peroneal \( n = 198 \)). On examination nerve was neither visible nor palpable in any of the ankles. With the addition of fourth toe flexion, the peroneal nerve, or its terminal branches, was identified by visualization in 27% (95% CI 21–33%) of the ankles \( n = 54 \) and was palpable in 38% (95% CI 33–43%) of \( n = 75 \). With the ankle in the combined maximal plantar flexed and inverted position, the visibility and palpability of the superficial peroneal nerve were,
respectively, 41 % (95 % CI 34–48 %) (CI 50–64 %) \((n = 113)\) (Fig. 2). Palpation in the combined \(N = 81\) and 57 % (95 % plantar flexion/inversion position was the most sensitive method to assess the location of the superficial peroneal nerve \((p < 0.001)\); visualization of the nerve was only possible in the ankles in which the nerve was also palpable. In the ankles in which the nerve was identified with fourth toe flexion, also the maximal plantar flexion and inversion the test was positive. Post hoc power analysis revealed a power of more than 99 % to detect the differences between the three positions (90° position, fourth toe flexion, plantar flexed, and inverted position) for both identification procedures (visualization and palpation).

BMI was the only significant determinant of visibility and palpability of the superficial peroneal nerve \((p = 0.001\) and 0.04), respectively, Table 1) with odds ratios of 0.68 (95 % CI 0.55–0.85) and 0.83 (95 % CI 0.69–0.99), respectively. This implies that for each unit the BMI increases and the odds of identification of the superficial peroneal nerve decreases with 32 and 17 %, respectively.

In the ankles in which the superficial peroneal nerve was visible, the mean BMI was 21.3 (SD 1.8) and the nerve was palpable in ankles with a mean BMI of 21.8 (SD 2.0). If the superficial peroneal nerve was not visible or palpable, the mean BMI was 23.3 (SD 4.5) and 23.4 (SD 5.2), respectively.
Table 1 Determinants for identification by palpation of the superficial peroneal nerve in the maximal combined plantar flexion and inversion position following the mixed logistic regression analysis.

**Discussion**

The most important finding of the present study was that the identification of the superficial peroneal nerve should ideally be performed in ankle plantar flexion and inversion, revealing this nerve in 57% of the cases. The nerve was more frequently identified by palpation than by visualization. The fourth toe flexion sign did not aid in revealing a nerve that had already been identified with combined maximal plantar flexion and inversion. BMI was the only statistically significant determinant influencing identification of the superficial peroneal nerve.

According to Stephens and Kelly, the superficial peroneal nerve can be identified with the fourth toe flexion sign in 85% of the volunteers. In our study, we could not reproduce this figure. Once they had clinically identified the nerve, an infiltration with a local anaestheti
followed. Identification was deemed positive if subsequent skin numbness was experienced in the superficial peroneal nerve supply area. It is, however, questionable whether such an infiltration is accurate enough in precise identification of the nerve. The anaesthetic agent at the infiltration site could diffuse widely, resulting in nerve inhibition and thereby a positive fourth toe flexion sign. Local anaesthetic diffusion could in our view result in false-positive values, overestimating the test results. Furthermore, it was suggested that in women the superficial peroneal nerve is more difficult to identify because of their increased amount of subcutaneous fat. Gender was not a significant determining factor for the identification of the superficial peroneal nerve in our study. However, the amount of subcutaneous fat at the anterolateral part of the ankle joint, as a separate determining factor, was not assessed. Harty reported that the superficial peroneal nerve can be identified with plantar flexion and inversion. In one of the figure legends, it was stated that this nerve could be identified in about 20% of the ankles. It is unclear how this number was obtained, and no references were given.

Since complication rates of anterior ankle arthroscopy are relatively high, ranging from 8 to 17%, and mainly involved iatrogenic damage to the superficial peroneal nerve, different clinical tests were described to visualize this nerve during physical examination. Preoperative identification of the superficial peroneal nerve could prevent iatrogenic damage during anterolateral portal placement in anterior ankle arthroscopy, external fixator applications, surgical decompressions for compartment
syndromes, rapid localization prior to local anaesthetic blocks, and in open reduction and internal fixation of distal fibula fractures. One should be aware, however, that marking the nerve in combined maximal plantar flexion and inversion can provide a false sense of safety. The position of this nerve changes with the position of the ankle. The superficial peroneal nerve moves on average 2 mm medially with maximal plantar flexion and inversion of the ankle, as compared to the neutral ankle position.

One of the study limitations is the single observer identification of the superficial peroneal nerve in the volunteers. The examiner was, however, trained in the local anatomy and performed dissections assisted by an experienced anatomist (PG) to avoid wrong identification. Also definitions were included in the study protocol to distinguish the superficial peroneal nerve from the surrounding anatomical structures such as the veins and tendons. The rate of inter- and intra-observer reliability remains to be determined.

Identification of the superficial peroneal nerve preoperatively may prevent iatrogenic damage while making the incisions for the arthroscopic portals. The superficial peroneal nerve is more difficult to identify in patients with a higher BMI. This group of patients may, as a consequence, have an increased risk of iatrogenic superficial peroneal nerve damage. Currently no literature supports this hypothesis, necessitating further studies to elicit this.

**Conclusion**
The best clinical test to identify the superficial peroneal nerve is forced ankle plantar flexion and inversion; thereby, the nerve can be identified
in about six out of ten ankles by palpation. Increasing BMI negatively
influences the identification of the superficial peroneal nerve by clinical
examination.

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The course of the superficial peroneal nerve in relation to the ankle position: anatomical study with ankle arthroscopic implications

Peter AJ de Leeuw, Pau Golanó, Inger N Sierevelt, C Niek van Dijk

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Abstract
Despite the fact that the superficial peroneal nerve is the only nerve in the human body that can be made visible; iatrogenic damage to this nerve is the most frequently reported complication in anterior ankle arthroscopy. One of the methods to visualize the nerve is combined ankle plantar flexion and inversion. In the majority of cases, the superficial peroneal nerve can be made visible. The portals for anterior ankle arthroscopy are however created with the ankle in the neutral or slightly dorsiflexed position and not in combined plantar flexion and inversion. The purpose of this study was to undertake an anatomical study to the course of the superficial peroneal nerve in different positions of the foot and ankle. We hypothesize that the anatomical localization of the superficial peroneal nerve changes with different foot and ankle positions. In ten fresh frozen ankle specimens, a window, only affecting the skin, was made at the level of the anterolateral portal for anterior ankle arthroscopy in order to directly visualize the superficial peroneal nerve, or if divided, its terminal branches. Nerve movement was assessed from combined 10 plantar flexion and inversion to 5 dorsiflexion, standardized by the Telos stress device. Also for the 4th toe flexion, flexion of all the toes and for skin tensioning possible nerve movement was determined. The mean superficial peroneal nerve movement was 2.4 mm to the lateral side when the ankle was moved from 10 plantar flexion and inversion to the neutral ankle position and 3.6 mm to the lateral side from 10 plantar flexion and inversion to 5 dorsiflexion. Both displacements were significant (P<0.01). The nerve consistently moves lateral when the ankle is manoeuvred from combined plantar flexion and inversion
to the neutral or dorsiflexed position. If visible, it is therefore advised to create the anterolateral portal medial from the preoperative marking, in order to prevent iatrogenic damage to the superficial peroneal nerve.
**Introduction**
Over the last three decades, the field of ankle arthroscopy has progressed significantly. Nowadays, anterior ankle arthroscopy is routinely used for the treatment of the anterior ankle impingement syndrome and talar osteochondral defects\(^9,27\), although the technique can be used for a wide variety of ankle pathology.

The anterolateral portal in anterior ankle arthroscopy is created lateral to the peroneus tertius tendon or, if not present, lateral to the extensor digitorum longus tendon.

The superficial peroneal nerve or its terminal branches, mainly the intermediate dorsal cutaneous nerve, is at risk with regard to this routine anterolateral portal\(^4,9,10,18,19,23\) (Fig. 1).

The superficial peroneal nerve provides motor innervation to the peroneus longus and brevis muscles and passes along the lateral intermuscular septum, subsequently perforating the crural fascia to function as a sensory nerve to the vast majority of the dorsal foot (Fig. 2). After fascia perforation, this nerve is usually divided into its terminal branches; the medial dorsal cutaneous—and intermediate dorsal cutaneous nerve.\(^12,14\) The level at which the superficial peroneal nerve divides into its terminal branches relatively to the level of the ankle joint was subject to numerous anatomical studies and different classification types.\(^1,5,14,19,24\) The superficial peroneal nerve, and if divided, its terminal branches are the only nerves in the human body that can be made visible (Fig. 3).\(^21\) Preoperative identification of this nerve should assist in preventing iatrogenic damage during foot and ankle surgery, rapid localization prior to local
anaesthetic blocks, external fixator applications as well as surgical decompressions.\textsuperscript{21}

Arthroscopic surgery, as compared to open surgical approaches, offers the advantage of direct and magnified visualization of the anatomical structures, less postoperative morbidity, faster and functional rehabilitation, earlier sport resumption, and the possibility of outpatient treatment.\textsuperscript{8, 10, 20} Despite these obvious advantages, complications do occur. The overall complication rate varies in between 8 and 17%\textsuperscript{2, 4, 6, 8–11, 13, 15, 17, 18, 20}, of which iatrogenic superficial peroneal nerve damage, related to anterolateral portal placement, is reported most frequently.\textsuperscript{4, 10, 18} Ferkel et al.\textsuperscript{9} reported an overall complication rate of 9%, of which iatrogenic superficial peroneal nerve damage accounts for 27%.

Numerous suggestions have been made to diminish these rates. Good anatomical knowledge, the use of vertical incisions only affecting the skin parallel to the tendons and neurovascular structures with subsequent blunt dissection up to the level of the joint have been postulated.\textsuperscript{9, 12} Furthermore, minimal endurance of distraction and tourniquet inflation within a protocol ensuring routine portal placement and usage of proper arthroscopic instrumentation are other considerations.\textsuperscript{9, 10, 16, 18, 22, 24} Preoperatively, the superficial peroneal nerve, or its terminal branches, can be made visible with ankle plantar flexion and inversion, while preoperatively it can be visualized with cutaneous transillumination.\textsuperscript{9, 21, 24, 25} If visible, it is recommended to mark the course of the nerve on the skin preoperatively.\textsuperscript{9} The effect of each intervention in reducing complication rates is unknown.
It is noteworthy that despite improved arthroscopic techniques and the fact that the superficial peroneal nerve can be visualized transcutaneously, damage to this nerve remains the most frequently reported complication in anterior ankle arthroscopy. Therefore, the purpose of this study was to perform an anatomical study to determine the course of the superficial peroneal nerve in different positions of the foot and ankle to possibly explain and clarify this rather contradiction, and eventually to diminish future complication rates. We hypothesize that the nerve localization changes with different foot and ankle positions.

Fig. 1 Transverse section at the level of the ankle joint.  

- **A.** Anatomical relations of the anterolateral portal.  
- **B.** Anatomical relations of the anteromedial portal  
Fig. 2 Anatomical dissection of the cutaneous nerves of the foot and ankle. 1 Superficial peroneal nerve, 2 Fascial piercing of the superficial peroneal nerve, 3 Superficial peroneal nerve before piercing the crural fascia, 4 Anterior compartment of the leg, 5 Lateral compartment of the leg, 6 Medial dorsal cutaneous nerve (medial terminal branch of superficial peroneal nerve), 7 Intermediate dorsal cutaneous nerve (lateral terminal branch of superficial peroneal nerve), 8 Lateral dorsal cutaneous nerve (terminal branch of sural nerve), 9 Sural nerve (the saphenous vein was removed), 10 Medial calcaneal nerve (Branco or sural nerve), 11 Common nerves digital of medial dorsal cutaneous nerve (medial terminal branch of superficial peroneal nerve), 12 Cutaneous branch (medial terminal branch) of deep peroneal nerve, 13 Superior extensor retinaculum, 14 Inferior extensor retinaculum, 15 Tip of lateral malleolus, 16 Inferior peroneal retinaculum, 17 Achilles tendon and 18 Tuberosity of the V metatarsal bone.
Fig. 3 Using the combined ankle plantar flexion and inversion position, the superficial peroneal nerve (the intermediate dorsal cutaneous nerve or lateral terminal branch of superficial peroneal nerve) could be visualized in 3 out of the 10 examined ankles (30%).

Materials and methods
Ten lower legs (five left and five right), amputated approximately 15 cm below the knee, from seven men and three women fresh frozen specimens were carefully examined in the Department of Pathology and Experimental Therapeutic Unit of Human Anatomy and Embryology in Barcelona, Spain. The specimens were from the Caucasian origin with a median age of 77 (range 65–90 years). Specimens were excluded in case of deformities or scars following ankle surgery and/or limited range of motion. The superficial peroneal nerve with its surrounding soft tissue was fixed with a mosquito clamp at the amputation level.
An experienced anatomist (PG) determined the course of the superficial peroneal nerve, or if divided its terminal branches, by
creating a window (20 mm wide and 15 mm long), only affecting the skin without manipulating the nerve. The localization of the window was at the level of the anterior joint line, lateral to the peroneus tertius tendons or if not present, lateral to the extensor digitorum longus tendon. Now, the superficial peroneal nerve or its terminal branches could directly be visualized. The ankle was subsequently moved from 10° plantar flexion and inversion to the neutral position (90) and then to 5° dorsiflexion to determine whether the course of the nerve changed.

The reference point was regarded being the combined plantar flexion and inversion position. In this position, the medial edge of the nerve was marked with a pin(Ø 0.5 mm). Possible nerve movements, relatively to the reference point, were recorded with a digital caliper (Australian measuring instruments 0–200 mm). Manipulating the ankle in the different ankle positions was standardized by means of the Telos stress device (Telos equipment, Weiterstadt, Germany) (Fig. 4).

Subsequently, the ankle was positioned in the neutral position (90) to assess whether the course of the superficial peroneal nerve, or its terminal branches, changed with manual tension on the skin covering the lateral aspect of the ankle, plantar flexion of the 4th toe and plantar flexion of all the toes.
Fig. 4 Photograph showing the used method in the study. The course of the superficial peroneal nerve, or if divided its terminal branches, was determined by creating a window (20 mm wide and 15 mm long), only affecting the skin without manipulating the nerve. Manipulating the ankle in the different ankle positions was standardized by means of the Telos stress device (Telos equipment, Weiterstadt, Germany). The reference point was regarded being the combined plantar flexion and inversion position. In this position, the medial edge of the nerve was marked with a pin (yellow in the photography).

**Statistical analysis**
Each of the measurements was performed by three independent observers, and inter-observer reliability was assessed through an intraclass correlation coefficient (ICC). The reliability was considered good if the coefficient exceeded 0.8. An one sample t test was performed to determine whether the nerve movement was significantly different from 0 (P < 0.05).

**Results**
The superficial nerve or its terminal branches consistently moved to lateral while the ankle was moved from 10° plantar flexion and inversion to the neutral and then to the 5° dorsiflexion position. From 10° plantar flexion and inversion to the neutral position, the average
nerve movement was 2.4 mm to the lateral side (SD 0.9, range 0.95–4.19). The standardized ankle movement from 10° plantar flexion and inversion to the 5° dorsiflexion resulted in an mean nerve movement of 3.6 mm to the lateral side (SD 1.8, range 1.38–7.68). Both displacements to the lateral side were significant (P <0.01) (Table 1). The inter-observer reliability coefficients (ICC) for the measurement of nerve displacement for both ankle movements were 0.98 (95% CI; 0.953–0.998) and 0.99 (95% CI; 0.980–0.998), respectively. With the ankle in the neutral position the superficial peroneal nerve or its terminal branches did not move while applying tension on the skin, flexion of the 4th toe or flexion of all toes.

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Table 1 General specimen characteristics with superficial peroneal nerve movement (mm) from combined 10° plantar flexion and inversion to neutral and to 5° ankle dorsiflexion.

**Discussion**
The most important finding of the present study is that the anatomical orientation of the superficial peroneal nerve consistently changes by altering the ankle position. The superficial peroneal nerve, or if divided the intermediate dorsal cutaneous nerve, and the medial
dorsal cutaneous nerve, are the only nerves in the human body that can be made visible in the majority of humans. Numerous manoeuvres have been described to visualize the superficial peroneal nerve or its terminal branches. These were introduced to attempt avoidance of iatrogenic damage during anterolateral portal placement, external fixator applications, surgical decompressions and rapid localization prior to local anaesthetic blocks. One of these manoeuvres includes combined plantar flexion and inversion of the ankle.

The possibility to visualize the superficial peroneal nerve has clinical implications in ankle surgery (open and arthroscopically) and in local regional anaesthetic techniques. As described, different manoeuvres were introduced to visualize this nerve, being able to mark its course preoperatively, with the aim of preventing complications. Despite the possibility to visualize the nerve, complication rates in ankle arthroscopy are still relatively high, ranging from 8–17%, mostly regarding the superficial peroneal nerve and especially the intermediate dorsal cutaneous nerve.

One of the possible limitations of our research was that the specimens were amputated below the knee. The present investigation concerns the movement of the superficial peroneal nerve in different foot and ankle positions, in below the knee amputated specimens. We assumed that with the amputation the normal nerve anatomy might was disturbed, and for this reason the nerve was fixed to its surrounding soft tissue with a mosquito clamp. However, we hypothesize that the amputation did not have a major influence on our results, since from proximal to distal the nerve divides several times to innervate the
peroneal muscles. Each division individually acts as an anchor, thereby stabilizing the nerve. The nerve is furthermore fixed along its route by the lateral intermuscular septum. Marking the superficial peroneal nerve in ankle plantar flexion and inversion provides a false sense of safety when making the anterolateral portal in the normal or slight dorsiflexion position, since the marking does not correspond to the subcutaneous position of the nerve in this position. When the ankle is moved from plantar flexion and inversion to the neutral position (90), the nerve consistently moves lateral relatively to the marking. It is this neutral or slightly dorsiflexed position in which the portals are created.\textsuperscript{26} If the anterolateral portal is made medial to the marking, this will prevent iatrogenic damage to the superficial peroneal nerve. Placing the anterolateral portal lateral to the marking places the nerve at risk to iatrogenic damage.

**Conclusion**
The current study shows that the superficial peroneal nerve consistently moves lateral when the ankle is manoeuvred from combined plantar flexion and inversion to the neutral or dorsiflexed position. If visible, it is therefore advised to create the anterolateral portal medial from the preoperative marking, in order to prevent iatrogenic damage to the superficial peroneal nerve.
References
Hindfoot Endoscopy for Posterior Ankle Impingement
Surgical Technique

C Niek van Dijk, Peter AJ de Leeuw, Peter E Scholten

Abstract
The surgical treatment of posterior ankle impingement is associated with a high rate of complications and a substantial time to recover. An endoscopic approach to the posterior ankle (hindfoot endoscopy) may lack these disadvantages. We hypothesized that hindfoot endoscopy causes less morbidity and facilitates a quick recovery compared with open surgery. Fifty-five consecutive patients with posterior ankle impingement were treated with an endoscopic removal of bone fragments and/or scar tissue. The symptoms were caused by trauma (65%) or overuse (35%). All patients were enrolled in a prospective protocol. At baseline, the age, sex, work and sports activities, American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot scores, and preinjury Tegner scores were determined for all patients. At the time of followup, AOFAS hindfoot scores and Tegner scores were assessed and the time to return to work and sports activities was determined. Complications were recorded. Patients scored the overall result as poor, fair, good, or excellent by means of a 4-point Likert scale. The median duration of follow-up was thirty-six months, and no patient was lost to follow-up. The median AOFAS hindfoot score increased from 75 points preoperatively to 90 points at the time of final follow-up. The median time to return to work and sports activities was two and eight weeks, respectively. At the time of follow-up, patients in the overuse group were more satisfied than those in the posttraumatic group, and the AOFAS hindfoot scores were higher in patients in the overuse group (median, 100 points) compared with patients in the posttraumatic group (median, 90 points). A
complication occurred in one patient who had a temporary loss of sensation of the posteromedial aspect of the heel. The outcome after endoscopic treatment of posterior ankle impingement compares favorably with the results of open surgery reported in the literature. Hindfoot endoscopy appears to cause less morbidity than open ankle surgery and facilitates a quick recovery. Patients treated for posterior ankle impingement caused by overuse have better results than those treated following trauma.
Introduction
Posterior ankle pathology can be treated with posterior ankle arthroscopy. The posteromedial and lateral hindfoot portals are anatomically proven to be safe and reliable\textsuperscript{1,2} and typically provide excellent access to the posterior aspects of the ankle and subtalar joints, including the extra-articular hindfoot structures.\textsuperscript{3} Since the introduction of the technique in 2000\textsuperscript{3}, an increasing number of pathological conditions have been treated successfully arthroscopically; arthroscopic treatment compares favorably to open surgery because it is associated with less overall morbidity and quicker recovery.\textsuperscript{4-6}

Surgical Technique
General considerations
The procedure is carried out in an outpatient setting with the patient under general or spinal anesthesia. The affected side is carefully marked preoperatively, and the patient is placed in a prone position. Prophylactic antibiotics are not routinely administered. A tourniquet is applied proximal to the knee and is inflated to a pressure of 300 mm Hg prior to instrument insertion. The ankle is positioned slightly over the distal edge of the operating table with a small triangular support under the distal part of the leg, allowing free movement of the ankle (Fig. 1). Normal saline solution or Ringer solution is used for irrigation; the flow is obtained by gravity. Typically, a 4.0-mm 30° arthroscope is used. Distraction is not routinely applied, but soft-tissue distraction may be used when indicated.\textsuperscript{7}
Fig. 1 Patient position during posterior ankle arthroscopy. During posterior ankle arthroscopy, the patient is placed in a prone position. A tourniquet is applied proximal to the knee (II). The ankle is placed over the distal edge of the operating table with a small triangular support under the distal part of the leg (I). A support is placed at the ipsilateral side of the pelvis to permit slight rotation of the operating table in a safe manner when needed (III).

**Portal placement**
The anatomical landmarks for portal placement are the sole of the foot, the lateral malleolus, and the medial and lateral borders of the Achilles tendon. With the ankle in the neutral position (90°), a straight line, parallel to the sole of the foot, is drawn from the tip of the lateral malleolus to the Achilles tendon and is extended over the Achilles tendon to the medial side.

The posterolateral portal is located just proximal to, and 5 mm anterior to, the intersection of the straight line with the lateral border of the Achilles tendon. The posteromedial portal is located at the same level as the posterolateral portal, but on the medial side of the Achilles tendon (Figs. 2-A and 2-B).
Fig. 2 Lateral (Fig. 2-A) and posterior (Fig. 2-B) views illustrating portal placement for posterior ankle arthroscopy in a left ankle. The anatomical landmarks are indicated and include the Achilles tendon (pink), the tip of the lateral malleolus (purple), and the level of the sole of the foot (horizontal black line). With the foot in the neutral position (90°), a straight line (blue line), parallel to the sole of the foot, is drawn from the tip of the lateral malleolus to the Achilles tendon and is extended over the Achilles tendon to the medial side. The posterolateral portal is located proximal to and 0.5 cm anterior to the intersection of the straight line with the lateral border of the Achilles tendon. The posteromedial portal is located at the same level as the posterolateral portal, but on the medial side of the Achilles tendon.

**Instrument introduction**

The posterolateral portal is made as a vertical stab incision, and the subcutaneous layer is spread with a mosquito clamp. The foot is now in a slightly (relaxed) plantar-flexed position. The clamp is directed anteriorly, toward the web space between the first and second toes (Fig. 3-A). When the tip of the clamp touches bone, it is exchanged for a 4.5-mm arthroscopic cannula, with the blunt trocar pointing in the same direction (Fig. 3-B). The trocar is situated extra-articularly at the level of the posterior talar process and is exchanged for the 4.0-mm 30° arthroscope, directed laterally (Fig. 3-C). At this time, the arthroscope is still outside the joint with its tip in the fatty tissue overlying the capsule.
Next, the posteromedial portal is made with a vertical stab incision, and a mosquito clamp is introduced through the stab incision and is directed toward the arthroscope shaft at a right angle until the clamp contacts the arthroscope (Fig. 3-D). The ankle is still in a slightly plantar-flexed position, and the arthroscope has remained in position through the posterolateral portal, directed toward the first web space. The arthroscope shaft is used as a guide for the mosquito clamp to travel anteriorly. While in contact with the arthroscope shaft, the clamp glides over the shaft toward the ankle joint until bone is reached (Fig. 3-E). Once the arthroscope and clamp are both touching bone, the mosquito clamp is left in position and the arthroscope is pulled slightly backward (Fig. 3-F) and is tilted until the tip of the clamp comes into view (Fig. 3-G). The soft-tissue layer covering the joints consists of fatty tissue and the deep crural fascia. At the lateral side a specialized part of the crural fascia can be recognized, which is called the Rouvière ligament.

Exchanging instruments through the posteromedial portal requires a careful step-by-step procedure. The described position of the arthroscope pointing in the direction of the first web space with the ankle in slight plantar flexion is always the starting point. Instruments introduced through the posteromedial portal are inserted perpendicular to the arthroscope until they are in contact. Subsequently, the arthroscopic shaft is routinely used to guide any instrument, introduced through the posteromedial portal, toward the posterior parts of the ankle and subtalar joints. For the correct orientation, the arthroscope is always directed to the lateral side.
Figs. 3-A through 3-H Stepwise introduction of arthroscope and instruments for posterior ankle arthroscopy in a left ankle. The Achilles tendon is indicated in pink. **Fig. 3-A** The posterolateral portal is made as a vertical stab incision, and the subcutaneous tissue is subsequently spread with a mosquito clamp in the direction of the first web space. The ankle is in a slightly plantar-flexed position. **Fig. 3-B** The mosquito clamp is exchanged for a 4.5-mm arthroscopic shaft, again pointing in the direction of the first web space with the ankle in a slightly plantar-flexed position. The end of the shaft is situated at the level of the posterior talar process. **Fig 3-C** The trocar is exchanged for a 4.0 mm arthroscope with a 30° inclination angle. The arthroscope points to the first web space, and the direction of view is routinely to the lateral side. **Fig 3-D** The posteromedial portal is made with a vertical stab incision, and a mosquito clamp is subsequently introduced toward the arthroscope at a 90° angle. **Fig 3-E** With use of the arthroscope as a guide, the mosquito clamp is moved anteriorly until the bone is reached. Both the arthroscope and the clamp are now touching bone. **Fig 3-F** The mosquito clamp remains in position, and the arthroscope is withdrawn slightly. **Fig 3-G** With the mosquito clamp left in position, the arthroscope is tilted to the lateral side until the clamp comes into view. **Fig 3-H** The arthroscope is used as a guide to direct the shaver toward the talus. While the arthroscope is retracted and tilted, the tip of the shaver is visualized.

**Surgical Procedure and Addressing the Pathology**

The clamp is now directed to the lateral side in an anterior and slightly plantar direction. This movement creates an opening in the crural fascia, just lateral to the posterior talar process. The fatty tissue and the subtalar joint capsule are subsequently opened. The mosquito clamp is then exchanged for a 5-mm full-radius shaver (Fig. 3-H). With a few turns of the shaver, the subtalar joint capsule and the soft tissue are gently removed (Fig. 4-A). The opening of the shaver blade is facing bone. This part of the procedure is carried out in a blind fashion. The shaver is then retracted (Fig. 4-B), and the arthroscope is brought anteriorly (as shown in Figure 5) through the opening in the crural fascia to visualize the posterolateral aspect of the subtalar joint (Fig. 4-C). Once the joint is recognized, the opening in the crural fascia is enlarged to create more working area. Figure 5 shows a schematic representation of the steps described above.
The cranial part of the posterior talar process is freed from the Rouvière ligament and crural fascia (Fig. 6-A, B, and C) to identify the flexor hallucis longus tendon (Fig. 6-D). The flexor hallucis longus tendon is an important safety landmark. Since the neurovascular bundle runs just medial to this tendon, the area lateral to the flexor hallucis longus tendon is regarded as being safe.

At the level of the ankle joint, the posterior talofibular ligament is identified. Proximally, the intermalleolar ligament, also called the tibial slip, and the deep portion of the posterior tibiofibular ligament, also called the transverse ligament, are identified in turn (Fig. 6-D). A distinction between these ligaments can easily be made by dorsiflexion of the ankle. The intermalleolar and transverse ligaments can be elevated with a probe in order to enter and inspect the ankle joint.

In the case of isolated flexor hallucis longus tendinitis, the flexor retinaculum can be released by detaching it from the posterior talar process or symptomatic os trigonum with an arthroscopic punch.

Subsequently, the tendon sheath can be opened up to the level of the sustentaculum tali and entered with the arthroscope, allowing accurate tendon inspection. The proximal part of the tendon and the distal part of the muscle belly are inspected and debrided if inflamed or thickened or if nodules are present. Adhesions and excessive scar tissue are removed with a shaver; however, a radiofrequency probe may also be used. Under all circumstances, care is required due to the proximity of the neurovascular bundle.

Removal of a symptomatic os trigonum, an ununited fracture of the posterior talar process, or a symptomatic large posterior talar prominence involves partial detachment of the posterior talofibular
ligament, detachment of the talocalcaneal ligament, and release of the flexor retinaculum (Fig. 6-E). All of these structures attach to the posterior talar prominence or symptomatic os trigonum, and the release of each is ideally performed with an arthroscopic punch or scissors (Fig. 6-F and G). The posterior talofibular ligament can also be detached with a shaver. After release of these structures (Fig. 6-H), a small blunt periosteal elevator with a curved tip is suited to detach the os trigonum from the talus (Fig 6-I and J). It can be applied both proximally and distally. A chisel is used to detach a symptomatic enlarged posterior talar process. Caution is required in relation to the position of the chisel, which should not be placed too far anteriorly, in order to avoid entering the subtalar joint.

With the application of manual traction to the calcaneus, the posterior compartment of the ankle is distracted and the arthroscope and a probe or shaver can be easily introduced into the ankle joint. We prefer to apply a soft-tissue distractor at this point. A synovectomy and/or capsulectomy can be performed when indicated. The talar dome as well as the complete tibial plafond can be inspected over almost their entire surface. An osteochondral defect or subchondral cystic lesion can be identified and debrided, and microfracture can be performed. The posterior syndesmotic ligaments are inspected and are debrided if fibrotic or ruptured. Syndesmotic stability can be tested with a hook, and loose bodies in the syndesmotic ligament complex can be released and subsequently removed.

On the medial side, the tip of the medial malleolus and the deep portion of the deltoid ligament can be visualized. Opening the joint capsule from inside out at the level of the medial malleolus can allow the
posterior tibial tendon sheath to be opened as desired. Subsequently, the arthroscope can be introduced into the tendon sheath to inspect the posterior tibial tendon. Bleeding is controlled by means of electrocautery at the end of the procedure. To prevent sinus formation, the skin incisions are sutured with 3.0 nylon. The incisions and surrounding skin are injected with 10 mL of a 0.5% bupivacaine-morphine solution. A sterile compressive dressing is applied.

Fig. 4 Arthroscopic images of a left ankle after penetration of the crural fascia to visualize the lateral aspect of the subtalar joint. A The shaver is pushed through the crural fascia in a lateral and plantar direction. While the shaver is retracted, the soft tissue anterior to the crural fascia is removed and the opening of the shaver is facing bone. B The shaver has been retracted, and thus the hole in the fascia can be visualized. C The arthroscope is pushed through the hole in the crural fascia to visualize the posterolateral aspect of the subtalar joint. PTFL = posterior talofibular ligament.
Fig. 5 Schematic step-by-step overview of arthroscope and instruments for posterior ankle arthroscopy in a left ankle. The 4.0-mm arthroscope with an inclination angle of 30° is in the posterolateral portal, with the tip resting on the posterior talar process and pointing in the direction of the first web space with the ankle in slight plantar flexion. First, the shaver is introduced through the posteromedial portal and glides over the arthroscope until it is in contact with the bone. Next, the arthroscope is retracted slightly while the shaver remains in position. The arthroscope is then tilted until the shaver comes into view. The shaver is directed in a lateral and slightly plantar direction, thereby perforating the crural fascia and removing the soft tissue located immediately anterior to the fascia. The opening of the shaver is always pointing toward bone. The shaver is then tilted to remove the soft tissue adjacent to the bone while the arthroscope remains in position. The shaver is retracted. The arthroscope is moved anteriorly. The arthroscope is tilted to enter and view the posterolateral aspect of the subtalar joint.
Fig. 6 Endoscopic images of a left ankle, indicating the different steps to remove a symptomatic os trigonum. A The red circle in the image is identical to the area as indicated in Figure 4.C. The arthroscope is in the posterolateral portal, and the shaver is introduced through the posteromedial portal. The shaver is situated proximal and just lateral to the Rouvière ligament, thereby lifting its insertion onto the top of the os trigonum (OT) (indicated with arrows). Shaving medially will release the Rouvière ligament from the os trigonum. B Endoscopic image of the Rouvière ligament. The ligament runs from the distal part of the fibula to insert onto the top of the os trigonum. The insertion of this ligament needs to be detached and the ligament can be partially removed in order to obtain an overview of the posterior ankle compartment. C The blue circle indicates the attachment of the Rouvière ligament and is a copy of B. The schematic transparent white cover indicates the crural fascia, which is an extension of the Rouvière ligament. It needs to be detached and partially removed to obtain the view seen in D. D After removal of the Rouvière ligament and crural fascia, the os trigonum (OT) and flexor hallucis longus (FHL) tendon can be recognized. On the medial side, the flexor retinaculum (FR) is attached to the os trigonum. On the medial distal side, the posterior talocalcaneal ligament (PTCL) is attached to the os trigonum and, on the lateral side, the posterior talofibular ligament (PTFL) runs between the os trigonum and the fibula. Proximal to the posterior talofibular ligament, at the level of the ankle joint, the tibial slip and the deep portion of the posterior tibiofibular ligament (transverse ligament) are identified. E Removal of the os trigonum (OT) requires a (partial) detachment of the posterior talofibular ligament (PTFL), the flexor retinaculum (FR), and the posterior talocalcaneal ligament (PTCL), respectively. The level for each incision is indicated. F The first step in os trigonum (OT) removal is the partial detachment of the posterior talofibular ligament (PTFL) with an arthroscopic punch. G Subsequently the flexor retinaculum (FR) and posterior talocalcaneal ligament (PTCL) are released with the arthroscopic punch. H The os trigonum (OT) as seen after release of the retinaculum of the flexor hallucis longus (FHL) tendon and the posterior talocalcaneal ligament, and partial detachment of the posterior talofibular ligament. I Detachment of the os trigonum from the talus with use of a 4-mm periosteal elevator. J View after removal of the os trigonum.
Critical concepts

Indications
The indications can be categorized according to their anatomical orientation.

Articular

• Osseous pathology includes loose bodies, ossicles, posttraumatic calcifications, avulsion fragments, and osteophytes. The osteophytes can be located either at the posterior tibial rim or at the level of the subtalar joint.

• Cartilage pathology includes chondromatosis; posterior talar, tibial, or calcaneal osteochondral defects; degenerative joint changes such as talar cystic lesions; bone spurs; and intraosseous talar ganglia.

• Soft-tissue pathology includes posttraumatic synovitis, villonodular synovitis, and syndesmotic soft-tissue impingement.

Periarticular

• Posterior ankle impingement (osseous and/or soft-tissue impingement). Osseous impingement includes a hypertrophic posterior talar process, an os trigonum, or a talus bipartita. Soft-tissue impingement includes a partial rupture or fibrosis of the posterior talofibular ligament, the intermalleolar ligament, or the deep portion of the posterior tibiofibular ligament.

• Avulsion fragments (Cedell fracture) and posttraumatic calcifications or ossicles in the deep portion of the deltoid ligament.

• Flexor hallucis longus tendinopathy.

• Recurrent peroneal tendon dislocation.

Procedures include removal of osseous and/or soft-tissue impediments, synovectomy, debridement of an osteochondral defect,
retrograde drilling of large cystic lesions, arthroscopically assisted arthrodesis, and groove deepening for the treatment of recurrent peroneal tendon dislocation.

**Contraindications**
- The absolute contraindication is a localized soft-tissue infection.
- Relative contraindications are severe edema, vascular diseases (including diabetic vascular disease), and moderate degenerative joint disease.

**Pitfalls**
- Correct portal placement is important in order to prevent neurovascular complications. The posteromedial and posterolateral portals must be positioned 5 mm anterior to the Achilles tendon, just proximal to the level of the tip of the lateral malleolus.
- For the correct orientation and reproducibility, the procedure is begun with the arthroscope in the posterolateral portal. Initially, it is directed toward the first web space. Instruments introduced through the posteromedial portal are inserted perpendicular to the arthroscopic shaft. The shaft is subsequently used as a guide to direct the instruments anteriorly.
- In the hindfoot, the crural fascia can be quite thick. This local thickening is called the ligament of Rouvière. It needs to be at least partially excised or sectioned, with use of an arthroscopic punch or scissors, to approach the ankle joint.
- The flexor hallucis longus tendon must always be located before addressing the pathology. Medial to this tendon, the tibial nerve and
the posterior tibial artery are situated. The working area is therefore lateral to the flexor hallucis longus tendon.

- The direction of the arthroscopic view (30° angulation) is routinely to the lateral side to provide a reproducible orientation throughout the procedure.
- Posterior ankle arthroscopy is an advanced endoscopic procedure; surgeons not familiar with endoscopic surgery are advised to practice in a cadaver setting.\textsuperscript{9}

**Author update**
Since our original paper was published, no substantial changes have been made in the surgical technique.

**References**
9. Amsterdam Foot and Ankle Platform. 
A 3-Portal Endoscopic Groove Deepening Technique for Recurrent Peroneal Tendon Dislocation

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Tech Foot Ankle Surg 2008;7(4):250–256
Abstract
We describe a 3-portal endoscopic technique for the treatment of recurrent peroneal tendon dislocation. This new endoscopic approach is based on the 2-portal endoscopic hindfoot technique, as has been described in the literature before. By adding an additional third portal, 4 cm proximal to the posterolateral portal, the peroneal tendons can be safely assessed, and subsequently, the fibular groove can be deepened. We describe a patient with chronic peroneal tendon dislocation. The patient was successfully treated by means of this groove deepening technique with excellent results, both on functional improvement and pain relief, without complications. This endoscopic technique seems to be a good and safe alternative to the present open surgical procedures for treatment of chronic peroneal tendon dislocation.
Historical perspective
Active sports activity can lead to sports-related injuries, for instance, peroneal tendon instability and or dislocation. In 1803, Monteggi\(^1\) was the first to describe peroneal instability in a ballet dancer. The cause of dislocation of the peroneal tendons can roughly be classified as superior peroneal retinaculum (SPR) attenuation or rupturing\(^2-6\) with or without a (congenital) inadequate fibular groove.\(^7\) This inadequacy is often related to a flat or convex shaped groove.\(^8,9\) It can also be explained through the cartilaginous rim, located in the lateral border of the peroneal groove. This rim adds to the overall depth of the fibular groove (Fig. 5). In case this rim is not present or is flat, the peroneal tendons are more likely to dislocate.\(^10\) Acute peroneal tendon dislocation can occur when the ankle is in a dorsiflexed position with the peroneal muscles strongly contracted.\(^11\) In the chronic situation, the patient typically complains of a snapping or popping sensation over the lateral aspect of their ankle, with, in some cases, a sensation of instability.

Treatment options for recurrent peroneal tendon dislocation include nonoperative management, open surgical procedures, or minimally invasive surgery. The results of chronic peroneal subluxation treated by nonoperative means are unpredictable and associated with a high incidence of redislocations. Most surgeons therefore advocate operative treatment.\(^9,12-18\) Endoscopic surgery favors open surgery because it offers the advantage of shortened hospital stay, rapid rehabilitation, lack of disfiguring scar, and reduced costs.\(^19\) In 2000, a 2-portal hindfoot approach was introduced.\(^20\) This endoscopic approach has been demonstrated to be reliable and
safe.\textsuperscript{21,22} Based on the 2-portal hindfoot approach,\textsuperscript{20} we describe a 3-portal endoscopic hindfoot approach for treatment of recurrent peroneal tendon dislocation.

**Indications/ contraindications**
The indication for endoscopic treatment is recurrent peroneal tendon dislocation with pain and dysfunction not responding to conservative treatment.

**Operative technique**
The endoscopic operation is carried out as an outpatient procedure under general or spinal anesthesia. The patient is positioned in the prone position with a tourniquet applied around the upper leg, pressured at 300 mm Hg. The ankle is slightly elevated by a small support, making free ankle movements possible. For irrigation, we use saline, flow obtained by gravity.

At the start of the procedure, standard posterolateral and posteromedial hindfoot portals are made. A 30-degree 4.0-mm arthroscope is introduced through the posterolateral portal while introducing a punch through the posteromedial portal. By opening the crural fascia (Fig. 1), the extraarticular posterior ankle structures are visualized. These include the posterolateral area of the subtalar joint, posterior talofibular ligament, and the posterior talar process (Fig. 2). Also, the flexor hallucis longus tendon, the syndesmotic posterior ligaments (superficial and deep component), the intermalleolar ligament, and the level of the ankle joint can be inspected, in case one suspects pathology of these structures. With the arthroscope at the level of the lateral part of the subtalar joint, looking 30 degrees to the
lateral side, the peroneal tendon sheath can be identified. The peroneal tendon sheath could now be opened using the punch (Fig. 3A). The tendon sheath can subsequently be bluntly released with a hook, exchanged through the posteromedial portal for the punch (Fig. 3B), and the peroneal tendons can be inspected (Fig. 4). When introducing the arthroscope inside the tendon sheath, a peroneal tendoscopy can be performed. The tendons can be inspected proximally 8 to 10 cm from the tip of the lateral malleolus, distally up to the level of the os peroneum.

The arthroscope is now removed from the posterolateral portal and is subsequently introduced through the posteromedial portal. The hook is introduced through the posterolateral portal. The hook is used to dislocate the peroneal tendons lateral and anterior over the lateral edge of the lateral malleolus, thus leaving the fibular groove empty (Fig. 5). One could consider introducing 2 hooks through the posterolateral portal to dislocate the peroneal tendons, if an insufficient amount of the fibular groove can be visualized.

Subsequently, 4 cm proximal to the posterolateral ankle portal, a vertical stab incision is made. The subcutaneous tissue is split, with a mosquito clamp, until it is positioned into the fibular groove (Fig. 6). Then a 5.5-mm full radius bonecutter shaver is introduced, pointing inferiorly down to the level of the most distal part of the fibular bony groove (Fig. 7). Subsequently, under direct arthroscopic view, the fibular groove can be deepened (Fig. 8). Because the outer diameter of this shaver is 5.5 mm, the width and depth of the groove can be judged. We aimed at a width of 6 to 7 mm and a depth of 5 mm. After deepening and widening the groove, the potential sharp edges are
smoothed (Fig. 9). The shaver is retracted, and the peroneal tendons are positioned back into their newly created fibular groove. By manipulating the foot, the stability of the peroneal tendons is checked under direct arthroscopic examination.

To verify its reproducibility, the procedure was first performed in 5 cadaveric ankles, which were subsequently dissected. In all 5 ankles, no iatrogenic damage to the posterior neurovascular bundle or to the sural nerve and small sapheneous vein was noted. The posterior syndesmotic ligaments, the posterior talofibular ligament and the calcaneofibular ligament remained intact (Fig. 10). The peroneal tendons had a nice fit into the deepened groove in all specimens. There were no fractures of the lateral ridge of the peroneal groove. The average width of the groove was 6.7 mm (range, 5.6-7.3 mm), and the average depth was 5.3 mm (range, 4.8-6.1 mm). Since then, we used this method as a treatment for patients with recurrent peroneal

Fig. 1 Endoscopic image of a right ankle with a mosquito clamp (1) in the posteromedial portal. The crural (sural) fascia (2) can be opened to subsequently visualize the posterior extra-articular ankle area.
Fig. 2 Arthroscopic image of the right ankle after having passed the crural fascia and having removed the posterior ankle and subtalar joint capsule. The subtalar joint (1), posterior talofibular ligament (2), and the level of the ankle joint (3) can now be inspected.

Fig. 3 Arthroscopic image of a right ankle with the 30-degree 4.0-mm arthroscope in the posterolateral portal, at the level of the lateral subtalar joint (1), looking laterally. A, The peroneal tendon sheath (4) can be opened using a punch (3), as introduced through the posteromedial portal (2, posterior talofibular ligament). B, The peroneal tendon sheath (4) is bluntly released with a hook (3); the peroneal tendons come in view (5) (2, posterior talofibular ligament).
Complications
Assessment of the posterior ankle compartment, through the posterolateral and medial portal, can be hindered by a quite thick crural fascia. This part of the fascia has been described by Rouvie`re and Canela Lazaro. Immediately anterior of this specialized part of the crural fascia, a fatty tissue pad is situated that covers the pericapsular structures. It should be remembered to open this fascia
sufficiently to be able to enter and subsequently remove this fatty
tissue to visualize the posterior capsule of the ankle joint and the
posterior ankle ligaments that stabilize the ankle mortise. The most
important landmark on the medial side is the flexor hallucis longus
tendon. Stay lateral to this tendon because, just medially, the
neurovascular bundle is situated.
Be cautious while deepening the fibular groove with respect to the
ligamentous structures. Medially from the groove, the posterior
syndesmotic ligaments and the posterior talofibular ligament are
located. Follow the contour of the groove from proximal to distal. The
calcaneofibular ligament inserts more anterior in the most distal part
of the lateral malleolus. When shaving the groove distally and
anteriorly, aim the shaver medial from the calcaneofibular ligament
insertion.
The depth of the fibular groove needs to be sufficient to prevent
redislocation of the peroneal tendons. Take away up to 5 mm of bone.
At the end of the procedure, check whether sufficient bone is excised
by manipulating the ankle. Removing too much fibular bone could
induce weakening, which could eventually result in a fracture of the
remaining lateral rim. It is important to smooth the created lateral
edge of the groove to prevent possible peroneal tendon (length)
ruptures.
Fig. 6 Arthroscopic image of a right ankle with arthroscope in the posteromedial portal. The peroneal tendons are dislocated over the lateral malleolus with the hook (3), as is introduced through the posterolateral portal. A mosquito clamp (4) is introduced through the posterolateral-superior portal until it lies in the fibular peroneal groove (1) (2, peroneus longus tendon; 5, synovial tissue).

Fig. 7 Macroscopic surgical image of a right ankle. The arthroscope is in the posteromedial portal with the hook in the posterolateral portal (1). A third portal is created 4 cm proximally of the posterolateral portal. A fullradius bone cutter shaver is introduced through this posterolateral-superior portal (2), pointing inferiorly.
Fig. 8 Arthroscopic image of a right ankle with the arthroscope in the posteromedial portal. The peroneal tendons are dislocated over the lateral malleolus with the hook. The fibular groove (1) can be deepened with the full-radius bone cutter shaver (2), as is introduced through the posterolateral-superior portal.

**Results**
A 29-year-old man presented with giving way mainly when walking on uneven grounds, pain, and a recurrent snap of his left ankle. This complain started 1 year ago after a fall during roller skating. He was not able to perform any sports activities. Because of this inability to perform sports, he gained approximately 10 kg. Wearing high-back shoes minimally decreased his symptoms. Physiotherapy and plaster immobilization did not resolve the problem.

On physical examination, both feet revealed a pes cavovarus deformity. There was recognizable tenderness over the peroneal retinaculum. Active eversion against resistance in a slight dorsiflexed position caused the peroneal tendons to dislocate over the lateral malleolus. The anterior drawer test was negative, although the left ankle showed a mild laxity as compared to the right ankle. Routine radiographs showed no abnormalities.
Preoperative American Orthopaedic Foot and Ankle Society (AOFAS) score was 59. The preoperative visual analog score (VAS) for pain and dysfunction was 4 and 8, respectively (analog scale from 0 to 10, 10 representing most severe pain or dysfunction). The patient was diagnosed with chronic peroneal tendon subluxation of his left ankle and was treated surgically, in an outpatient setting, by means of the 3-portal endoscopic approach as described before. The endoscopic procedure took 35 minutes. The patient was stimulated to perform active maximal plantarflexion and dorsiflexion exercises, and weight bearing was allowed, as tolerated, starting a few hours after the surgery. A soft brace was applied 5 days after surgery. On follow-up 2 weeks after the operation, the patient was able to fully bear weight on the operated ankle without pain. On follow-up 4 weeks after the operation, the patient had no pain at all. He was seen for follow-up 6 and 12 months postoperatively. The AOFAS score was 95, and the VAS for pain and dysfunction was 0 and 1, respectively, at both follow-up intervals. He was able to return to his former normal level of activity 7 weeks after surgery. The tendons had not subluxated, and he was able to perform roller skating again 4 months postoperatively. At 1-year follow-up, he had gained his former weight (weight loss of 10 kg).
Fig. 9 Arthroscopic image of a right ankle indicating the deepened fibular peroneal groove (1) with the remaining cartilaginous rim (2). The calcaneofibular ligament is also indicated (3).

Fig. 10 Macroscopic anatomical image of a right cadaveric ankle. The instruments, as used for this procedure, are inserted in the dissected ankle. Their relation to the posterior syndesmotic ligament complex, the posterior talofibular ligament, and the calcaneofibular ligament is assessed for possible iatrogenic damage.
Discussion
Surgical treatment for recurrent peroneal tendon dislocation comprises basically 5 different categories: bone block procedures, tissue transfer procedures, rerouting procedures, anatomical reattachment of the retinaculum, and groove deepening procedures.25 No consensus is presently available concerning the best surgical procedure. Available literature on each of these procedures is based on small case series.26 Rehabilitation time could be prolonged in open surgical procedures for their invasive character, as compared with minimal invasive endoscopic techniques. In our clinic, we have a good experience with the groove deepening technique for chronic peroneal tendon dislocation, as described by Kelly in 1920.27 This procedure is technically demanding and requires 6-week plaster immobilization. An endoscopic operative technique shortens the recovery time and is followed by functional after-treatment with better cosmetic results.28 Recently, an endoscopic peroneal retinaculum reconstruction for the management of peroneal tendon instability was introduced. This minimal invasive technique restricts the surgeon to treat the different causes of peroneal tendon dislocation because it only allows treatment of grade 1 and 2 peroneal retinaculum tears.28 Moreover, it is technically demanding. A minimal invasive groove deepening procedure by means of a peroneal tendoscopy was recently reported. This tendoscopic approach allows the surgeon to deepen the fibular groove, but the drawback is the restricted working area. The groove has to be deepened while the peroneal tendons remain in their fibular groove. This procedure therefore runs the risk of iatrogenic damage to the peroneal tendons.
Another drawback is the difficulty of determining the depth and width of the groove.\textsuperscript{29}

In open surgical groove deepening procedures, an additional reefing of the SPR is usually performed. Reefing is performed because the retinaculum has to be detached to reach the fibular groove. It is, however, unknown whether reefing is really needed and whether solely groove deepening would be sufficient. Endoscopic suturing the SPR would be an additional step in the operation, increasing the difficulty, which could consequently induce complication rates, as for instance, sural nerve entrapment. We feel that a deepened groove in itself is sufficient to prevent dislocation of the tendons. Even in case of retinaculum laxity, the tendons will remain in their groove when this groove has a sufficient depth. This idea was already proved and surgically accepted for over years by the treatment, as described by Kelly in 1920.\textsuperscript{27}

In case peroneal tendon ruptures are identified preoperatively, our current practice is not to suture them. Peroneal tendon (length) ruptures will flatten the tendon when tensioned at the level of the flat distal fibula. Reconstruction of the semitubular shape of the fibular groove prevents the ruptured tendon to widen and spread out. Also, the tendons will obtain a shorter path until their final insertion, and they become compressed into their newly deepened groove. These changed biomechanical properties may prevent symptoms to occur, resulting from peroneal tendon tears. In case of persisting symptoms, consider secondary arthroscopic or open surgery to repair the tendons.
We describe a 3-portal safe endoscopic technique, with excellent results, both in function and pain without recurrence of the dislocation in one patient. This technique favors the other described minimal invasive approaches for its possibility to treat the different causes of peroneal tendon dislocation with good overview of the tendons in relation to their surrounding anatomical structures. Possible additional posterior ankle pathology can additionally be accessed.

For a surgeon familiar with the endoscopic 2-portal hindfoot approach, this endoscopic treatment option will not pose a big challenge. More patients and longer follow-up are required to definitely conclude on the effectiveness of this endoscopic technique, but it is likely to be a good and safe alternative to the present open surgical procedures.

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Midterm results of posterior arthroscopic ankle fusion

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**Abstract**

The presented study was performed to evaluate the midterm clinical and radiological results and complication rates of the first 40 patients with an ankle fusion through a posterior arthroscopic approach. Forty consecutive patients with end-stage posttraumatic ankle osteoarthritis were treated with posterior arthroscopic ankle fusion. All patients were assessed clinically as well as radiologically with a minimum follow-up of 2 years. The Foot and Ankle Ability Measure (FAAM) and Foot Function Index (FFI) were used to assess clinical improvement.

Clinical fusion was achieved in 40 patients within 3 months (100%), and radiological fusion was achieved in 40 patients at 12 months. Two screw mal-placements occurred. Both complications were solved following revision surgery. A significant improvement was noted for both the FAAM [median 38 (range 17–56) to 63 (range 9–84)]. The posterior arthroscopic ankle fusion is an effective and safe treatment option for end-stage post-traumatic ankle osteoarthritis at midterm follow-up.
Introduction
Several methods have been described for fusion of the ankle joint. Secure fusion can be accomplished arthroscopically, by open surgery or by using a so-called mini-open technique.\textsuperscript{5, 9, 17–19} An open procedure might allow for a better correction of mal-alignment of the hindfoot, when significant deformity is present. However, recent evidence supports the use of arthroscopic techniques for more markedly deformed ankles as well.\textsuperscript{6} Arthroscopy assisted fusion is becoming more popular with equivalent high union rates, but lower complications, as compared to open surgery.\textsuperscript{5, 19, 21} The posterior ankle arthroscopic technique, also known as hindfoot endoscopy, is safe and reliable.\textsuperscript{7, 10} A posterior arthroscopic approach allows for two important biomechanical advantages: enhanced primary stability can be achieved through contour-shaped cuts, and optimal compression can be applied through parallel screw positioning.\textsuperscript{10, 13, 15, 25} Prior to commencing the presented technique in our patients, an anatomical study was performed to evaluate its safety and efficiency.\textsuperscript{10} The purpose of this prospective cohort study was to assess the midterm results of the first 40 ankle fusions in which the posterior ankle arthroscopic surgical technique was used.\textsuperscript{11}

Material and methods
Between 2010 and 2013, a consecutive series of 40 ankles in 40 patients were treated with posterior arthroscopic ankle fusion. All surgeries were performed by a single surgeon (GK). The inclusion criteria were patients with end-stage post-traumatic ankle osteoarthritis refractory to conservative treatment options. Exclusion
criteria were revision fusion surgery, failed ankle prosthesis or double fusions.
Preoperative data consisted of a common clinical evaluation (history and physical examination) and plain radiographs in orthogonal planes (Fig. 1). In addition validated subjective outcome instruments, such as the Foot and Ankle Ability Measure (FAAM) and a Foot Function Index (FFI), were obtained.²,⁴,¹⁶

*Surgical technique*

The standard two-portal technique for hindfoot arthroscopy was used.²³,²⁴ Routine instruments for debridement of the ankle joint consisted of a 5.5-mm platinum Dyonics Bonecutter shaver blade (Smith&Nephew®), small curette and a 5.0-mm chisel. In selected cases, when a “bowlerhat”-shaped talus was present an accessory anteromedial portal was used for debridement of the anterior rim of the talus.¹¹ The technique allows for debridement of >95 % of the ankle joint.¹⁰ Following debridement of the ankle joint a limited transAchilles tendon approach was used for insertion of two parallel orientated non-cannulated 6.5-mm partially threaded cancellous compression screws. This approach was preferred over the posteromedial or lateral ankle approach due to the good working area with the ability to nicely orientate the screws. Screw insertion was performed under fluoroscopic guidance.
Post-operative rehabilitation
Patients were kept in a non-weight-bearing cast for 6 weeks.
Following clinical and radiological assessment, a weight-bearing cast (or walker) was applied for another 6 weeks. Once a solid fusion was obtained, the patient was allowed to wear regular shoes and could resume activities as tolerated.

Clinical and radiological evaluation
The follow-up protocol demanded regular visits at 2, 6, 12 and 52 weeks post-operatively. Additionally, 2 years following surgery an evaluation of all patients included abilities to sport and physical functioning, the FAAM score and a FFI score.2,16
The FAAM comprises the separately scored 21-item ADL and eight-item sports subscales. Each item is scored on a five-point Likert scale anchored by 4 (no difficulty at all) and 0 (unable to do). Item score totals, which range from 0 to 84 for the ADL subscale and from 0 to 32 for the sports subscale, are transformed to percentage scores. A higher score represents a higher level of function for each subscale.
[16]. The FFI consists of 23 items grouped in three subscales (limitation in activity, disability and pain). Visual analogue scales are used for each item. The subscale scores are averaged together to obtain a total mean score. A lower FFI score represents a higher level of function.

Radiographs were obtained immediately post-operative and at the regular controls (6, 12 and at 52 weeks postsurgery). A standard anterior-to-posterior and lateral X-ray of the ankle without a cast was obtained to assess fusion. Clinical union was based on lack of ankle motion and full weight bearing without pain, whereas radiological union was defined as bridging trabeculae in two radiographic planes.

Institutional review board approval from the University of Amsterdam, the Netherlands, for the prospective inclusion of the patients was obtained under registration number W14_237

Fig. 2 Radiographs in the anterior-to-posterior and lateral direction at 2 weeks following posterior arthroscopic ankle fusion with the two screws in an orientation from posterolateral to anteromedial over the ankle joint.
Statistical analysis
Statistical analysis was performed using SPSS 23 for Mac (SPSS Inc, Chicago, Illinois). Single \( t \) test for repeated measures was used. Significance levels of \( p < 0.05 \) were used throughout this study. Additionally, post hoc power analysis was performed.

Results
The median follow-up on 40 patients was 42 months, with a range of 24–66 months. The study population consisted of 24 males (60 %) and 16 females (40 %). The median age was 53 years old (range 21–80). The median operation time was 93 min (range 63–121). All surgeries were performed in the hospital with a single overnight stay. At 3 months post-operatively, 40 patients (100 %) were fused on clinical evaluation, whereas radiological union was achieved at 12 months post-operatively in all 40 patients (Figs. 2, 3). Two patients (5 %) needed secondary surgery. The reasons for secondary surgery were screw malplacements; however, these patients both united within 3 months of the index surgery. There were no post-operative infections or transient or permanent neurovascular injuries.
Return to sports
Prior to suffering from ankle OA, the majority of the treated patients were active in some fields of sports. Recreational sports (golf, swimming, hiking) were most commonly performed by 48% of the subjects. Fourteen per cent were active in endurance sports (running, biking). Twenty per cent was performing contact sports (soccer, hockey, martial arts). At the time our population suffered from end-stage OA of the ankle, 59% were unable to participate in any sports activity. A substantial group of 41% remained active, however, in recreational sports. No subject was able to perform endurance or contact sports after the ankle fusion surgery.
Two years following surgery, a shift in sportive capabilities was seen. Still 37% was not sportively active. Fifty per cent performed recreational sports. Thirteen percent had (actively) joined a fitness programme (Table 1).
**Patient-reported outcome measures**
Self-reported outcome measures were taken prior and at 2 years following surgery. For this purpose the Foot and Ankle Ability Measure and FFI were used.\(^2\)\(^,\)\(^26\) (Table 2).

The FAAM ADL and sports subscales were scored separately. The values for ADL increased from a median of 38 (range 17–56) to 63 (range 9–84). This increase is statistically significant ($p < 0.05$), with a power of 99%.

The FFI decreased from 66 (range 31–89) to 32 (range 11–98). This decrease is statistically significant ($p < 0.05$), also with a power of 99%.

<table>
<thead>
<tr>
<th></th>
<th>No sports (%)</th>
<th>Recreational Sports (%)</th>
<th>Endurance Sports (%)</th>
<th>Contact Sports (%)</th>
<th>Fitness (%)</th>
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<td>19</td>
<td>48</td>
<td>14</td>
<td>19</td>
<td>0</td>
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<tr>
<td>End-stage OA</td>
<td>59</td>
<td>51</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Two-year follow-up</td>
<td>37</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 1 Sports behaviour.

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Range</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAAM baseline</td>
<td>38</td>
<td>(17-56)</td>
<td></td>
</tr>
<tr>
<td>FAAM 2 year</td>
<td>63</td>
<td>(9-84)</td>
<td>&lt;0.05</td>
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<tr>
<td>FAAM sport baseline</td>
<td>2</td>
<td>(0-9)</td>
<td></td>
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<tr>
<td>FAAM sport 2 year</td>
<td>4</td>
<td>(0-20)</td>
<td>&lt;0.05</td>
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<tr>
<td>FAAM total baseline</td>
<td>42</td>
<td>(17-63)</td>
<td></td>
</tr>
<tr>
<td>FAAM total 2 year</td>
<td>71</td>
<td>(9-96)</td>
<td>&lt;0.05</td>
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<tr>
<td>FFI baseline</td>
<td>66</td>
<td>(31-89)</td>
<td></td>
</tr>
<tr>
<td>FFI 2 year</td>
<td>32</td>
<td>(11-98)</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Table 2 Outcomes of self-reported questionnaires.
**Discussion**
The main finding of this study is that an ankle fusion through a posterior arthroscopic approach is an effective and safe technique to treat end-stage post-traumatic ankle OA with an union rate of 100 % in the first 40 cases. Two (5 %) complications were encountered. Patient-reported outcome measures improved significantly after surgery. Arthroscopic ankle fusion is an established treatment option for end-stage ankle OA resulting in equivalent union rate, lower complication rate and shorter hospital stay, as compared to open-ankle fusions.\textsuperscript{1,20,22} The most reported arthroscopic techniques to fuse the ankle joint use anterior portals.\textsuperscript{3,12,27} However, in most posttraumatic (and instability-induced) osteoarthritic ankles, the anterior part of the joint has the least remaining cartilage, the worst soft tissues after earlier surgeries and therefore presents less proper accessibility to the ankle joint in some cases and higher chance of wound problems and subsequent infections. Additionally, through an anterior approach, the posterior part of the ankle joint is less accessible. Although the most posterior part of the talar surface might not be of utmost importance to achieve a solid fusion, we feel that the posterior part of the tibial plafond do is very important in obtaining union. With the posterior approach, we are able to debride this part meticulously, and with the direction of the compression forces from the two screws, the talar surface is pooled circular into this posterior part of the distal tibial plafond, allowing early fusion over a large posterior surface area. We consider a posterior approach, therefore, a more suitable technique allowing good access, enabling more accurate compression on the joint surfaces and probably also a more proper removal of the remaining cartilage. Recently,
Malekpour et al. performed an anatomical study in 10 specimens to assess the effectiveness of posterior arthroscopy for debridement of the ankle joint.\textsuperscript{14} In all specimens complete debridement of the tibia plafond was noted. On the talar side about 80 \% could be addressed. The anterior one-third of the talar dome was hard to reach. Prior to the current clinical study, we conducted an anatomical study as well. With the described technique, we were able to debride 96 \% of the articular surface of the entire ankle joint.\textsuperscript{10}

The overall non-union rates after anterior arthroscopic assisted ankle fusions are 8.6 \%.\textsuperscript{1} The union rates in the presented study compare favourably to these. To achieve a bony fusion, both an adequate debridement and compression is needed. The presented technique addresses both of these principles, and possibly therefore, the presented union rates were achieved. However, we are the first to realize that this percentage will be lower with an increase in the patient number.

In two cases an early revision surgery was indicated; the screw malplacements were in the first 10 operated patients. These complications might be marked as part of the learning curve, and in the first operated patients, screw length was maximized up to the subcortical talocalcaneal joint border to assure for optimal compression. In the consecutive patients, diminished screw lengths were used which apparently did not result in diminished union rates.

The Foot and Ankle Ability Measure (FAAM) showed significant increase for ADL and sportive activity in our patients after 2-year follow-up. However, only improvement in the ADL subscale can be considered clinical relevant according to the instructions for use of the
FAAM scoring system. Following fusion a significant improvement in the Foot Function Index (FFI) was noted. These findings are similar to the current literature.

References

General discussion
Nowadays numerous ankle pathologies can be surgically treated through a minimally invasive technique in which the arthroscope is the leading device. This instrument enables the surgeon to assess the pathology through a small skin incision, i.e. portal. The main advantage of the arthroscope is its ability to magnify the pathology and its relation to the surrounding anatomy. Through an additional portal the pathology can then actually be addressed and treated. The theoretical advantage of this type of surgery is that only small (stab) incisions are required resulting in minimal scars and potentially a quicker recovery, as compared to open surgical approaches. In relation to several ankle pathologies there is evidence that arthroscopy has favourable results compared to open surgery with respect to less morbidity.1-5 The drawback of operating through small holes is that the anatomy outside the view of the arthroscope cannot be seen. The surgeon therefore should have a high knowledge of the anatomy around and at the level of the portals in order to prevent iatrogenic damage.6 Chapter 2 describes and explains both the anterior- and posterior ankle arthroscopic techniques including their specific potential pitfalls. Also numerous ankle disorders suitable for arthroscopy are highlighted.

**Anterior ankle arthroscopy**

Using minimally invasive ankle surgery to reduce the perioperative risk for our patients requires several important considerations. First of all the location of the portal itself is of great importance in relation to the prevention of surgery related complications. Ideally the portal provides excellent access to the joint, is reproducible and does not
interfere with the important anatomical structures. In anterior ankle arthroscopy the anteromedial and anterolateral portals are believed to adhere to these principles and are therefore regarded as being the routine portals for anteriorly located ankle pathology. The anteromedial portal is regarded safe, if created just medial to the anterior tibial tendon at the level of the anterior ankle joint. This medial location with respect to the anterior tibial tendon prevents potential damage to the anterior neurovascular bundle during the introduction of an (arthroscopic) instrument. The surgeon should however be aware that the saphenous nerve and great saphenous vein could potentially be injured, being the closest neurovascular structures in relation to this portal. The other routine portal in anterior ankle arthroscopy is the anterolateral portal. This portal actually does not adhere to the overall principle of a safe location. Iatrogenic damage to the superficial peroneal nerve is the most frequently reported complication in relation to the anterolateral portal placement in anterior ankle arthroscopy. The unique feature of this nerve is that it can be identified clinically through the patient's skin. Chapter 5 reveals that in 57% of the patients the superficial peroneal nerve can be identified by palpating the anterolateral skin while maximally passive ankle plantarflexion and inversion is provided. Increasing body mass index negatively influences the possibility to identify the nerve. It is advised to mark its location on the skin prior to the skin incision. Chapter 6 emphasizes the potential pitfall in marking the nerve once identified. The marked location could be false if the position of the ankle changes. In maximal plantarflexion and inversion
the superficial peroneal nerve is fully tensioned forcing it to move under the skin in a medial direction. The anterolateral portal should therefore preferably be made just medial to the marking, thereby the nerve will be safe in any of the foot and ankle positions needed during anterior ankle arthroscopy. Transillumination is another potential trick to identify the superficial peroneal nerve. The arthroscope inserted through the anteromedial portal is pushed against the skin at the lateral side of the ankle and occasionally the nerve can subsequently be identified. A recent publication by Harnroongroj and Chuckpaiwong however reported that in none of the 53 patients where the superficial peroneal nerve was identified by plantar flexion, inversion and 4th flexion, the nerve could be visualized by transillumination. It was concluded that transillumination has no added value. Interestingly the observed superficial peroneal nerve visibility by the described identification technique was nearly 43%, which is identical to our findings (Chapter 5).

Secondly, the technique to create the arthroscopic ankle portals and the way to introduce the surgical instruments are important. These techniques include a vertical skin incision, in order to be in line with the underlying anatomical structures. The incision through the skin only is followed by a blunt dissection down into the joint. The surgical instruments should preferably be blunt, and the ankle joint should manually be forced into dorsiflexion, thereby preventing potential iatrogenic cartilage damage by the inserted instruments. Finally the awareness and knowledge of the superficial anatomy is essential when the portal is sutured at the end of the procedure. Superficial anatomical structures, such as the superficial peroneal
nerve, orientated in close proximity of the anterolateral portal, can easily become entrapped in the suture.\textsuperscript{15} Besides the location of the portal itself, the technique how to make a portal and safely introduce the instruments, also the ankle arthroscopic technique is important in the prevention of iatrogenic events. Either continuous ankle distraction or the ankle dorsiflexion technique are used to arthroscopically gain access to the anterior ankle pathology. In the continuous distraction technique, the ankle is strapped and connected to a device to provide distraction throughout the procedure.\textsuperscript{22} With the dorsiflexion technique the surgeon pushes with his or her tummy against the patient’ foot sole, thereby bringing the ankle in dorsiflexion.\textsuperscript{23} In both techniques the surgeon’ hands are free to perform the surgery without the need for an assistant. In order to be able to treat pathology through an anterior ankle arthroscopy one should gain access by entering the anterior joint capsule. Once within the capsule, pathology can be addressed. The amount of space within this joint capsule determines the working area. Ankle distraction pulls the anterior joint capsule tight towards the joint, thereby decreasing the working area whereas in ankle dorsiflexion the joint capsule is not tensioned and actually moves away from the joint, thereby creating a working area. Furthermore the anterior neurovascular bundle (anterior tibial artery/deep peroneal nerve) is closer to the joint and therefore more prone to iatrogenic damage in continuous distraction, as compared to ankle dorsiflexion, as specified in chapter 4.\textsuperscript{24} Another advantage of the dorsiflexion technique over the continuous distraction technique, is that in ankle dorsiflexion the extra-articular anatomical structures are not under tension, providing
the structures with the ability to move away in case surgical instruments contact them.\textsuperscript{25} When using the dorsiflexion technique and joint distraction is needed, as for instance in case of intraarticular ankle pathology like an osteochondral defect, this can be obtained intermittently with a non-invasive soft tissue distractor.\textsuperscript{26} The correct location of the portals, the technique how to make a portal and how to perform anterior ankle arthroscopy theoretically could minimize the chance of causing complications while performing this kind of surgery. There are no scientific papers comparing different portal locations and different arthroscopic technical principles in the light of complication rates. However it is questionable if such a study can be performed given the unethical considerations. What is known from literature are the complication figures for both the dorsiflexion – and continuous distraction technique. The overall complication rates for the continuous distraction technique is in between 8-17\%\textsuperscript{2-4,11,13,14,27-33}, on average 10.3\%. The reported complication rates for the dorsiflexion technique is 3.4\%.\textsuperscript{15} We conclude that there might be a direct relation between the surgical technique and the complication rates. Whether the concept of portal placement has a direct influence on the neurological complications with respect to the superficial peroneal nerve is unclear. The overall neurological complications rate as reported in literature is 3.7\%\textsuperscript{11-14,22,34-37} For the dorsiflexion technique the neurological complication rate is 1.9\%.\textsuperscript{15} The articles published on the location and anatomical features of the superficial peroneal nerve need to prove themselves in future and hopefully will further reduce iatrogenic superficial peroneal nerve injury figures, as was emphasized on in chapter 5 and 6.\textsuperscript{17,18}
**Hindfoot endoscopy – peroneal tendon instability**

As previously discussed, an ankle arthroscopic portal should provide excellent access to the joint, should be reproducible and should not interfere with the important anatomical structures. The routine anterior ankle arthroscopic portals are not suitable to treat pathology in the posterior ankle compartment. Since 2000, these pathologies can be treated through hindfoot endoscopy, with the use of the posterolateral and posteromedial portal. These portals meet the ideal portal criteria.\(^{38-41}\) A clear trend in literature is the strong growth of hindfoot endoscopy practice since 2009. From the initial description of the technique by van Dijk et al. in 2000\(^{41}\) up to 2009, 41 scientific papers were published in indexed journals. From 2009 onward, when the technique was republished with a step by step visual explanation on how to perform this type of surgery (chapter 7)\(^{42}\), up to present, 167 scientific papers were published on this topic. This popularity might be explained by the published paper in 2009 or otherwise by the clear-cut anatomical paper by Golanó et al. in 2010\(^{43}\), that added to and enhanced the knowledge of the surgical anatomy, chapter 3.

One of the posterior ankle pathologies is peroneal tendon instability. When reviewing literature on the surgical treatment of this pathology, more than 20 surgical techniques have been described for its treatment. These can be subdivided into four main categories; (1) repair or replacement of the superior peroneal retinaculum (SPR)\(^{44-51}\), (2) groove deepening + SPR reattachment\(^{52-55}\), (3) bony procedures\(^ {56,57} \) or (4) rerouting procedures.\(^ {58-60}\)

Since peroneal tendon instability is a relatively rare pathology, it is noteworthy that so many different techniques have been described.
All techniques have reported good to excellent outcomes in up to 90% of the cases. One could argue that if so many different surgical treatment strategies apparently result in good to excellent clinical outcomes, not the specific surgical technique is important but the surgery in itself is the key factor to success. As generally known and accepted, a surgical intervention results in tissue damage, in itself leading to scar tissue formation and increased tissue stiffness. This scar tissue formation might be the reason for the tendons to become stable.

It would be interesting to introduce a minimally invasive technique for treating peroneal tendon instability, based on one of the previously described open techniques. Up to 2008, all publications but two described open surgical techniques. The minimally invasive techniques were a tendoscopic approach to deepen the fibular groove and the other an endoscopic approach to suture the retinaculum. The drawback of these procedures was the limited working area and the limited possibilities to stabilize the peroneal tendons, respectively. Since an endoscopic approach can theoretically be advantageous over an open surgical approach resulting in smaller wounds and a quicker recovery, an endoscopic 3 portal groove deepening technique was developed and introduced. This technique was developed in human cadaveric specimens and was based on the two ‘safe’ hindfoot endoscopic portals with one additional portal. In the specimens no neurovascular compromises were encountered following the dissections. Only the groove was deepened, leaving the retinaculum unaffected, chapter 8. Up to present, results following this endoscopic procedure have not been published yet. It would be
interesting to assess whether groove deepening alone is sufficient for stability of the tendons without suturing and or repairing the retinaculum. Other important outcome measures to assess are the return to sports and the time to return to sports, since this pathology mainly occurs in the athlete population. Future studies should include a prospective multicentre randomized controlled trial, comparing the open surgical groove deepening to the endoscopic one. The unstable peroneal tendons, occasionally also have secondary partial ruptures due to the recurrent dislocations or subluxations. These can be left or be addressed depending on the severity of the rupture and/or local tenosynovitis. As the biomechanical properties of the tendons will change by deepening the groove, partial tendon ruptures may occur being asymptomatic and could potentially be left untreated. Whether this principle is actually true could be subject to future studies. If these partial ruptures should be treated surgically in the same setting, preferably a newly designed technique should be introduced to enable the surgeon to arthroscopically suture the tendon following the groove deepening.

**Ankle joint fusion**
Fusing an ankle joint is a valid treatment option for patients with symptomatic ankle osteoarthritis, unresponsive to conservative treatment. In line with the current trend of minimally invasive orthopaedic surgery, an arthroscopically assisted ankle fusion was firstly published in 1983 by Schneider. Together with the improved, dedicated and specialized arthroscopic instruments in the last decade, arthroscopic ankle fusion has gained popularity, because of the
advantages over open surgery, i.e. a better pain control during the
direct postoperative period\textsuperscript{68}, less morbidity and a faster
rehabilitation with shorter hospital stays\textsuperscript{69} with shorter operation
time\textsuperscript{70}, higher union rates\textsuperscript{71}, as well as reduced costs.\textsuperscript{72} Up to 2014,
arthroscopic techniques to debride and fuse the ankle joint were
performed using an anterior arthroscopic approach.\textsuperscript{73-75} These
techniques are safe and result in a high, but not 100 \% union rate.\textsuperscript{15,76}
Anterior arthroscopically assisted techniques allow visualization of
the ankle joint up to 76\% (±12\%) of the articular surface area. The
posterior 10\% of the joint is not accessible and can thereby not be
visualized with standard instrumentation through the anterior
arthroscopic approaches.\textsuperscript{77} Since the ankle joint fusion with anterior
arthroscopically assisted techniques does not allow for an optimal
joint visualization, it could lead to an suboptimal cartilage
debridement resulting in a potential non- or delayed union. A
posterior arthroscopically assisted technique to fuse the ankle joint
was developed to allow optimal cartilage debridement.\textsuperscript{78} Furthermore
this technique aims to provide enhanced primary stability achieved by
contour shaped cuts and optimal compression being applied through
parallel screw positioning, as compared to the anterior approach. The
posterior arthroscopically assisted technique was at first tested in a
cadaveric setting in which the cartilage on both sides of the ankle joint
was debrided through the standard posterior ankle arthroscopic
portals. As previously discussed, the portals should provide excellent
access to the joint, should be reproducible and should not interfere
with the important anatomical structures. The posterolateral – and
medial portals fit these principles in relation to the arthroscopic
fusion. Following a cadaveric study, the important surrounding anatomical structures were not harmed, and also the vast majority of the cartilage could be debrided (up to 96%). For the ankle joint there are no scientific papers reporting the direct relation between the amount of debrided cartilage and the chance of – and time to fusion. However, for the subtalar joint fusion, Tuijthof et al. published a review in 2010, in which the lack of sufficient cartilage removal is one of the main pitfalls in the achievement of a union. In chapter 9 the midterm results of posterior arthroscopic ankle fusion showed a 100% union in 40 patients with posttraumatic ankle osteoarthritis. These findings could potentially be explained by the optimal joint debridement, thereby improving the biological conditions for bony fusion.

Another reason to introduce the posterior ankle arthroscopic fusion technique is to reduce the infection rates. Off course infection rates not only depend on the surgical approach but also depend on the host, being the patient with or without factors to increase infection rates such as smoking, diabetes etcetera. The posttraumatic ankle osteoarthritis most frequently follows from an (intraarticular) ankle fracture. The initial treatment of the fracture is mostly through an anterior surgical approach. Ongoing disabling symptoms following fracture union will frequently result in hardware removal, compromising the soft tissues for the second time. In case of ongoing disabling symptoms, due to ankle osteoarthritis not responding to conservative treatment options, an ankle fusion can be considered. If an anterior ankle arthroscopic approach is chosen, one should introduce the scope through compromised soft tissues potentially
increasing the chance of infection. Also the arthroscopic visibility following several open surgical procedures could be difficult and at least be reduced, which could inevitably lead to suboptimal joint debridement, potentially leading to other complications as previously discussed. The posterior arthroscopically assisted fusion technique, through non-compromised soft tissue, can potentially lead to a lower chance of infection, as was reported in a published paper on the midterm results of the posterior arthroscopic fusion technique, chapter 9.

**Future perspectives**
Reviewing and comparing current orthopaedic surgical practise in treating ankle pathologies with the orthopaedic practise in the fifties and sixties, reveals that nowadays the orthopaedic surgeon is supplied with more sophisticated tools and materials. Not the brighter surgeon, but innovative tools enables them to perform minimally invasive surgery. Since current evidence favours key hole surgery over open surgery for many ankle pathologies, the orthopaedic future basically lies also in the hands of the engineers to stretch the possibilities to treat ankle pathologies in a minimally invasive way. They will need to be encouraged by the enthusiastic, skilled, innovative and open minded orthopaedic surgeons. One could imagine the portals to perform the arthroscopy to become smaller thereby less harming the anatomy by the introduction of smaller diameter arthroscopes with similar flow capacities. Another interesting feature nowadays is the three dimensional printing models. These could provide the surgeon with individualized patient
specific anatomical details with references to the important anatomical landmarks to be used during the surgery, potentially further reducing complication rates. Also the magnetic resonance imaging techniques are improving which might in future provide us with a marking tool for the ideal, perfectly orientated and safe individualized portal position, depending on the pathology to be addressed.

All doctors swore that they would not harm patients. Ideally patients should be treated conservatively since surgery in itself is a harmful but accepted activity for patients with quality of life diminishing problems. If surgery is the only possibility to obtain acceptable outcomes, it should at least be performed in such a way that the patient is safe. Besides improving minimally invasive surgical techniques, future research should further focus on the prevention of disabling conditions. An example in this respect is the prevention of osteoarthritis. Probably medicine cannot prevent patients from sustaining fractures and if these fractures include the cartilage layers, this will inevitably lead to cartilage damage and increased risks of developing osteoarthritis, the so called secondary (posttraumatic) osteoarthritis. Recent work by Martin et al. revealed interesting pathways in developing posttraumatic osteoarthritis. Interfering in these pathways might be the key answer to prevent osteoarthritis and might cause surgeons to become unnecessary in the treatment of this pathology.\textsuperscript{80}

Finally all surgeons should be optimally trained in surgical procedures prior to performing surgery in patients. Training should primarily focus on the anatomy in the specific human body part to operate on.
Learning and understanding the surgical anatomy will direct the surgeon in performing surgical techniques and will lead to less complications. Residents and surgeons must go through the surgical learning curve in a surgical training centre instead of in patients, thereby reducing complication rates.

**Conclusions**
This thesis has focused on ankle arthroscopy, both the anterior and posterior techniques. In a review, the existing ankle arthroscopic techniques for a wide variety of ankle disorders was added to literature. The cornerstone of surgery is anatomy, more specific surgical anatomy, which was published specifically for the ankle. Anterior ankle arthroscopy should be performed with the ankle dorsiflexion method and not with continuous distraction. In ankle dorsiflexion the working area and safe distance to the neurovascular structures are increased, as compared to the distraction technique. The dorsiflexion method has shown a substantial lower percentage of complications.

We demonstrated that in 57 % of the patients the superficial peroneal nerve can be identified by palpating the anterolateral skin while maximally forced passive ankle plantarflexion and inversion is provided. Marking its course on the skin will provide a false sense of safety since the position of this nerve changes if the position of the ankle changes. By making the anterolateral portal medial to the skin marking, direct iatrogenic superficial peroneal nerve damage can be prevented.
Hindfoot endoscopy is a relatively new minimally invasive technique which was at first difficult to understand and learnt for many surgeons. The step by step visual report aided surgeons to understand and learn this technique, as witnessed by the recent increase of hindfoot endoscopic publications.

A new surgical technique, based on hindfoot endoscopy, was developed to be able to treat recurrent peroneal tendon dislocation in a safe, reliable and minimally invasive manner.

The midterm results of posterior arthroscopically assisted ankle fusion for posttraumatic ankle osteoarthritis showed a 100% fusion rate without infections. These compare favourably over the existing results of minimally invasive techniques to fuse the ankle.

References


Summary

Ankle Arthroscopy under the Scope
Chapter 1 General introduction
The current trend in orthopaedic surgery is to treat patients minimally invasive. Surgically treating patients in a minimally invasive manner is in line with the oath in which all doctors have promised to not harm patients. As surgery in itself is harmful for patients, if needed, it should be performed only with as less damage to the tissues surrounding the pathological condition as possible. By ankle arthroscopy, with an advanced camera system and specifically designed tools through small incisions, most pathologies in and around the ankle joint can be visualized and treated. The surgeon performing this form of surgery should have a detailed knowledge of the surgical anatomy. The anatomy books fail to teach the surgical anatomy. Anatomical structures with significant importance for adequate functioning of the foot may easily be harmed, since these most frequently are not directly identified nor visualized during this form of surgery.
In general anteriorly located pathology can best be treated with anterior ankle arthroscopy, whereas posterior ankle pathology by hindfoot endoscopy. The standard portals in anterior ankle arthroscopy are the anteromedial and anterolateral portals. Most reported complications in literature regarding these portals include iatrogenic damage to the superficial peroneal nerve, which is in close proximity to the anterolateral portal. Since this nerve is the only nerve in the human body that can directly be visualized through the skin, reported complication rates regarding this nerve are difficult to understand. Besides the location of the portals and their potential for damage to the local anatomy, the technique how to perform anterior
ankle arthroscopy is important. It can either be performed with continuous distraction or with ankle dorsiflexion. Which technique is better over the other is a continuous debate in literature. Hindfoot endoscopy was introduced by van Dijk et al. as a new surgical technique to treat posterior ankle pathologies in a minimally invasive fashion. The initial textual description not supported with visual feedback seemed difficult for many surgeons. Recurrent peroneal tendon dislocation frequently needs surgical intervention. Numerous surgical options are provided in literature, however an endoscopic technique to treat all stages of this pathology is lacking. Kerkhoffs et al. developed a minimally invasive technique to treat symptomatic ankle osteoarthritis. Of this technique, that is based on the hindfoot endoscopy, the postoperative results are not yet reported in literature.

The general aim of this thesis is to contribute to the reduction of complications in ankle arthroscopy, mainly by providing and improving the knowledge of surgical anatomy. Furthermore a new minimally invasive technique to treat recurrent peroneal tendon dislocation is introduced and another previously introduced minimally invasive technique to fuse the ankle joint is evaluated.

Chapter 2 Arthroscopy and Endoscopy of the Ankle and Hindfoot
In this chapter a narrative review of literature on the indications for ankle arthroscopy is provided. The indications are divided by their location in and around the ankle. The surgical technique for anterior-and posterior ankle arthroscopy is emphasized on. Potential pitfalls for each technique are described to prevent surgeons from facing
surgery related complications. Ankle arthroscopy for the treatment of ankle pathologies not responding to specific conservative treatment options is favourable over open surgery, providing a quicker recovery and a lower morbidity.

Chapter 3 Anatomy of the ankle ligaments: a pictoral essay
This chapter describes the surgical anatomy around the ankle, specifically of the ligaments. Understanding and applying the anatomical ankle features assists the surgeon in correctly diagnosing pathology. Furthermore it could add to the orientation during arthroscopy, thereby improving its effectiveness. By grouping the different ankle ligaments depending on their location and orientation, clarity and systematics are improved. Groups of ligaments are subsequently discussed in detail to provide the most adequate and latest anatomical knowledge.

Chapter 4 Anterior ankle arthroscopy, distraction or dorsiflexion?
Anterior ankle arthroscopy can be performed by two different methods; the dorsiflexion- or distraction method. The aim of this chapter was to determine the size of the anterior working area for both the dorsiflexion and distraction method. The anterior working area is anteriorly limited by the overlying anatomic structures which include the neurovascular bundle. It was hypothesized that in ankle dorsiflexion the anterior neurovascular bundle will move away anteriorly from the ankle joint, whereas in ankle distraction the anterior neurovascular bundle is pulled tight towards the joint,
thereby decreasing the safe anterior working area. Six fresh frozen ankle specimens, amputated above the knee, were scanned with computed tomography. Prior to scanning, the anterior tibial artery was injected with contrast fluid and subsequently each ankle was scanned both in ankle dorsiflexion and in distraction. A special device was developed to reproducibly obtain ankle dorsiflexion and distraction in the computed tomography scanner. The distance between the anterior border of the inferior tibial articular facet and the posterior border of the anterior tibial artery was measured. The median distance from the anterior border of the inferior tibial articular facet to the posterior border of the anterior tibial artery in ankle dorsiflexion and distraction was 0.9 cm (range 0.7–1.5) and 0.7 cm (range 0.5–0.8), respectively. The distance in ankle dorsiflexion statistically significantly exceeded the distance in ankle distraction (P = 0.03). The current study shows a statistically significantly increased distance between the anterior distal tibia and the overlying anterior neurovascular bundle with the ankle in a slightly dorsiflexed position as compared to the distracted ankle position. It is implicated that the distracted ankle position puts the neurovascular structures more at risk for iatrogenic damage when performing anterior ankle arthroscopy.

Chapter 5 Identification of the superficial peroneal nerve - Anatomical study with surgical implications - Damage to the superficial peroneal nerve or its terminal nerve branches, depending on the level of bifurcation, is the most frequently reported iatrogenic complication in anterior ankle arthroscopy. This
nerve has the unique ability to be identified through the skin, potentially leading to a reduced chance of a complication. Multiple identification techniques have been described in literature. The purpose of the present chapter was to determine which clinical test identified the superficial peroneal nerve most frequently and which determinants negatively affected the identification. Each ankle was placed in the neutral (90 degrees) position, followed by maximal combined plantar flexion and inversion of the ankle and finally the nerve identification was assessed with maximal plantar flexion of the 4th toe with the ankle in the neutral position. A total of 198 ankles (99 volunteers) were examined for identification of the superficial peroneal nerve. Race, gender, body mass index (BMI), shoe size and frequency of physical activity were collected. The best method to identify the superficial peroneal nerve was the maximal combined ankle plantar flexion and inversion test. In this position, the nerve was identified in 57 % of the ankles by palpation (95%-CI 50-64%). BMI was the only independently influential factor in the identification of the superficial peroneal nerve (p<0.05). Since in nearly six out of the ten ankles the superficial peroneal nerve can be identified, it is advised to assess its location prior to portal placement. A higher BMI negatively influences the identification of the superficial peroneal nerve.

Chapter 6 The course of the superficial peroneal nerve in relation to the ankle position: anatomical study with ankle arthroscopic implications
One of the methods to visualize the superficial peroneal nerve is combined ankle plantar flexion and inversion. It is advised to mark
the orientation of the nerve on the skin, as a reminder to prevent iatrogenic nerve damage. The portals for anterior ankle arthroscopy are created with the ankle in the neutral or slightly dorsiflexed position and not in combined plantar flexion and inversion. The purpose of this study was to undertake an anatomical study of the course of the superficial peroneal nerve in different positions of the foot and ankle. We hypothesize that the anatomical localization of the superficial peroneal nerve changes with different foot and ankle positions. In ten fresh frozen ankle specimens, a window, only affecting the skin, was made at the level of the anterolateral portal for anterior ankle arthroscopy in order to directly visualize the superficial peroneal nerve, or if divided, its terminal branches. Nerve movement was assessed from combined 10 degrees plantar flexion and inversion to 5 degrees of dorsiflexion, standardized by the Telos stress device. Also for the 4th toe flexion, flexion of all the toes and for skin tensioning possible nerve movement was determined. The mean superficial peroneal nerve movement was 2.4 mm to the lateral side when the ankle was moved from 10 degrees plantar flexion and inversion to the neutral ankle position and 3.6 mm to the lateral side from 10 degrees of plantar flexion and inversion to 5 degrees of dorsiflexion. Both displacements were statistically significant (p<0.01). The nerve consistently moves lateral when the ankle is manoeuvred from combined plantar flexion and inversion to the neutral or dorsiflexed position. If visible, it is therefore advised to create the anterolateral portal medial from the preoperative marking, in order to prevent iatrogenic damage to the superficial peroneal nerve.
Chapter 7 Hindfoot Endoscopy for Posterior Ankle Impingement
This chapter describes a step by step textual and visual description of hindfoot endoscopy to improve understanding of this minimally invasive surgical technique. Specifically the treatment of an os trigonum as a cause of symptomatic hindfoot impingement is provided. Furthermore it describes surgery specific technical tips and tricks to treat hindfoot disorders. Also potential pitfalls for this surgical technique are presented.

Chapter 8 A 3-Portal Endoscopic Groove Deepening Technique for Recurrent Peroneal Tendon Dislocation
A 3-portal endoscopic technique for the treatment of recurrent peroneal tendon dislocation is described. This new endoscopic approach is based on the 2-portal hindfoot endoscopy. By adding an additional third portal, located 4 cm proximal to the posterolateral portal, a fibular groove deepening can be performed. Prior to adapting this technique to patients, it was performed in 5 cadaveric ankles. These were subsequently dissected to assure surgical safety. In none of the dissected ankles iatrogenic damage to neurovascular or ligamentous structures was found. Results of this technique in a single patient with chronic peroneal tendon dislocation is described. This groove deepening technique resulted in excellent outcome in this patient, both on functional improvement and pain relief, without complications. The endoscopic groove deepening technique seems to be a good and safe alternative to the present open surgical procedures for treatment of recurrent peroneal tendon dislocation.
Chapter 9 Midterm results of posterior arthroscopic ankle fusion
In chapter 9 the midterm clinical and radiological results and complication rates of the first 40 patients with an ankle fusion through a posterior arthroscopic approach are evaluated. Forty consecutive patients with end-stage posttraumatic ankle osteoarthritis were treated with posterior arthroscopic ankle fusion. All patients were assessed clinically as well as radiologically with a minimum follow-up of 2 years. The Foot and Ankle Ability Measure (FAAM; higher score with better function) and Foot Function Index (FFI; high score with poor function and more pain) were used to assess clinical improvement. Clinical fusion was achieved in all patients within 3 months, and radiological fusion was achieved in all patients at 12 months. Two screw mal-placements occurred. Both complications were solved following revision surgery. A significant improvement was noted for both the FAAM [median 38 (range 17–56) to 63 (range 9–84)] and FFI scores [median 66 (range 31–89) to 32 (range 11–98)] for all 40 patients. The posterior arthroscopic ankle fusion is an effective and safe treatment option for end-stage post-traumatic ankle osteoarthritis at midterm follow-up.

Chapter 10 General discussion
This thesis has focused on ankle arthroscopy, both the anterior and posterior techniques. In a review, the existing ankle arthroscopic techniques for a wide variety of ankle disorders was added to literature. The cornerstone of surgery is anatomy, more specifically surgical anatomy, which was published specifically for the ankle.
Anterior ankle arthroscopy should be performed with ankle dorsiflexion and not with continuous distraction. In ankle dorsiflexion the working area and safe distance to the neurovascular structures are increased, as compared to the distraction technique. In 57% of the patients the superficial peroneal nerve can be identified by palpating the anterolateral skin while maximally manual ankle plantarflexion and inversion is applied. Marking its course on the skin will provide a false sense of safety since the position of this nerve changes if the position of the foot changes. By making the anterolateral portal medial to the skin marking, direct iatrogenic superficial peroneal nerve damage can be prevented.

Hindfoot endoscopy is a relatively new minimally invasive technique which was at first difficult to understand for many surgeons. The step by step visual report will aid surgeons to understand and learn to perform this technique, as witnessed by the recent increase of publications.

A new surgical technique, based on hindfoot endoscopy, was developed to treat recurrent peroneal tendon dislocation in a safe, reliable and minimally invasive manner.

The midterm results of posterior arthroscopically assisted ankle fusion for posttraumatic ankle osteoarthritis showed a 100% fusion rate without infections.

In order to further reduce complication rates in ankle arthroscopy, the future focus should be on adequate training in surgical anatomy. The anatomy will not change and therefore will dictate surgical possibilities. Technical improvements may allow for stretching the minimally invasive treatment options.
Samenvatting

Enkelarthroscopie onder een vergrootglas
Hoofdstuk 1 Algemene inleiding
De huidige trend in de orthopedische chirurgie is om patiënten minimaal invasief te behandelen. Het chirurgisch minimaal invasief behandelen van patiënten strookt met de belofte die artsen doen tijdens het afleggen van de eed om patiënten niet te schaden. Omdat chirurgie patiënten in potentie schaadt, dient dit zodanig te worden gedaan dat schade aan de weefsels tot een minimum wordt beperkt. Met een geavanceerd camerasytseem en het gebruik van speciaal ontworpen instrumenten (arthroscopie) kunnen de meeste pathologische afwijkingen in en rond de enkel tegenwoordig worden behandeld. Voorwaarde voor het toepassen van deze techniek is dat de operateur gedetailleerde kennis moet bezitten van de chirurgische anatomie. Anatomieboeken doceren deze vorm van anatomische kennis niet. De anatomische structuren die van significante betekenis zijn voor het goed functioneren van een leedemaat kunnen gemakkelijk worden beschadigd, aangezien deze meestal buiten het gezichtsveld van de arthroscopie liggen.

In het algemeen kunnen pathologische afwijkingen aan de voorzijde van de enkel het best worden behandeld via een anterieure arthroscopie, terwijl pathologie aan de achterzijde van de enkel het best kan worden benaderd via een posterieure arthroscopie. De standaard portals voor een anterieure arthroscopie zijn de mediale en laterale portals. De meest frequent gerapporteerde complicatie is iatrogene schade aan de oppervlakkige peroneusvenen, welke gesitueerd is in de nabijheid van de laterale portal. Aangezien deze zenuw de enige is die met het blote oog door de huid kan worden waargenomen, is het niet logisch dat hij alsnog zo frequent wordt beschadigd tijdens het maken van de laterale
portal. De anterieure arthroscopie kan worden verricht met continue distractie of door middel van dorsaalflexie van de enkel. Welke techniek superieur is boven de andere blijft in de literatuur een punt van discussie.

De posterieure enkelarthroscopie werd door Van Dijk en collegae als nieuwe minimaal invasieve operatietechniek geïntroduceerd. De initiële beschrijving werd niet vergezeld met veel beeldmateriaal waardoor het voor veel chirurgen moeilijk te begrijpen was. Recidiverende peroneuspees dislocaties dienen veelal chirurgisch te worden behandeld. In de literatuur zijn hiervoor veel verschillende technieken beschreven, echter een minimaal invasieve techniek om alle verschillende verschijningsvormen te behandelen bestaat nog niet. Voor het behandelen van gevorderde enkelartrose, door middel van een arthrode, ontwikkelden Kerkhoffs en collegae een nieuwe minimaal invasieve operatietechniek. Deze techniek is gebaseerd op de posterieure enkelarthroscopie, postoperatieve resultaten zijn in de literatuur nog onbekend.

Het algemene doel van dit proefschrift is om het percentage complicaties gerelateerd aan de enkelarthroscopie te reduceren door het verschaffen en verbeteren van de kennis van de chirurgische anatomie. Verder wordt een nieuwe minimaal invasieve operatietechniek geïntroduceerd om recidiverende peroneuspees dislocaties te behandelen en worden de uitkomsten van een minimaal invasieve enkelarthrodese techniek geëvalueerd.
Hoofdstuk 2 Arthroscopy and Endoscopy of the Ankle and Hindfoot
In dit hoofdstuk wordt een review gegeven over de verschillende indicaties van de enkelarthroscopie. Deze worden verdeeld in separate groepen afhankelijk van de anatomische oriëntatie in en rond de enkel. De operatietechnieken van zowel de anterieve- als de posterieve enkelarthroscopie worden behandeld. Mogelijke valkuilen bij iedere chirurgische techniek worden belicht om chirurgiegerelateerde complicaties te voorkomen. Enkelarthroscopie als operatietechniek voor het behandelen van enkelpathologie is te prefereren boven open chirurgie vanwege een sneller herstel en minder morbiditeit.

Hoofdstuk 3 Anatomy of the ankle ligaments: a pictorial essay
Het doel van hoofdstuk 3 is om de chirurgische anatomie rondom de enkel te beschrijven, met specifieke aandacht voor de ligamenten. Het begrip en de toepassing van de anatomische eigenschappen zal de chirurg assisteren om te komen tot een juiste diagnose. Ook kan het bijdragen aan de oriëntatie tijdens een enkelarthroscopie waardoor de effectiviteit kan worden vergroot. Door de verschillende ligamenten te groeperen, afhankelijk van de anatomische lokalisatie, is verduidelijking en systematiek verschaf. Iedere groep van ligamenten is in detail besproken om de meest recente en adequate anatomische karakteristieken te beschrijven.
Hoofdstuk 4 Anterior ankle arthroscopy, distraction or dorsiflexion?
Anterieure enkelarthroscopie kan in basis op twee verschillende manieren worden verricht, door middel van dorsaalflexie of door middel van distractie. Het doel van dit hoofdstuk is om de grootte van het werkgebied aan de voorzijde van de enkel te bepalen voor deze verschillende technieken. Het werkgebied wordt aan de voorzijde beperkt door de overliggende anatomische structuren met daarin de neurovasculaire structuren. De hypothese was dat de anterieure neurovasculaire structuren verder van het enkelgewricht werden gemanipuleerd door dorsaalflexie van de enkel, terwijl deze structuren juist dichter naar de enkel werden getrokken door distractie. Het laatste zou dan resulteren in een verminderde grootte van het werkgebied. Zes kadaverenkels van benen geamputeerd boven de knie, werden gescand met een CT. Voorafgaand aan de scan werd de anterieure tibiale slagader geïnfiltrereerd met contrastvloeistof, waarna de enkels werden gescand, zowel in distractie als in dorsaalflexie. Een speciaal apparaat werd ontworpen om reproductieve dorsaalflexie en distractie te verkrijgen tijdens de scans van de verschillende enkels. De mediane afstand tussen de anterieure rand van de distale tibia en de posterieure begrenzing van de anterieure tibiale slagader in dorsaalflexie van de enkel en distractie was respectievelijk 0,9 cm (spreiding 0,7-1,5cm) en 0,7 cm (spreiding 0,5-0,8cm). Het verschil in deze afstanden voor de twee verschillende standen van de enkel was significant (P=0,03). Deze studie toont een significant grotere afstand van de anterieure distale tibiarrand tot de anterieure tibiale slagader in dorsaalflexie van de enkel in vergelijking met distractie.
Neurovasculaire structuren aan de voorzijde van de enkel lopen meer risico op iatrogene schade door het toepassen van de distractietechniek vergeleken met de dorsaalflexie techniek bij enkelarthroscopie.

**Hoofdstuk 5 Identification of the superficial peroneal nerve - Anatomical study with surgical implications** -
Eén van de methoden om de oppervlakkige peroneusvenen te visualiseren is om de enkel te positioneren in gecombineerde plantairflexie en inversie van de enkel. Het wordt geadviseerd om de locatie van deze zenuw op de huid te markeren om zodoende iatrogene letsels te voorkomen. De portals voor een anterieure enkelarthroscopie worden gemaakt in een neutrale enkelpositie of in enige dorsaalflexie maar niet in gecombineerde plantairflexie en inversie van de voet. Het doel van deze studie was om de positie van de oppervlakkige peroneusvenen te bepalen bij verschillende voet- en enkelstanden. In 10 verse kadaverenkelens werd een kleine huidflap geprepareerd op het niveau van de anterolaterale enkel arthroscopische portal. Zodoende kon de oppervlakkige peroneusvenen, of zijn distale vertakkingen indien reeds gesplitst, worden gevisualiseerd. Er werd onderzocht wat er met locatie van deze zenuw gebeurd indien de enkel van gecombineerde 10 graden plantairflexie en inversie naar 5 graden dorsaalflexie werd gemanoeuvreerd, dit werd gestandaardiseerd met behulp van het Telos apparaat. Ook werd geanalyseerd wat er met de zenuw gebeurde indien de vierde teen werd geflecteerd, indien alle tenen werden geflecteerd en indien de huid op spanning werd gebracht. De gemiddelde verplaatsing van de oppervlakkige peroneusvenen was 2,4 mm naar de laterale zijde indien de enkel van 10 graden
plantairflexie en inversie naar een neutrale stand werd gebracht en 3,6 mm naar lateraal indien de enkel van 10 graden plantairflexie en inversie naar 5 graden dorsaalflexie werd gebracht. De beide verschuivingen waren statistische significant (p<0,01). De zenuw verschuift in alle gevallen naar lateraal indien de enkel van 10 graden plantairflexie en inversie naar neutraal of dorsaalflexie wordt gemanoeuvreerd. Als de oppervlakkige peroneusnerven gevisualiseerd en gemaakte kan worden, dan wordt geadviseerd de portal altijd mediaal van deze markering te maken om zodoende iatrogene letsel aan deze zenuw te voorkomen.

Hoofdstuk 6 The course of the superficial peroneal nerve in relation to the ankle position: anatomical study with ankle arthroscopic implications

Iatrogene letsel aan de oppervlakkige peroneusnerven of zijn distale vertakkingen, afhankelijk van het niveau waar de zenuw zich splitst, is de meest frequent gerapporteerde complicatie bij de anterieuze enkelarthroscopie. Deze zenuw heeft de bijzondere eigenschap te kunnen worden geïdentificeerd door oppervlakkige beschouwing van de huid. Dit zou potentieel tot minder iatrogene letsel kunnen leiden. Er zijn meerdere identificatiemethoden beschreven in de literatuur. Het doel van deze studie was om te bepalen met welke klinische test de oppervlakkige peroneusnerven het vaakst te identificeren was. Ook werd geanalyseerd welke factoren de identificatie belemmerden. In totaal werden 198 enkels van 99 vrijwilligers onderzocht. Ras, geslacht, body mass index (BMI), schoenmaat, en de sportfrequentie werden verzameld als potentiele factoren die invloed zouden kunnen hebben op de identificatie. De beste methode om de oppervlakkige peroneusnerven
te identificeren was door de enkel in maximale plantairflexie en inversie te manoeuvreren. In deze positie kon de oppervlakkige peroneusvenuïn 57% van de onderzochte enkels worden gepalpeerd (95% betrouwbaarheidsinterval 50-64%). BMI was de enige onafhankelijke factor die van invloed was op de identificatie van de oppervlakkige peroneusvenuïn (p<0,05). Bij patiënten met een hoger BMI kan de oppervlakkige peroneusvenuïn minder frequent worden geïdentificeerd. Aangezien de oppervlakkige peroneusvenuïn in bijna 6 van de 10 enkels kan worden geïdentificeerd, wordt geadviseerd de anatomie nauwkeurig te inspecteren alvorens de portal wordt gemaakt.

**Hoofdstuk 7 Hindfoot Endoscopy for Posterior Ankle Impingement**
Het doel van hoofdstuk 7 is om een stapsgewijze operatieve beschrijving te geven van de posterieure enkelarthroscopie. Deze beschrijving is zowel tekstueel als in afbeeldingen weergegeven met als doel een beter begrip over deze minimaal invasieve techniek te bewerkstelligen. Specifiek wordt ingegaan op de behandeling van een symptomatische inklemming van het os trigonum bij plantairflexie. Ook specifieke technische tips en trucs beschreven voor de behandeling van de inklemming en zijn de mogelijke valkuilen bij het gebruik van de posterieure enkelarthroscopie behandeld.

**Hoofdstuk 8 A 3-portal Endoscopic Groove Deepening Technique for Recurrent Peroneal Tendon Dislocation**
In hoofdstuk 8 wordt een endoscopische 3-portal techniek voor de behandeling van recidiverende peroneuspeesdislocaties beschreven. Deze nieuwe techniek is gebaseerd op de op de 2-portal posterieure
enkelarthroscopie. Door het toevoegen van een derde portal, welke 4 cm proximaal van de posterolaterale portal is gelegen, kan de fibulaire groeve worden verdiept. Alvorens deze techniek toe te passen in patiënten, werd het getest op vijf kadaveren. Na de operatie op de kadavers werd een dissectie verricht om na te gaan of de procedure veilig kan worden uitgevoerd. In de onderzochte kadavers werd geen letsel aan de neurovasculaire - of ligamentaire structuren waargenomen. De resultaten in een patiënt met chronische peroneuspeesdislocaties worden uiteengezet. De uitgevoerde uitdieping van de fibulaire groeve resulteerde in uitstekende resultaten, zowel in functionele zin als ook in het verminderen van pijn, zonder complicaties. De endoscopische behandeling van recidiverende peroneuspeesdislocaties, door het uitdiepen van de fibulaire groeve, is een goed alternatief voor de open chirurgische behandeling.

**Hoofdstuk 9 Midterm results of posterior arthroscopic ankle fusion**

In hoofdstuk 9 zal worden ingegaan op de resultaten op de middellange termijn van de eerste 40 patiënten die een enkelartrodese hebben ondergaan met behulp van een posterieure arthroscopisch geassisteerde techniek. Bij veertig opeenvolgende patiënten met een eindstadium van posttraumatische enkelartrose werd de enkelartrodese verricht. Alle patiënten werden zowel klinisch als radiologisch vervolgd gedurende tenminste 2 jaar. The Foot and Ankle Ability Measure (FAAM) en Foot Function Index (FFI) werden gebruikt om de klinische verbetering te onderzoeken. Klinische fusie van het enkelgewricht werd bereikt in alle 40 patiënten binnen 3 maanden (100%), een radiologische fusie werd tevens in alle 40 patiënten
bereikt op 1 jaar na de operatie. In twee patiënten was sprake van
malpositie van een schroef. In beide gevallen werd dit gecorrigeerd
door middel van een revisieoperatie. Een statistisch significante
verbetering werd geconstateerd voor de FAAM [mediaan 38 (spreiding
17-56) naar 63 (spreiding 9-84)]. Ook de FFI-uitkomsten verbeterden
statistische significant [mediaan 66 (spreiding 31-89) naar 32 (11-98).
The posterieure arthroscopisch geassisteerde techniek voor het fuseren
van de enkel is een effectieve en veilige procedure bij patiënten met een
eindstadium van enkelartrose.

**Hoofdstuk 10 Algemene discussie**
De enkelarthroscopie is het onderwerp van dit proefschrift, waarbij
zowel de anterieure als posterieure techniek worden behandeld. In een
reviewartikel worden de bestaande arthroscopische behandelingen
voor een grote verscheidenheid aan enkelaandoeningen beschreven. De
anatomie vormt de hoeksteen van iedere operatie, en dan met name de
chirurgische anatomie. Deze specifieke anatomische kennis voor de
enkel werd in dit proefschrift beschreven. Anterieure enkelarthroscopie
dient de worden verricht met de enkel in dorsaalflexie en niet door
middel van continue distractie. Met dorsaalflexie van de enkel, in
tegenstelling tot distractie, wordt de veilige afstand tot de
neurovasculaire structuren vergroot. In 57% van de patiënten kan de
oppervlakkige peroneusveneuw worden geïdentificeerd door palpatie
met de voet in gecombineerde maximale plantairflexie en inversie. Het
vervolgens markeren van het verloop van deze zenuw op de huid geeft
een onteerd gevoel van veiligheid, aangezien de locatie veranderd bij
het positioneren van de enkel in een andere positie. Echter indien de
anterolaterale portal mediaal van de markering wordt gemaakt, kan iatrogeen letsel aan de oppervlakkige peroneuszenew worden voorkomen, omdat deze naar lateraal verschuift van flexie en inversie naar neutraal en verder naar dorsaalflexie.
De posterieure enkelarthroscopie is een relatieve nieuwe minimaal invasieve operatietechniek, welke in beginsel moeilijk te begrijpen was voor veel chirurgen. Het gepubliceerde artikel waarbij stap-voor-stap de techniek visueel inzichtelijk werd gemaakt heeft bijgedragen aan het begrip. De recente toename in het aantal publicaties omtrent de posterieure enkelarthroscopie is hier bewijs van.
Een nieuwe chirurgische techniek, gebaseerd op de posterieure enkelarthroscopie, werd ontwikkeld om recidiverende peroneuspeesdislocaties veilig en betrouwbaar te verhelpen op een minimaal invasieve manier door het arthroscopisch verdiepen van de fibulaire groeve.
De middellange termijn resultaten van de posterieure arthroscopisch geassisteerde techniek om een posttraumatische enkelartrose te behandelen middels een arrodese, toonde een fusie percentage van 100% zonder het voorkomen van infecties. Deze resultaten zijn beter dan de bestaande minimaal invasieve technieken om de enkel te fuseren.
Om het aantal complicaties van de enkelarthroscopie verder te reduceren moet de chirurgische anatomie in de toekomst beter worden onderwezen. De anatomie van de enkel zal niet veranderen en deze zal daarom de chirurgische mogelijkheden beperken. Technische vooruitgang kan ervoor zorgen dat minimaal invasieve operatietechnieken verder worden ontwikkeld.
Addendum

PhD Portfolio
Curriculum Vitae
Dankwoord
PhD Portfolio

1. PhD training

<table>
<thead>
<tr>
<th>Courses, Seminars, workshops and master classes</th>
<th>Year</th>
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</thead>
<tbody>
<tr>
<td>Radiation course Boerhaave Leiden, The Netherlands</td>
<td>2012</td>
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<tr>
<td>Anatomical dissection course, Barcelona, Spain</td>
<td>2012</td>
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<tr>
<td>Hip and Shoulder Course Luzern, Swiss</td>
<td>2013</td>
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<tr>
<td>Plating lower Extremity Course Hamburg, Germany</td>
<td>2013</td>
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<td>Arthroscopy &amp; Arthroplasty Course Utrecht, The Netherlands</td>
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<td>Oxford Instructional Course, Amsterdam, The Netherlands</td>
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<td>Oxford hemi knee course, Amsterdam – Breda, The Netherlands</td>
<td>2013</td>
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<tr>
<td>Total Hip arthroplasty Nijmegen, The Netherlands</td>
<td>2014</td>
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<tr>
<td>Knee Course Arthrex, München, Germany</td>
<td>2014</td>
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<td>Knee Course, AMC, Amsterdam, The Netherlands</td>
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<tr>
<td>Anatomy course upper extremity dissections, York, United Kingdom</td>
<td>2014</td>
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<tr>
<td>Shoulder course, Rotterdam, The Netherlands</td>
<td>2015</td>
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<tr>
<td>Osteotomy Course, Maartenskliniek Woerden, The Netherlands</td>
<td>2015</td>
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<td>Exeter Course, Amsterdam, The Netherlands</td>
<td>2016</td>
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<tr>
<td>Shoulder arthroplasty course, Hamburg, Germany</td>
<td>2017</td>
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<tr>
<td>LCS total knee arthroplasty course, Belfast, Ireland</td>
<td>2017</td>
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Presentations


de Leeuw PA, JE Brouwers, GJ Streekstra, L Blankevoort (2005) Diagnosing fractures with osteophony; an experiment in goat tibiae. Congress biomechanics, ISAB, Montreal, Canada
Brouwers JE, de Leeuw PA, Streekstra GJ, Blankevoort L (2005) Resonant frequency shifts in osteotomised goat tibiae. Congress biomechanics, ISB 2005, Cleveland, Ohio, USA and for the IFKB meeting, Nijmegen, The Netherlands

de Leeuw PA, Brouwers JE, Streekstra GJ, Blankevoort L (2005) Osteophone as a device to detect bone fractures. Congress for medical devices, ASM 2005, Boston Massachusetts, USA


de Leeuw PA, van Dijk CN (2010) Anterior arthroscopic anatomy of the ankle. 14th Annual congress ESSKA, Oslo, Norway
de Leeuw PA (2012) Instructional Course Lecture; Surgical Anatomy of Hindfoot Endoscopy. 15th Annual congress ESSKA, Geneva, Swiss

de Leeuw PA, Kerkhoffs GM (2013) How to treat an ankle sprain – is surgery an option? Sprunggelekschirurgie, Leipziger Gelenksymposium, Leipzig, Germany


Kerkhoffs GM, de Leeuw PA (2013) Arthroskopisch gestützte Arthrodese am OSG. Annual congress Österreichische Gesellschaft für Unfallchirurgie (OGU), Salzburg, Austria


de Leeuw PA, Golanó P, Kerkhoffs GM, van Dijk CN (2014) What is there to see in the ankle, an anatomical journey. EFORT, Londen, United Kingdom


de Leeuw PA, Kerkhoffs GM (2015) Knee pathology. MR Symposium Academic Medical Center Amsterdam, The Netherlands

dee Leeuw PA, Hendrickx RP, van Dijk CN, Stufkens SA, Kerkhoffs GM (2016) Posterior ankle arthroscopic fusion, midterm results. Thames Valley Trauma Meeting, University of Reading, Reading, United Kingdom

dee Leeuw PA, Hendrickx RP, van Dijk CN, Stufkens SA, Kerkhoffs GM (2016) The posterior approach to arthroscopic ankle arthrodesis, 17th ESSKA Annual congress Barcelona, Spain

dee Leeuw PA (2016) Posterior ankle anatomy through the eyes of Pau Golanó, 17th ESSKA Annual congress, Barcelona, Spain

Reviewer

KSSTA journal 2013 - up to present

2. Teaching

<table>
<thead>
<tr>
<th>Course instructor / Organization / DVD projects</th>
<th>Year</th>
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Normal Arthroscopic Anatomy of the Major Joints’, 2007
Arthroscopic teaching DVD project. International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS)

Ankle Arthroscopy DVD project, European Society of Sports Traumatology Knee Surgery and Arthroscopy (ESSKA), KLEOS 2010


Faculty 5th Curso Arthroscopia De Rodilla y Tobillo, Course Director J Batista, Buenos Aires, Argentina 2012

Athletic injuries of the ankle; Chapter ‘Peroneal Tendon Dislocation, Chapter ‘Peroneal Tendon Disorders’, ESSKA DVD project 2014

Organization Committee Live Surgery, Annual congress ESSKA, Amsterdam, The Netherlands 2014

Faculty Amsterdam Foot and Ankle Course (AFAC), Course Director CN van Dijk 2006-2017

Faculty and session moderator 17th ESSKA Annual congress, Barcelona, Spain 2016

Board member ESSKA Academy 2014-2018
Board member ESSKA Educational Committee 2016-2018

Board member ESSKA Scientific Committee 2016-2018
for organisation of ESSKA congress in Glasgow 2018

Board member ESSKA science Committee under 45 2018-2020

### 3. Parameters of Esteem

<table>
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<th></th>
<th>Year</th>
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<tr>
<td>Collegium Chirurgicum Neerlandicum Award</td>
<td>2004</td>
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<tr>
<td>Best Paper Award KSSTA; Anatomy of the Ankle Ligaments: A pictorial essay</td>
<td>2012</td>
</tr>
<tr>
<td>Golanó P, Vega J, de Leeuw PA, Malagelada F, Manzanares MC, Götzens V, van Dijk CN</td>
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### 4. Fellowships

<table>
<thead>
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<th>Fellowship Dutch Society of Orthopaedic Traumatology (NVOT), St Gallen, Swiss, Host Prof. dr. Jost</th>
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<tr>
<td>Fellowship Dutch Arthroscopy Society (NVA), Germany Senior trauma fellow, John Radcliffe Hospital, Oxford, United Kingdom</td>
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<th>2014</th>
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264
Traveling fellowship ESSKA-SLARD, Godfather Prof. dr. Monllau, Mexico, Bolivia, Chili, Argentina and Brasil

## 5. Publications

<table>
<thead>
<tr>
<th>Authors</th>
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<th>Title</th>
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<tr>
<td>Kok EE, de Leeuw PA, Meulenbergh MC, Sinnema NC, Kok</td>
<td>2009</td>
<td>CT versus MRI in diagnosing ligamental injury in adults with a vertebral corpus fracture. Eur J Radiol Extra. 69:109-112</td>
</tr>
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<tr>
<th><strong>Book Chapters</strong></th>
<th><strong>Year</strong></th>
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van Sterkenburg MN, de Leeuw PA, van Dijk CN (2011) 2011
Endoscopic calcaneoplasty. In: Minimally invasive surgery of the foot and ankle, editors Maffulli and Easley, page 299-313

van Sterkenburg MN, de Leeuw PA, van Dijk CN (2011) 2011
Tendoscopy. In: Minimally invasive surgery of the foot and ankle, editors Maffulli and Easley, page 35-53

de Leeuw PA, van Sterkenburg MN, van Bergen CJ, 2012


van Dijk CN, Kerkhoffs GM, van Sterkenburg MN, de Leeuw PA 2012


In: The Ankle in Football, first edition, editors Gino Kerkhoffs and Pieter d’Hooge


In: Minimally Invasive Surgery in Orthopedics (Second Edition), editors Dr. Giles R. Scuderi and Dr. Alfred J. Tria, page 921-928


de Leeuw PA, Ophuis J, Kerkhoffs GM (2017) Arthroscopic ankle (talocrural joint) fusion. Accepted In: Arthroscopy and Endoscopy of the foot and ankle: Principle & Practice, editor Prof TH Lui

Curriculum Vitae
Peter de Leeuw was born on the 23rd of August 1979 in Oldenzaal and was raised in Groningen. After graduating from the Zernike College in Haren, he went to Utrecht to study Pharmacy for three years. Finally he managed to be accepted for the passion in his life; medical school at the University of Amsterdam. Already during this study he became increasingly interested in Orthopaedic Surgery and before even starting his internships he went abroad to Professor Pau Golanó, a famous anatomists and artist working at the University of Barcelona, Spain. Prof CN van Dijk at that time became his tutor. In Barcelona a scientific research was undertaken on a forgotten ligament in the hindfoot. This certainly was the starting point of his scientific career, and formed the base of his thesis. Understanding the surgical anatomy to improve daily orthopaedic practise became his main interest. He was accepted for the orthopaedic surgical residencies in 2010.

The two years of general surgery, as part of the orthopaedic training, were performed in the Diakonessenhuis in Utrecht (Dr Clevers). After that, the orthopaedic training consisted of the Academic Medical Centre in Amsterdam (Prof van Dijk), the Slotervaart hospital (Dr van der Vis), Tergooi hospital (Dr Vervest) and the Amphia hospital (Prof Eygendaal). He became and orthopaedic surgeon in 2015 and decided to go to Oxford, United Kingdom, for a one year trauma fellowship at the John Radcliffe hospital (Mr Noyes). Together with his family he returned to the Netherlands to work as a chef de Clinique in the Amphia hospital in Breda. In February 2017 he became a consultant in orthopaedic surgery at the Flevo hospital in Almere, focusing on sports
medicine and traumatology, with special emphasis on shoulder and knee arthroscopy, and foot and ankle surgery.

He was chosen for the ESSKA-SLARD travelling fellowship (Prof Monllau) in 2017. Visiting Mexico, Chili, Bolivia, Argentina and Brasil in 3.5 weeks not only improved his orthopaedic knowledge and skills but certainly brought him life lasting friends throughout South America and Europe.
Dankwoord

‘Als je geen tijd hebt voor je passie, is het dan wel je passie’ zullen mensen gedacht hebben gezien de duur van afronding van dit proefschrift. Het is gelukt maar niet zonder de hulp van zovelen, in het bijzonder:

Prof. dr. C.N. van Dijk, promotor en voormalig opleider, Professor, tijdens mijn wetenschappelijke stage vroeg u mij promotieonderzoek te gaan doen binnen uw afdeling. Mijn voorkeur was om eerst de artsenbul te behalen, maar een avontuur in Barcelona zag ik wel zitten. Dit bracht zoveel inspiratie dat we alsnog een promotietraject gingen starten. Met veel bewondering heb ik gedurende mijn opleiding en onderzoek uw onuitputtelijke energie en compassie met ons vak mogen aanschouwen. Inmiddels gepensioneerd maar zo mogelijk nog drukker dan voorheen, ik wens u al het goede.

Dr. ir. L. Blankevoort, copromotor, beste Leendert, een betere copromotor was voor mij niet mogelijk. Altijd betrouwbaar en bereikbaar, je correcties op de manuscripten zijn scherp en innovatief en hebben mijn proefschrift tot een hoger niveau gebracht. Leendert dank je wel en hopelijk nog een lange samenwerking in onderzoeksland.

Overige leden van de promotiecommissie, Prof. dr. R.J. Oostra, Prof. dr. M. Maas, Prof. dr. F. Nollet, Prof. dr. D. Eygendaal, Prof. dr. F.J.G. Backx en Dr. R. Krips, hartelijk dank voor het beoordelen van het manuscript.
Prof. Dr. G.M.M.J. Kerkhoffs, beste Gino, inmiddels zijn we collega’s geworden binnen de alliantie AMC-Flevoziekenhuis. Voor mij ben je meer dan een collega, samen deden we onderzoek, bezochten we veel congressen en was en ben je een leermeester in zowel persoonlijke – als werkomstandigheden. Jouw persoonlijke attitude in de dagelijkse patiëntenzorg maken je uniek. Een gezamenlijke vriend viel weg, zijn initialen leven voort in ons.

Drs. I.N. Sierevelt, Beste Inger, de statistiek achter al mijn onderzoek komt van jouw pen, zonder jou had ik dit nooit kunnen bereiken. Je bent altijd vrolijk, en hebt zelfs mij de statistiek kunnen leren, respect is het enige juiste woord.


Dan een dankwoord aan twee overleden personen, beiden onmisbaar in de toestandkoming van dit proefschrift. Allereerst Prof. dr. Pau Golanó, in 2006 maakten we kennis in de haven van Barcelona, jij Professor, ik student, vanaf het allereerste moment eiste je gelijkwaardigheid. We hebben onuitputtelijk op een geweldige manier mogen samenwerken tot jouw fatale herseninfarct. Pau, muchos gracias, wat was jij een fantastisch persoon! GJW Dekkers,
Jan, als nieuwe man van mama heb jij mij altijd met zeer veel interesse en toewijding geholpen in het schrijven van de manuscripten. Een zeer intelligente man die met veel liefde mij altijd probeerde te prikkelen om beter te worden, je naam leeft voort in onze oudste zoon.

Pau en Jan, ik mis jullie nog iedere dag, sorry dat ik dit geheel niet eerder heb afgerond zodat jullie lijfelijk aanwezig konden zijn. Er staan altijd 2 sterren aan de hemel die net wat sterker schijnen, veel lol samen!

Rosalie van de Sandt, Marga Lammerts, Tineke Nagel, Ellen Rolleman en last but not least Veerle Montes Klaver, secretariaat orthopedie AMC, heel hartelijk dank voor jullie ondersteuning in al die jaren.


Traditiegewijs volgt nu het dankwoord aan de familie, eerlijk gezegd zouden jullie allemaal voorin dit proefschrift horen, echter hou ik stiekem ook wel van traditionele zaken dus dan toch maar hier..

Papa, samen sterk, jij meer in jezelf, ik een grote mond, nooit wierp je me ook maar een enkele barrière op in al mijn studieplannen, je stond erachter, was zeer geïnteresseerd en steunde me waar je kon, dank je wel, ga genieten van je welverdiende pensioen! Moeders, we lijken
veel op elkaar, naar bed gaan kan altijd nog, want altijd veel te veel te bepraten. Dank je wel, je liefde en opvoeding zijn en waren geweldig.

**Elske**, wauw wat een vrouw! Je bent sexy en lief, je laat me mijn gang gaan, relativeert, sponst mijn klaagzang, brengt rust en regelt alles als ik weer eens (teveel) moet werken, trots dat je mijn kanjer bent! Je liefde voor mij en als moeder voor onze 2 kinderen Teun en Harm weerspiegeld onze liefde maar is zeker terug te zien in hun karakters. Mijn mannen; **Teun**, pappa’s boekje is af, dus meer tijd om met onze laarzen aan te struinen en **Harm** we gaan samen aan de wandel!