Ankle Arthroscopy

Johannes I. Wiegerinck and C. N. van Dijk

Contents

J.I. Wiegerinck (✉) • C.N. van Dijk
Department of Orthopaedic Surgery, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands
e-mail: j.i.wiegerinck@amc.uva.nl; c.n.vandijk@amc.uva.nl

G. Bentley (ed.), *European Surgical Orthopaedics and Traumatology*,
DOI 10.1007/978-3-642-34746-7_147,

Abstract

Ankle arthroscopy is increasingly used to deal with a wide range of ankle pathologies. Technological advancement and a more thorough understanding of the anatomy have resulted in improved ability to perform ankle arthroscopy. Arthroscopic surgery offers the advantages related to any minimally-invasive procedure: fewer wound infections, less blood loss, smaller incisions and less morbidity. This chapter describes the major indications for arthroscopy and presents current techniques.

Keywords

Aetiology and diagnosis of disorders-ankle impingement, tendonitis and synovitis, osteochondral defects, subtalar conditions, dislocating tendons • Anatomy • Ankle • Arthroscopy • Complications • Landmarks • Surgical indications • Techniques

General Introduction

In 1931, Burman, one of the pioneers in arthroscopic surgery, was the first Orthopaedic surgeon attempting arthroscopy of the ankle joint in a cadaveric setting [1]. He concluded that the ankle joint "is not suitable for arthroscopy," due to the narrow joint space. However, he also concluded that "something" might be possible once smaller arthroscopes became available. The development of (fiberoptic) arthroscopes gradually improved during the following decades, resulting in Wantanabe's report on a series of 28 ankle arthroscopies in 1972 [2]. Several publications followed in the 1980s [3–10]. Ever since, ankle arthroscopy has been used as a powerful diagnostic and therapeutic method.

Anterior ankle arthroscopy is currently indicated in multiple ankle disorders: the treatment of anterior impingement syndrome, osteochondral defects (OCD's) of the talus, loose body removal, ossicles, adhesions and synovitis [11, 12].

With the introduction of a two-portal endoscopic hindfoot approach in 2000 [13], access to the posterior aspect of the ankle and subtalar joint has become a safe possibility, thereby resulting in a superior approach to posterior located intra-articular pathology as well as the possible treatment of multiple extra-articular structures of the hindfoot such as the os trigonum, flexor hallucis longus and the deep portion of the deltoid ligament [13].

Arthroscopic technique carries major advantages over open techniques, including lower postoperative morbidity; absence of limb-threatening complications; less blood loss; shorter hospital stay; faster rehabilitation and mobilization and a decrease in complication rate [14–18]. To realize these advantages the surgeon should be thoroughly familiar with the anatomy of the region [19] and endoscopic techniques.

This chapter will discuss many different ankle pathologies: anterior pathology; posterior pathology as well as subtalar and peroneal tendon disorders. All will be discussed, from the anatomy and diagnosing through to the operative treatment and rehabilitation.

Anatomy and Landmarks

A detailed knowledge of the anatomy of the ankle joint, including the tendineous and neurovascular structures around the ankle, is important to plan and perform arthroscopic surgery. The anatomical landmarks of bone and soft tissues in and around the ankle joint can easily be palpated and can be marked on the patient's skin. Landmarks are important for a proper portal positioning and can assist through the course of the procedure. The following landmarks are important: both malleoli and the anterior joint line, which can palpated by dorsi- and plantarflexing the ankle. Also, the anterior tibial tendon; peroneal tertius tendon and the Achilles tendon act as landmarks. Vascular landmarks include the great saphenous vein, and the small saphenous vein. Neural landmarks are the sural nerve, running 2 cm posterodistally to the lateral malleolus, and the superficial peroneal nerve.

Anatomy of the Flexor Hallucis Longus

The flexor hallucis longus (FHL) is the most laterally located bipennate muscle of the human calf. Its tendon runs distally in a fibro-osseous gliding channel, located between the posteromedial and posterolateral talar process, at the ankle-subtalar joint complex level. The flexor retinaculum, situated inbetween both processes, keeps the tendon in place. The FHL tendon inserts in the distal phalanx of the hallux after passing distally and medially underneath the sustentaculum tali [20]. The FHL tendon is an important landmark in hindfoot endoscopy, as the posterior tibial neurovascular bundle runs just medial to this tendon. Hence, the safe area is lateral oto the FHL tendon.

Anatomy of the Subtalar Joint

A functional subtalar joint consists of an anterior, middle, and posterior facet. The posterior facet has both an intra-capsular and extra-capsular ligamentous support. The intra-capsular ligamentous support includes the posterior talo-calcaneal ligament, the lateral talo-calcaneal ligament and the anterior capsular ligament of the posterior subtalar joint. The extra-articular ligamentous support consists of the cervical ligaments, the calcaneofibular ligament, superficial deltoid ligament and the interosseous talo-calcaneal ligaments [21]. Talo-calcaneal coalitions may occur in any of these facets. However, the middle facet is predominantly involved [22, 23]. A talocalcaneal coalition may be osteofibrous, cartilaginous, or osseous union of the talus and calcaneus [21]. Some coalitions may resolve during childhood as a result of weight-bearing biomechanical activity [24]. Limited movement between two or more bones of the subtalar joint complex leads to excessive stresses in the hindfoot joint, thereby causing painful inflammations and premature bone degeneration.

Anatomy of the Peroneal Tendons

The peroneus brevis muscle is situated dorsomedially to the peroneus longus muscle from its proximal aspect up to the fibular tip. Here, the peroneus brevis tendon is still relatively flat. Proximal to the lateral malleolus tip the peroneus longus tendon is located dorsally to the peroneus brevis tendon. Distal to the lateral malleolus tip, the peroneus brevis tendon becomes rounder, and crosses the round peroneus longus tendon. The distal posterolateral part of the fibula forms a fibrocartilaginous sliding channel for the two peroneal tendons. The tendons lie constrained in the malleolar groove by the superior peroneal retinaculum and distally by the inferior peroneal retinaculum [25, 26].

Aetiology

Anterior Ankle Impingement

Anterior ankle impingement syndrome is a pain syndrome, characterized by anterior ankle pain on (hyper) dorsiflexion [27]. Symptoms are caused by impingement of hypertrophied soft tissue and bony spurs within the ankle joint. The most frequent cause of chronic pain after an ankle sprain is known as soft tissue impingement syndrome [28]. The primary aetiology of this condition is injury to the ligamentous structures. Bony impingement though, is believed to be elicited by mechanical factors: repetitive capsuloligamentous traction, by for instance repetitive kicking with the foot in full plantar flexion, may cause traction spurs [29]. This hypothesis is supported by the fact that these spurs are found frequently in athletes, who repetitively force their ankle in hyper plantarflexion [3, 5, 29–31].

Posterior Ankle Impingement

Posterior ankle impingement syndrome covers a group of pathologies characterized by posterior ankle pain in plantar flexion. It may be caused by overuse or after trauma. Differentiation between these groups is important as posterior impingement due to overuse has a better prognosis [32] and patients are more satisfied after arthroscopic treatment [17].

The overuse group mainly exists in ballet dancers, downhill runners and soccer players [32–34]. In professional ballet the specific dancing steps force the ankle into hyper plantarflexion. Through exercise the dancer will attempt to increase the range of motion and joint mobility, ultimately decreasing the distance between the calcaneus and talus. This can lead to a compression of the anatomical structures between the calcaneus and the posterior part of the distal tibia. In soccer, the anatomical structures of the hindfoot are exposed to high forces when kicking the ball with the foot in plantarflexion. Eventually these repetitive forces may cause posterior ankle impingement. An isolated or combined hyper plantarflexion, and supination, trauma can damage the structures of the hindfoot and if so, result in a chronic posterior ankle impingement syndrome. Congenital anatomical anomalies, for example a prominent posterior talar process, os trigonum or a talus bi-partitus [35] can facilitate the occurrence of the syndrome. All mechanisms can result in impingement of the soft tissue structures. Eventually, this may result in a swelling, partial rupture or fibrosis.

FHL Tendinopathy

Posterior ankle impingement syndrome is often accompanied by tenosynovitis or degeneration of the FHL tendon, especially in ballet dancers [36–40]. Posterior ankle impingement based on the os trigonum syndrome and FHL tendinitis are two distinct entities, nevertheless they frequently co-exist because of their close anatomical relationship [32, 41, 42]. Athletes performing repetitive forceful push-offs are at risk of developing a FHL tendinitis [43]. Isolated FHL tendon pathology is almost exclusively located behind the medial malleolus, at the level of the fibro-osseous tunnel [32, 40, 41, 44]. Stenosing tenosynovitis, hallux saltans or triggering of the great toe can be the result of the musculotendineous junction being pulled inside the narrow tunnel during ankle dorsiflexion [45]. This tenosynovitis may be caused by hypertrophy, a nodule, or a low-riding muscle belly. The fibro-osseous tunnel is the region with the highest incidence of tendon degeneration and ruptures. One explanation could be a relative incongruity between the FHL and its tunnel in the fully plantarflexed or dorsiflexed position [32]. Another cause may be the existence of an avascular zone at this level in the tendon [32, 46]. Other pathology causing FHL tendinopathy includes posteromedial talar osteochondral defects and scar tissue formation around the tendon [47].

Osteochondral Defects of the Talus (OCD's)

Trauma is widely accepted as the most important aetiological factor in osteochondral defects (OCD) of the talus. In 93–98 % of the lateral talar lesions they are preceded by trauma, for medial lesions this is 61–70 % [48, 49]. OCDs can heal and remain asymptomatic or, amongst other symptoms, progress to deep ankle pain on weight-bearing.

Synovitis

Ankle joint synovitis may be defined as inflammation and hypertrophy of the synovial lining of the ankle joint, which can be either acute or chronic. Synovitis can result after previous surgery, ankle distortions or after fractures. A haematoma may develop subsequent to an injury, causing an exudate and swelling, this is followed by an extensive cellular response, inflammatory reaction of fibrous tissue, hyalinization and ultimately synovitis.

Subtalar Coalitions

Subtalar pathology can be divided into post-traumatic and congenital pathology.

Post traumatic subtalar pathology consists largely of osteoarthritis, whereas a talocalcaneal coalition is the main problem in congential subtalar pathology. Longstanding osteoarthritis however, may result in a talocalcaneal coalition. A talocalcaneal coalition is the partial union of one or more facets of the talocalcaneal joint, resulting in a restriction or absence of motion. A coalition causes pain if it allows micro-motion in the bar and the subtalar joint. In general, the timing of the onset of the symptoms is explained by the ossification of cartilaginous coalition. A talocalcaneal coalition usually becomes symptomatic in the early teenage years [50]. However, some may not present until their third or fourth decade. Forceful ankle trauma seems to be required for a coalition to become symptomatic later in life [51].

Peroneal Tendon Dislocations

Peroneal tendon disorders are an under-recognized source of posterolateral hindfoot pain and dysfunction. Pathology of the peroneal tendons is often overlooked as it may be difficult to distinguish them from lateral ankle ligament disorders [52].

In 1803, Monteggia was the first to describe peroneal instability in a ballet dancer [53]. Two factors can cause the tendons to dislocate; First, the superior peroneal tendon retinaculum can be too lax or disrupted [54–56]. The retinaculum normally tightly covers the peroneal tendons at the posterior-distal fibula, maintaining the tendons at their anatomical site. In cases 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 [57, 58], with or without an inadequate amount of cartilaginous rim [55]. In the normal situation this part of the fibula is concave with a cartilaginous rim at the most distal part, stabilising the peroneal tendons behind the lateral malleolus. Superior peroneal retinacular dysfunction and an inadequate fibular groove often co-exist in recurrent peroneal tendon dislocation.

Diagnosis

Anterior Ankle Impingement

A recognizable tenderness on palpation of the anteromedial or anterolateral aspect of the ankle joint should be present. Some swelling and/or limitation of dorsiflexion may also be present [30]. Pain on forced hyperdorsiflexion can be present. However, a negative impingement test does not rule out an anterior impingement test. The cause of the impingement may be revealed on a plain lateral radiograph, but an oblique anteromedial impingement (AMI) view is mandatory to detect bony ankle impingement on the anteromedial side of the joint (Fig. 1a, b) [59]. Confirmation of the diagnosis can be obtained through a CT-scan, which is usually not necessary.

Posterior Ankle Impingement

The diagnosis is made by means of physical examination. The forced passive hyper plantar flexion test is positive when the patient complains of recognizable pain during the test. A negative test rules out the posterior ankle impingement syndrome. After a positive test a diagnostic infiltration with Xylocaine® can be given. The diagnosis is confirmed if the pain diminishes following infiltration (i.e. negative hyperplantarflexion test after infiltration).

Both standard AP radiography as well as a standard lateral views typically do not show abnormalities in posterior impingement. For a proper detection of these structures we recommend a lateral radiograph with the foot in 25° of external rotation in relation to the standard lateral radiographs (Fig. 2a, b) [60]. A CT-scan can be of use to confirm the diagnosis and is important for pre-operative planning.

FHL Tendinopathy

In FHL tenosynovitis the pain is typically located posteromedial behind the medial malleolus [36]. The pain is exacerbated by ankle motion and hallux dorsiflexion, it diminishes at rest. Behind the medial malleolus, the tendon can be palpated at the level of the ankle joint. The ability to palpate the tendon in its gliding channel is increased if the patient repetitively flexes the big toe with the ankle in 10–20° of plantar

Fig. 1 X-rays of a 23 year-old female patient with anteromedial impingement complaints. The standard lateral view (**a**) shows no abnormalities. The AMI view (**b**) however shows osteophyt formation anteriorly (*arrow*)

flexion. This manoeuvre will also differentiate between FHL and posterior tibial tendon pathology. A crepitus and recognizable tenderness can be provoked in case of a stenosing tendinitis or chronic inflammation. On active motion of the great toe, a vertical moving nodule may be palpable at the level of the gliding channel behind the medial malleolus in some patients. In patients with posteromedial ankle pain associated with a positive hyperplanterflexion test, standard weight-bearing radiographs in AP and lateral direction are made. A MRI scan can be a valuable diagnostic tool in possible tenosynovitis and to rule out tendon ruptures [61]. Especially in post-traumatic cases, a CT scan is of value to ascertain the extent of the injury of the osteochondral defect and/or the exact location of calcifications, ossicles or bony fragments.

OCD's

Patients with an OCD presents with deep ankle pain on or after weight-bearing. Physical examination may show a diminished range of motion and a (prolonged) joint swelling.

The last two symptoms are however absent in the majority of cases. In most patients a normal ankle is seen without restriction of movement, swelling or recognizable tenderness on palpation.

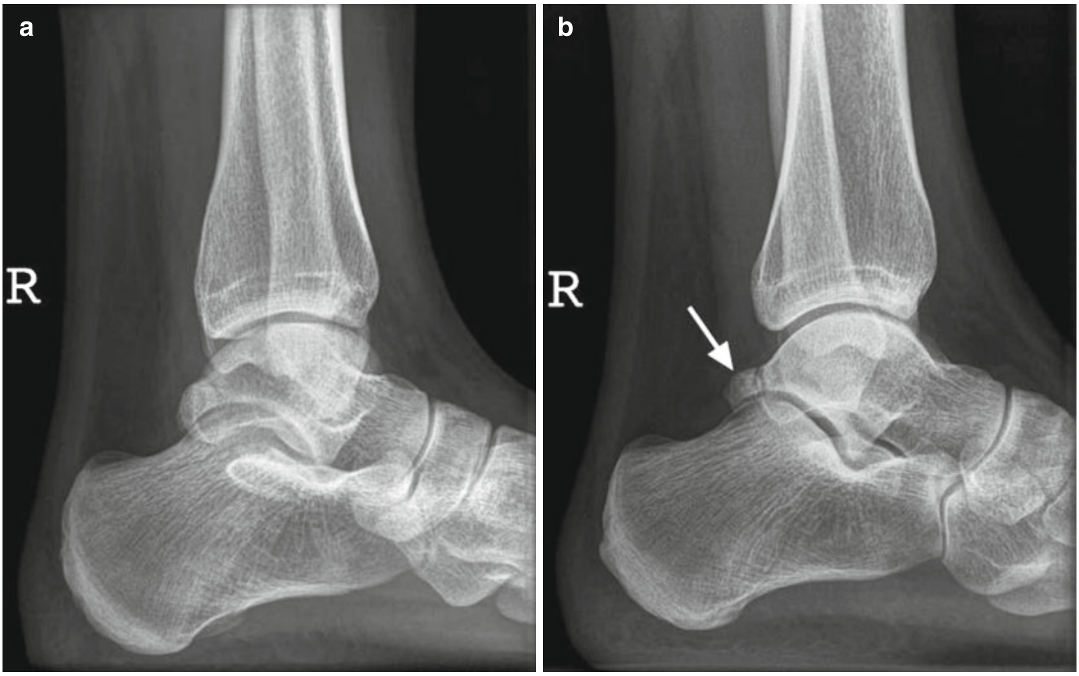

Fig. 2 A 22 year-old female volleyball player with posterior impingement complaints: standard lateral X-ray (**a**) showed no abnormality. The PIM view (**b**), clearly shows an os trigonum (*arrow*)

An anteroposterior (mortise) and lateral weight-bearing view of both ankles are made. Initially the damage may be too small to be visualized on a routine radiograph. The OCD may become apparent on radiographs at a later stage. One may also find subchondral bone cysts as an expression of an OCD. A posteromedial or posterolateral defect may be revealed by a heel-rise mortise view with the ankle in plantar flexion [62]. Furthermore, CT-scan can be performed to confirm the diagnosis and plan treatment. CT-scan and MRI have shown equal accuracy for detection of a talar OCD, but CT-scan is much preferred for pre-operative planning [62].

Synovitis

Patients with chronic synovitis have complaints of pain within the ankle joint, with or without effusion. Their history may involve a traumatic event, either significant or trivial. A local tenderness with some localized or generalized swelling can be seen on physical examination. If complaints are suspect for synovitis additional diagnostics are indicated, this includes laboratory testing for infection parameters, uric acid and if suspect, rheumatic factors. MRI is the preferred method of imaging in synovitis.

Subtalar Pathology

Osteoarthritis

(Post-traumatic) ankle osteoarthritis causes pain, loss of function and swelling of the ankle. One should ask in specifically for a history of fractures in the subtalar region. Longstanding osteoarthritis may result in an increased stiffness of the joint. When the ankle is moved crepitus may be found. Osteoarthritis is easily detected on conventional anteroposterior and lateral radiographs. These may show joint space narrowing, subchondral sclerosis, subchondral cysts and osteophytes. Longstanding osteoarthritis may result in a talocalcaneal coalition.

Fig. 3 Standard lateral X-ray of the foot. A C-sign is clearly shown, indicated by the *arrows*. The C-sign indicates a talocalcaneal bar

Talocalcaneal Coalition

Patients with talocalcaneal coalition usually present with non-specific hindfoot pain. Most patients are initially completely asymptomatic [63]. Complaints often start after a trivial trauma. An inversion injury of the ankle may elicit these complaints and the patient's history may indicate repeated ankle sprains [64]. Physical examination shows a reduced or absent inversion and eversion of the ankle [65]. Frequently, some degree of fixed hindfoot valgus is seen. Conventional anteroposterior and lateral weight-bearing radiographs are made. The C-sign is an important indicator for a subtalar coalition. It is easily recognised sign of a talocalcaneal coalition on the lateral radiograph [66] (Fig. 3). Other important signs on the lateral radiograph include: the talar "beak sign" and subchondral sclerosis. [24, 67–69].

Further imaging must include a CT-scan which is currently regarded as the best method of imaging for talocalcaneal coalitions [66].

Peroneal Tendon Dislocations

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 ground. The pain and dislocation can be provoked by combined dorsiflexion and eversion of the foot during physical examination (Fig. 4a, b). As peroneal tendon dislocation is a clinical diagnosis it does not require additional diagnostics. However, as multiple pathological conditions can co-exist, routine anteroposterior and lateral weight-bearing radiographs are made in case posterolateral ankle pain persists after trauma. Additional radiographic imaging, like MRI and ultrasonography, may be helpful in diagnosing (partial) tears of the peroneal tendons [70]. Both are considerably accurate and precise [71].

Conservative Treatment, Indications for Surgery and Contra-Indications

In general, patients with aforementioned symptomatic ankle problems are treated conservatively first. When conservative treatment fails, arthroscopic surgical intervention is indicated in all these types of pathology.

Anterior Ankle Impingement

Anterior impingement complaints may respond to rest, activity modifications and non-steroidal anti-inflammatory medications (NSAID's). Physical therapy modalities or intra-articular cortisone injections may also relieve pain symptoms. In anterior impingement, excision of soft tissue overgrowths and osteophytes is an effective

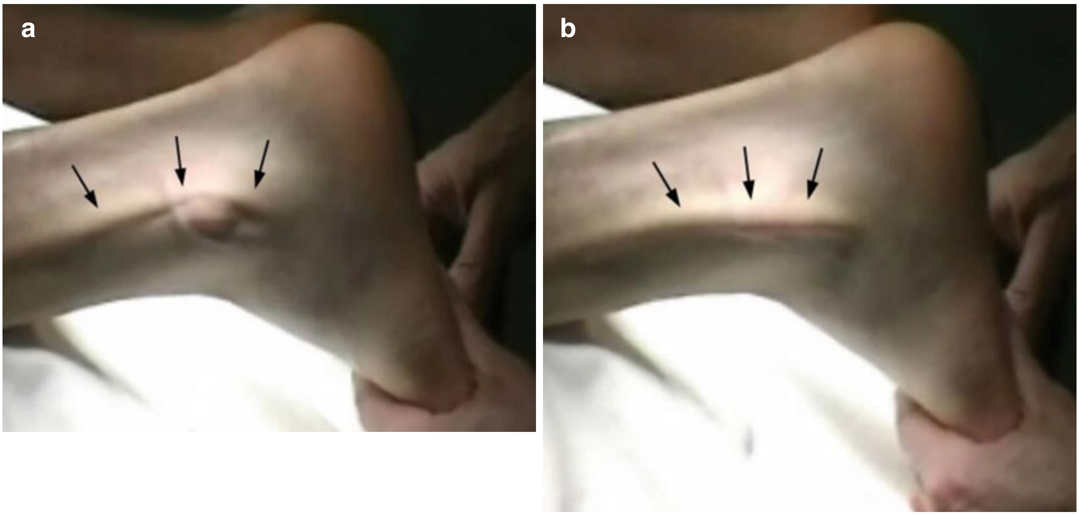

Fig. 4 Patient with a recurrent peroneal tendon dislocation. (**a**) shows the peroneal tendons (*arrows*) in place. (**b**) shows the same patient in which the peroneal tendons (*arrows*) are dislocated

treatment in patients without joint space narrowing. Tibial and talar osteophytes can easily be detected during the procedure with the ankle in forced dorsiflexion. The capsule does not need to be detached to locate these osteophytes.

Posterior Ankle Impingement

Conservative interventions include rest, NSAID's, physical therapy modalities or intra-articular cortisone injections. Good functional and clinical outcome have been described after arthroscopic excision of soft tissue overgrowth; osteophytes or a hypertrophic posterior talar process and os trigonum in symptomatic posterior ankle impingement [17, 18].

FHL Tendinopathy

Non-operative options include rest, activity modification, ice application, NSAIDs. and physical therapy modalities, for instance stretching exercises [32, 41]. If these fail, a corticosteroid injection around the tendon at the level of the tunnel can be applied. However, one should be cautious for the neurovascular bundle and tendon lesions. Conservative treatment often does not completely resolve complaints. Highly active athletes with a competitive attitude will not permit themselves to be inactive for a prolonged period. In these cases a surgical intervention is indicated. In order to achieve unrestricted movement of the tendon FHL and treat tendinopathy. An arthroscopic debridement of the tendon can be performed. This may involve removal of an os trigonum. The flexor retinaculum and tendon sheath can also be released.

OCD's

In cases of a symptomatic OCD, arthroscopic debridement and bone marrow stimulation is currently the best treatment option for defects up to 15 mm in diameter [49, 72]. All unstable cartilage including the underlying necrotic bone is removed using this technique. After debridement, multiple connections with the subchondral bone are created by drilling or microfracturing. The objective is to disrupt intra-osseous blood vessels, hereby enhancing the release of growth factors leading to fibrin-clot formation. It is thought that the formation of local new blood vessels is stimulated, marrow cells are introduced into the defect and fibrocartilaginous tissue is formed [73].

Synovitis

Patients with an (acute) synovitis of the ankle may respond to non-steroidal anti-inflammatory medications, intra-articular cortisone injections, or physical therapy modalities. Synovitis and especially chronic synovitis, which does not respond well to conservative treatment may sometimes require an arthroscopic synovectomy. If, after adequate and work-up the patient fails to respond to conservative treatment, ankle arthroscopy is indicated

Subtalar Coalitions

Non-operative intervention includes modification of activity level; orthotics and use of NSAIDs. or cast immobilisation. During a 6 week cast immobilization period patients may show a resolution of symptoms. If, after cast removal, symptoms reoccur, a second period of casting can be tried [65]. Surgical intervention is however often required. In children, resection of the talocalcaneal bar should be postponed until the bar is ossified. Arthrodesis is the intervention of choice in skeletally-mature patients with recurrent pain [51, 74].

Peroneal Tendon Pathology

The primary indication for treating peroneal tendon pathology, is pain [75]. Conservative management should include activity modification; change of footwear; temporary immobilization or corticosteroid injection. Also, lateral heel wedges can take the strain off the peroneal tendon which may allow healing [76]. After several months of conservative treatment with minimal results, open or endoscopic/tendoscopic surgery is indicated. Recurrent dislocation of the peroneal tendons is an indication for a stabilizing procedure.

Contra-Indications

Relative contra-indications for arthroscopy of the ankle include moderate degenerative joint disease, a tenuous vascular status and severe oedema. More absolute contra-indications include localized soft-tissue infection and severe degenerative joint disease. Obesity, although not a contra-indication, significantly contributes to a prolonged intra-operative surgical time and post-operative morbidity [77].

Pre-Operative Preparation and Planning

Always start with routine weight-bearing radiographs in an anteroposterior (AP) and lateral directions. If weight-bearing views are negative in anteromedial impingement an oblique AMI radiograph is indicated. Anteromedially located tibial or talar osteophytes are 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 (AMI) view, the beam is tilted in a 45° craniocaudal direction with the leg in 30° external rotation and the foot in plantarflexion in relation to the standard lateral radiograph position [78] (Fig. 1b). In patients with an osteochondral defect the standard weight-bearing 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 [62]. For further diagnostic evaluation CT and MRI have demonstrated similar accuracy [62]. A multi-slice 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 [62]. In patients with posterior ankle impingement the AP ankle view typically does not show abnormalities. Osteophytes, calcifications, loose bodies, chondromatosis as well as 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° external rotation in relation to the standard lateral radiograph (Fig. 2b). Especially in post-traumatic 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 MRI scan. Ultrasonography seems to be a good and relatively cheap alternative, with a positive predictive value of 100 % for peroneal tendon dislocation [71, 79].

Surgical Techniques

Anterior Ankle Arthroscopy

Anterior ankle arthroscopy is carried out as an outpatient procedure under general or spinal anaesthesia. The patient is placed supine. A support is placed at the contralateral side of the pelvis to safely turn the table sideways. The involved leg is marked to avoid wrong side surgery. The heel of the affected foot rests on the very end of the operating table. This way the surgeon can fully dorsiflex the ankle by leaning against the foot sole, and use the table as a lever when maximal plantar flexion is needed. Correct placement of the arthroscopic portals is important for successful arthroscopy. The anteromedial and anterolateral portal will provide adequate access to the ankle joint, additional 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 (Fig. 5). As the skin is incised just medial to the anterior tibial tendon, the subcutaneous layer is bluntly dissected with a mosquito clamp at the level of the ankle joint. A 4.0 mm 30° angled arthroscope is introduced while the ankle is in full dorsiflexion. This protects the talar cartilage as it is covered by the tibial cartilage. For irrigation normal saline is used; flow is obtained by gravity. The anterolateral portal is made under direct vision. A spinal needle is introduced just lateral to the peroneus tertius tendon. A vertical skin incision is made with special attention not to damage the

Fig. 5 Portal placement for anterior ankle arthroscopy, the anteromedial portal (M) and anterolateral portal (L) are marked

superficial peroneal nerve. The subcutaneous layers are bluntly dissected with a mosquito clamp and the desired instrument can be introduced. The contour of the anterior tibia is identified and in case of an osteophyte, soft tissue superior to the osteophyte is removed with a shaver. The extent of the osteophyte is determined and the osteophyte is subsequently removed using a 4 mm chisel and/or shaver. When an osteophyte is located at 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. We use a non-invasive soft-tissue distraction device when indicated [80]. An accessory portal in front of the tip of the medial malleolus, can be helpful. In case of osteophytes at the tip of the medial malleolus, usually overcorrection of the tip is feasible using a bone cutting shaver. The skin incisions are sutured with 3.0 Ethilon. The incisions and surrounding skin are injected with 10 ml of a 0.5 % bupivacaine/morphine solution. Finally a sterile, compressive dressing is applied.

Posterior Ankle Arthroscopy

The procedure is carried out as outpatient surgery under general anaesthesia or spinal anaesthesia. The patient is placed prone. The involved leg is marked to avoid wrong side surgery. The patient's ankle is placed slightly over the distal edge of the table and a small support is placed under the lower leg, enhancing free movement of the ankle. A support is placed at the ipsilateral side of the pelvis to safely rotate the table when needed; a tourniquet is inflated around the thigh. Normal saline is used for irrigation. Along with the standard excisional and motorised instruments for treatment of osteophytes and ossicles, a 4 mm chisel and periosteal elevator can be useful. The anatomical landmarks, pre-operatively marked, are the lateral malleolus, medial and lateral border of the Achilles tendon and the sole of the foot. A straight line, parallel to the sole, is drawn from the tip of the lateral malleolus to the Achilles tendon. The posterolateral portal is made directly in front of the Achilles tendon just proximal to this line (Fig. 6a). After making a vertical stab incision, the subcutaneous layer is split by a mosquito clamp. The mosquito is directed toward the interdigital webspace between the first and second toe. As the tip of the clamp touches the bone, it is exchanged for a 4.5-mm arthroscope 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 two joints. The trocar is situated extra-articular at the level of the ankle joint. It is exchanged for a 4 mm arthroscope with the direction of view 30° to the lateral side. The posteromedial portal is made medially to the Achilles tendon, at the same level as the posterolateral portal, just above the line from the tip of the lateral malleolus (Fig. 6b). After making a vertical stab incision, a mosquito clamp is pointed in the direction of the arthroscopic shaft in a 90° angle. Once the mosquito clamp touches the arthroscopic shaft, the shaft is used as a guide to move anteriorly towards the ankle joint, touching the arthroscope shaft all the way until it reaches the bone. The shaft is subsequently pulled slightly backwards until the tip of the mosquito clamp becomes visible. The clamp is used to spread the extra-articular soft tissue in front of the arthroscope. After exchanging the mosquito clamp for a 5 mm full radius resector, the fatty tissue lateral from the FHL tendon overlying the posterior ankle capsule is resected. The tip of the shaver is directed in a lateral and slightly plantar direction towards the lateral aspect of the subtalar joint. Once this tissue is debrided, the ankle and subtalar joints are entered easily by penetrating the joint capsule. At the level of the ankle joint, the posterior tibiofibular ligament is recognized as well as 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 as it is an important safety landmark. After removal of the joint capsule of the ankle joint, the intermalleolar and transverse ligament can be lifted in order to enter and inspect the ankle joint (Fig. 7). On the medial side, the tip of the medial malleolus can be visualized as well as 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

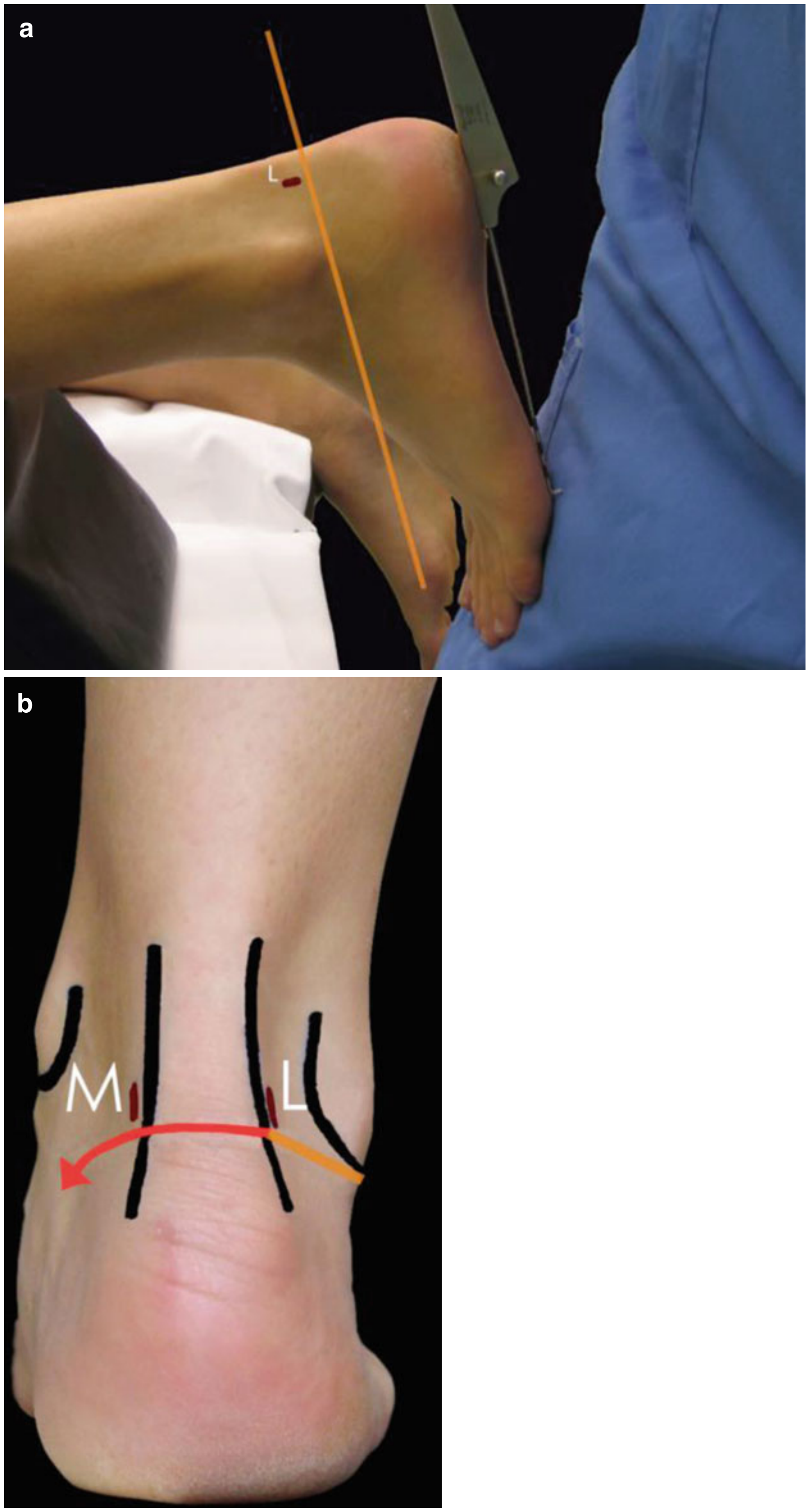

Fig. 6 (**a**) Portal placement for posterior ankle arthroscopy: the lateral portal, to determine the position of the portal a *straight line*, parallel to the sole of the foot (*orange*) is made. (**b**) Portal placement in posterior ankle arthroscopy: the medial portal. To determine the position of the medial portal the anatomical landmarks are drawn (*black*), the lateral line (*orange*) is extended medially over the Achilles tendon (*red arrow*)

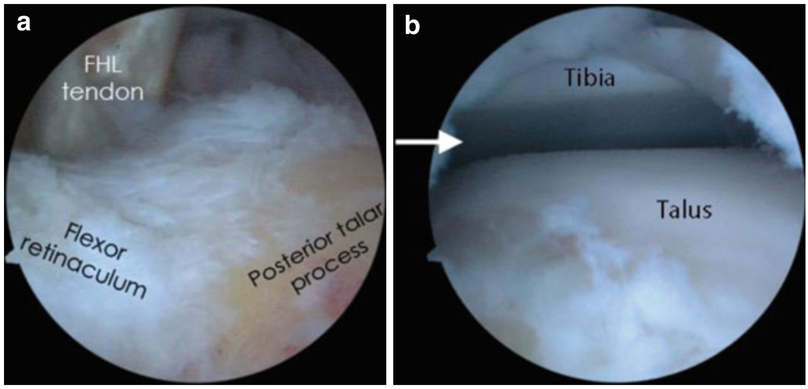

Fig. 7 Posterior ankle arthroscopy in a right foot. The photograph shows the identification of the FHL tendon (**a**) with its retinaculum, hereafter the ankle joint (*arrow*) is inspected (**b**)

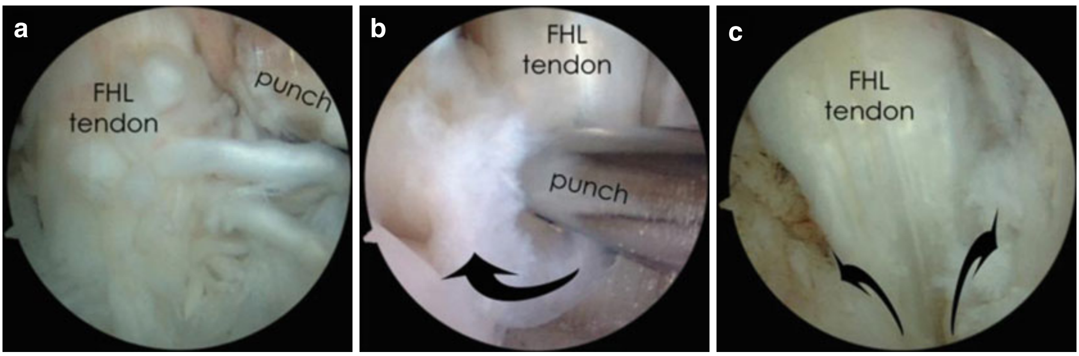

Fig. 8 FHL tendoscopy of the left ankle in a 20 year-old male patient. Endoscopic situation prior to debridement and release (**a**). The tendon is released from its retinaculum (*arrow*) by means of a punch (**b**). Final situation after debridement and release, the arrows show the released FHL retinaculum (**c**)

of the posterior tibial tendon can be opened when desired. The arthroscope can now be introduced into the tendon sheath and the posterior tibial tendon can be inspected. The same procedure can be done for the flexor digitorum longus tendon. By applying manual distraction to the calcaneus, 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 [80]. A synovectomy and/or capsulectomy can be performed. Inspection of the talar dome is possible over almost its entire surface as well as the complete tibial plafond. Identification of an osteochondral defect or subchondral cystic lesion may require debridement and drilling. The posterior syndesmotic ligaments are inspected and debrided if fibrotic or ruptured. Removal of a symptomatic os trigonum, a non-union 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 (Fig. 8). The FHL tendon sheath can be entered, permitting an accurate inspection of the tendon and if required a further release can be performed anteriorly and distally (Fig. 9) Possible length ruptures are debrided. The proximal part of the tendon and the distal part of the muscle belly are inspected and debrided in case of inflammation, thickening or if nodules are present. Adhesions and excessive scar tissue are removed. Wound closure and dressing are performed in accordance with anterior ankle arthroscopy.

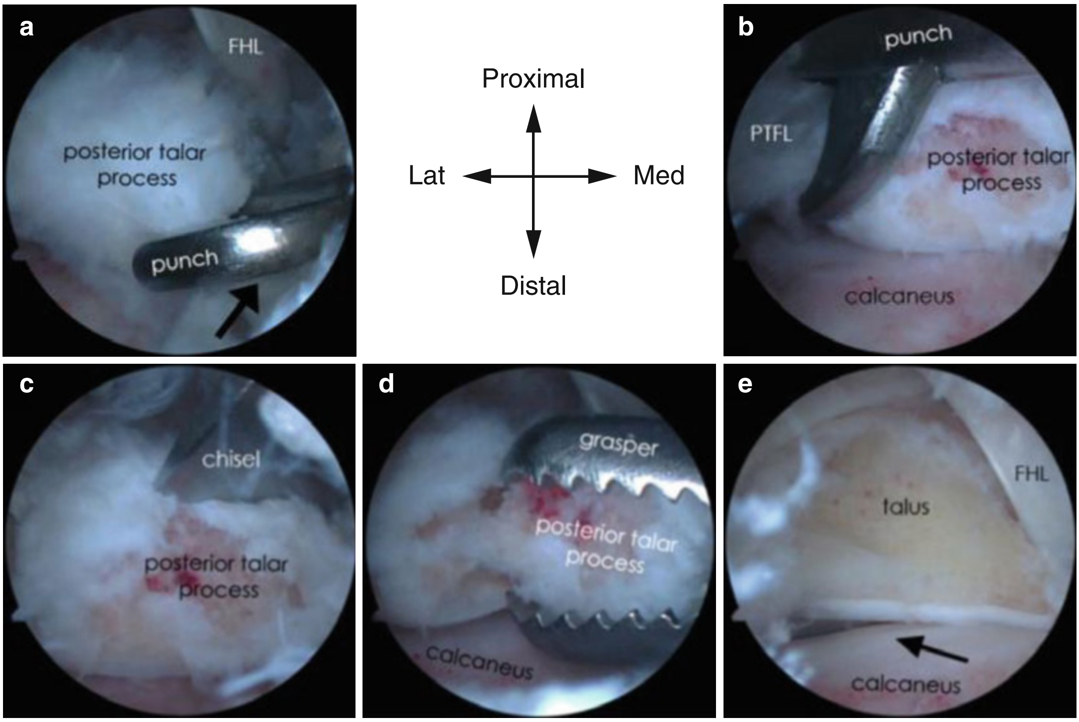

Fig. 9 Posterior talar process removal in the left ankle of a 15 year-old female patient complaining of posterior impingement problems. The hypertrophied posterior talar process is released from the flexor retinaculum and the PTFL by means of a punch (**a**, **b**). Hereafter, the talar process is resected by means of a chisel and removed using a large grasper (**c**, **d**). End situation after removal (**e**), the subtalar joint is visible (*arrow*)

Post-Operative Care and Rehabilitation

Anterior Ankle Arthroscopy

The patient can be discharged on the same day as surgery with a compression bandage applied around the operated 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 weight-bearing is allowed. Large osteochondral lesions (>1 cm) require partial weight- bearing up to 6 weeks, while anterior ankle arthroscopy for an osteophyte allows the patient to fully bear weight after 5 days.

Posterior Ankle Arthroscopy

The patient can be discharged on the same day as surgery and weight-bearing is allowed as tolerated. The patient is instructed to elevate the foot when not walking to prevent oedema. The dressing is removed 3 days post-operatively and the patient is permitted to shower. Performing active range of motion exercises for at least three times a day for 10 min each is encouraged. Patients with limited range of motion are directed to a physiotherapist.

Complications

Most arthroscopic complications can be avoided if the surgeon becomes thoroughly familiar with the anatomy of the region [19]. The increasing use of ankle arthroscopy and its risks have been well documented [6, 8, 19, 81–86]. Complications in ankle arthroscopy vary widely and ranges from 9 % to 17 % [6, 19, 85, 87]. Ferkel reported in the largest series an overall complication rate of 9.0 % in 612 patients [85]. The most of these complications were neurological (49 %), involving the superficial peroneal nerve (56 %), the sural nerve (24 %), or the saphenous nerve (20 %). Neurovascular injures are due to incorrect portal placement, pin placement, use of a tourniquet, or prolonged or inappropriate distraction [11]. A recent complication survey was performed in our department: 1.300 consecutive patients with ankle arthroscopy without routine joint distraction were included; the overall complication rate was 3.4 %. This includes 1.4 % for hindfoot endoscopy [88]. Most investigators have commented that the anteriomedial and anterolateral portals are safe. In the past, the posteromedial portal was not advised [5, 6, 84, 89–91], as the medial neurovascular bundle is at risk during instrument penetration. However, with the correct technique and experience there is little risk of injury of this neurovascular structure [13, 92]. Other possible complications in joint arthroscopy include infection; instrument breakage; distractor-pin site pain or fracture when using invasive distraction and damaging the articular cartilage [85]. One must always be alert to potential injury to the tendons crossing the ankle joint. Careful pre-operative planning; knowledge of anatomy and the use of appropriate instrumentation and distraction methods help to avoid these complications.

Summary

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 procedures. The surgeon must be familiar with the anatomy and must use routine portals in ankle arthroscopy. Ideally these routine portals can be used to treat most pathology, without the need for additional portals. Reports of complications in ankle arthroscopy vary widely and rates from 9 % to 17 % have been reported [6, 19, 85, 87]. In the largest series, nearly 50 % of these complications were neurological [85]. This high complication rate is technique-related. When using the proper techniques the percentage reduces to 3 %.

Open and arthroscopic resection of osteophytes were compared by Scranton and McDermott [16]. Arthroscopic resection is favourable as compared to open removal for both the length of hospitalization and time to recovery. Prospective studies report on success rates varying from 73 % to 96 % [93–95]. The authors feel that the posteromedial and posterolateral portals, as described in 2000 [13] possess the criteria, as discussed above. These portals provide a safe access [92, 96]. Recently, a retrospective study has been published in which 16 posterior ankle arthroscopies were evaluated [18]. All patients 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. We published a prospective series of 52 patients with posterior ankle impingement, treated with hindfoot endoscopy [17]. The two-portal endoscopic hindfoot approach compares favourably with open surgery with regard to less morbidity and a quicker recovery [17]. The technique has now expanded to other areas in the hindfoot. Endoscopic groove deepening and subtalar arthrodesis techniques are examples of this expension [97].

References

1. Burman MS. Arthroscopy of direct visualization of joints. An experimental cadaver study. J Bone Joint Surg Am. 1931;13:669–95.
2. Watanabe M. Selfoc-arthroscope (Watanabe no 24 arthroscope). Monograph. Tokyo: Teishin Hospital; 1972
3. Biedert R. Anterior ankle pain in sports medicine: aetiology and indications for arthroscopy. Arch Orthop Trauma Surg. 1991;110(6):293–7.
4. Feder KS, Schonholtz GJ. Ankle arthroscopy: review and long-term results. Foot Ankle. 1992;13(7):382–5.
5. Ferkel RD, Scranton Jr PE. Arthroscopy of the ankle and foot. J Bone Joint Surg Am. 1993;75(8):1233–42.

6. Guhl JF. Foot and ankle arthroscopy. New York: Slack; 1993.
7. Jerosch J, Steinbeck J, Schneider T, Strauss JM. Arthroscopic treatment of anterior synovitis of the upper ankle joint in the athlete. Sportverletz Sportschaden. 1994;8(2):67–72.
8. Martin DF, Baker CL, Curl WW, Andrews JR, Robie DB, Haas AF. Operative ankle arthroscopy. Long-term followup. Am J Sports Med. 1989;17(1):16–23.
9. Parisien JS, Vangsness T. Arthroscopy of the subtalar joint: an experimental approach. Arthroscopy. 1985;1(1):53–7.
10. Parisien JS. Ankle and subtalar joint arthroscopy. An update. Bull Hosp Jt Dis Orthop Inst. 1987;47(2):262–72.
11. Ferkel RD, Small HN, Gittins JE. Complications in foot and ankle arthroscopy. Clin Orthop Relat Res. 2001;391:89–104.
12. van Dijk CN, Scholte D. Arthroscopy of the ankle joint. Arthroscopy. 1997;13(1):90–6.
13. van Dijk CN, Scholten PE, Krips R. A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. Arthroscopy. 2000;16(8):871–6.
14. O'Brien TS, Hart TS, Shereff MJ, Stone J, Johnson J. Open versus arthroscopic ankle arthrodesis: a comparative study. Foot Ankle Int. 1999;20(6):368–74.
15. Myerson MS, Quill G. Ankle arthrodesis. A comparison of an arthroscopic and an open method of treatment. Clin Orthop Relat Res. 1991;268:84–95.
16. Scranton Jr PE, McDermott JE. Anterior tibiotalar spurs: a comparison of open versus arthroscopic debridement. Foot Ankle. 1992;13(3):125–9.
17. Scholten PE, Sierevelt IN, van Dijk CN. Hindfoot endoscopy for posterior ankle impingement. J Bone Joint Surg Am. 2008;90(12):2665–72.
18. Willits K, Sonneveld H, Amendola A, Giffin JR, Griffin S, Fowler PJ. Outcome of posterior ankle arthroscopy for hindfoot impingement. Arthroscopy. 2008;24(2):196–202.
19. Barber FA, Click J, Britt BT. Complications of ankle arthroscopy. Foot Ankle. 1990;10(5):263–6.
20. Sarrafian SK. Anatomy of the foot and ankle: descriptive, topographic, functional. Philadelphia: Lippincott; 1983.
21. Linklater J, Hayter CL, Vu D, Tse K. Anatomy of the subtalar joint and imaging of talo-calcaneal coalition. Skeletal Radiol. 2009;38(5):437–49.
22. Conway JJ, Cowell HR. Tarsal coalition: clinical significance and roentgenographic demonstration. Radiology. 1969;92(4):799–811.
23. Masciocchi C, D'Archivio C, Barile A, et al. Talocalcaneal coalition: computed tomography and magnetic resonance imaging diagnosis. Eur J Radiol. 1992;15(1):22–5.
24. Lateur LM, Van Hoe LR, Van Ghillewe KV, Gryspeerdt SS, Baert AL, Dereymaeker GE. Subtalar coalition: diagnosis with the C sign on lateral radiographs of the ankle. Radiology. 1994;193(3):847–51.
25. Scholten PE, van Dijk CN. Tendoscopy of the peroneal tendons. Foot Ankle Clin 2006;11(2):415–20, vii
26. Kumai T, Benjamin M. The histological structure of the malleolar groove of the fibula in man: its direct bearing on the displacement of peroneal tendons and their surgical repair. J Anat. 2003;203(2):257–62.
27. Tol JL, van Dijk CN. Anterior ankle impingement. Foot Ankle Clin 2006;11(2):297–310, vi
28. Ferkel RD. Soft-tissue lesions of the ankle. In: Whipple TL, editor. Arthroscopic surgery: the foot and ankle. Philadelphia: Lippincott-Raven; 1996. p. 121–43.
29. McMurray T. Footballer's ankle. J Bone Joint Surg. 1950;32:68–9.
30. Cutsuries AM, Saltrick KR, Wagner J, Catanzariti AR. Arthroscopic arthroplasty of the ankle joint. Clin Podiatr Med Surg. 1994;11(3):449–67.
31. Handoll HH, Rowe BH, Quinn KM, de Bie R. Interventions for preventing ankle ligament injuries. Cochrane Database Syst Rev. 2001;(3):CD000018
32. Hamilton WG, Geppert MJ, Thompson FM. Pain in the posterior aspect of the ankle in dancers. Differential diagnosis and operative treatment. J Bone Joint Surg Am. 1996;78(10):1491–500.
33. van Dijk CN, Lim LS, Poortman A, Strubbe EH, Marti RK. Degenerative joint disease in female ballet dancers. Am J Sports Med. 1995;23(3):295–300.
34. Hedrick MR, McBryde AM. Posterior ankle impingement. Foot Ankle Int. 1994;15(1):2–8.
35. Weinstein SL, Bonfiglio M. Unusual accessory (bipartite) talus simulating fracture. A case report. J Bone Joint Surg Am. 1975;57(8):1161–3.
36. Hamilton WG. Tendonitis about the ankle joint in classical ballet dancers. Am J Sports Med. 1977;5(2):84–8.
37. Krackow KA. Acute, traumatic rupture of a flexor hallucis longus tendon: a case report. Clin Orthop Relat Res. 1980;150:261–2.
38. Holt KW, Cross MJ. Isolated rupture of the flexor hallucis longus tendon. A case report. Am J Sports Med. 1990;18(6):645–6.
39. Gould N. Stenosing tenosynovitis of the flexor hallucis longus tendon at the great toe. Foot Ankle. 1981;2(1):46–8.
40. Solomon R, Brown T, Gerbino PG, Micheli LJ. The young dancer. Clin Sports Med. 2000;19(4):717–39.
41. Sammarco GJ, Cooper PS. Flexor hallucis longus tendon injury in dancers and nondancers. Foot Ankle Int. 1998;19(6):356–62.
42. van Dijk CN. Hindfoot endoscopy for posterior ankle pain. Instr Course Lect. 2006;55:545–54.
43. Leach RE, DiIorio E, Harney RA. Pathologic hindfoot conditions in the athlete. Clin Orthop Relat Res. 1983;177:116–21.
44. Benjamin M, Qin S, Ralphs JR. Fibrocartilage associated with human tendons and their pulleys. J Anat. 1995;187(Pt 3):625–33.
45. McCarroll JR, Ritter MA, Becker TE. Triggering of the great toe. A case report. Clin Orthop Relat Res. 1983;175:184–5.
46. Petersen W, Pufe T, Zantop T, Paulsen F. Blood supply of the flexor hallucis longus tendon with regard to

dancer's tendinitis: injection and immunohistochemical studies of cadaver tendons. Foot Ankle Int. 2003;24(8):591–6.
47. van Dijk CN, de Leeuw PA, Krips R. Diagnostic and operative ankle and subtalar joint arthroscopy. In: Porter DA, Schon LC, editors. Baxter's the foot and ankle in sport. 2nd ed. Philadelphia: Mosby Elsevier; 2008.
48. Flick AB, Gould N. Osteochondritis dissecans of the talus (transchondral fractures of the talus): review of the literature and new surgical approach for medial dome lesions. Foot Ankle. 1985;5(4):165–85.
49. Verhagen RA, Struijs PA, Bossuyt PM, van Dijk CN. Systematic review of treatment strategies for osteochondral defects of the talar dome. Foot Ankle Clin 2003;8(2):233–42, ix
50. Cowell HR. Talocalcaneal coalition and new causes of peroneal spastic flatfoot. Clin Orthop Relat Res. 1972;85:16–22.
51. Scranton Jr PE. Treatment of symptomatic talocalcaneal coalition. J Bone Joint Surg Am. 1987;69(4):533–9.
52. Molloy R, Tisdel C. Failed treatment of peroneal tendon injuries. Foot Ankle Clin 2003;8(1):115–29, ix
53. Monteggia GB. Instituzini chirurgiche. pt III ed. Milan, Italy: 1803. p. 336–41
54. Brage ME, Hansen Jr ST. Traumatic subluxation/dislocation of the peroneal tendons. Foot Ankle. 1992;13(7):423–31.
55. Eckert WR, Davis Jr EA. Acute rupture of the peroneal retinaculum. J Bone Joint Surg Am. 1976;58(5):670–2.
56. Zoellner G, Clancy Jr W. Recurrent dislocation of the peroneal tendon. J Bone Joint Surg Am. 1979;61(2):292–4.
57. Edwards ME. The relations of the peroneal tendons to the fibula, calcaneus and cuboideum. Am J Anat. 1928;42:213–53.
58. Poll RG, Duijfjes F. The treatment of recurrent dislocation of the peroneal tendons. J Bone Joint Surg Br. 1984;66(1):98–100.
59. van Dijk CN, Wessel RN, Tol JL, Maas M. Oblique radiograph for the detection of bone spurs in anterior ankle impingement. Skeletal Radiol. 2002;31(4):214–21.
60. van Dijk CN. Anterior and posterior ankle impingement. Foot Ankle Clin. 2006;11(3):663–83.
61. Michelson J, Dunn L. Tenosynovitis of the flexor hallucis longus: a clinical study of the spectrum of presentation and treatment. Foot Ankle Int. 2005;26(4):291–303.
62. Verhagen RA, Maas M, Dijkgraaf MG, Tol JL, Krips R, van Dijk CN. Prospective study on diagnostic strategies in osteochondral lesions of the talus. Is MRI superior to helical CT? J Bone Joint Surg Br. 2005;87(1):41–6.
63. Kulik Jr SA, Clanton TO. Tarsal coalition. Foot Ankle Int. 1996;17(5):286–96.
64. Snyder RB, Lipscomb AB, Johnston RK. The relationship of tarsal coalitions to ankle sprains in athletes. Am J Sports Med. 1981;9(5):313–7.
65. Bohne WH. Tarsal coalition. Curr Opin Pediatr. 2001;13(1):29–35.
66. Sakellariou A, Sallomi D, Janzen DL, Munk PL, Claridge RJ, Kiri VA. Talocalcaneal coalition. Diagnosis with the C-sign on lateral radiographs of the ankle. J Bone Joint Surg Br. 2000;82(4):574–8.
67. Resnick D. Talar ridges, osteophytes, and beaks: a radiologic commentary. Radiology. 1984;151(2):329–32.
68. Resnick D, Niwayama G. Diagnosis of bone and joint disorders. 2nd ed. Philadelphia: Saunders; 1988. p. 3564–9.
69. Pistoia F, Ozonoff MB, Wintz P. Ball-and-socket ankle joint. Skeletal Radiol. 1987;16(6):447–51.
70. Rosenberg ZS, Bencardino J, Astion D, Schweitzer ME, Rokito A, Sheskier S. MRI features of chronic injuries of the superior peroneal retinaculum. AJR Am J Roentgenol. 2003;181(6):1551–7.
71. Rockett MS, Waitches G, Sudakoff G, Brage M. Use of ultrasonography versus magnetic resonance imaging for tendon abnormalities around the ankle. Foot Ankle Int. 1998;19(9):604–12.
72. Tol JL, Struijs PA, Bossuyt PM, Verhagen RA, van Dijk CN. Treatment strategies in osteochondral defects of the talar dome: a systematic review. Foot Ankle Int. 2000;21(2):119–26.
73. O'Driscoll SW. The healing and regeneration of articular cartilage. J Bone Joint Surg Am. 1998;80(12):1795–812.
74. Swiontkowski MF, Scranton PE, Hansen S. Tarsal coalitions: long-term results of surgical treatment. J Pediatr Orthop. 1983;3(3):287–92.
75. Selmani E, Gjata V, Gjika E. Current concepts review: peroneal tendon disorders. Foot Ankle Int. 2006;27(3):221–8.
76. Heckman DS, Reddy S, Pedowitz D, Wapner KL, Parekh SG. Operative treatment for peroneal tendon disorders. J Bone Joint Surg Am. 2008;90(2):404–18.
77. Japour C, Vohra P, Giorgini R, Sobel E. Ankle arthroscopy: follow-up study of 33 ankles–effect of physical therapy and obesity. J Foot Ankle Surg. 1996;35(3):199–209.
78. Tol JL, Verhagen RA, Krips R, et al. The anterior ankle impingement syndrome: diagnostic value of oblique radiographs. Foot Ankle Int. 2004;25(2):63–8.
79. Waitches GM, Rockett M, Brage M, Sudakoff G. Ultrasonographic-surgical correlation of ankle tendon tears. J Ultrasound Med. 1998;17(4):249–56.
80. van Dijk CN, Verhagen RA, Tol HJ. Technical note: Resterilizable noninvasive ankle distraction device. Arthroscopy. 2001;17(3):E12.
81. Amendola A, Lee KB, Saltzman CL, Suh JS. Technique and early experience with posterior arthroscopic subtalar arthrodesis. Foot Ankle Int. 2007;28(3):298–302.
82. Andrews JR, Previte WJ, Carson WG. Arthroscopy of the ankle: technique and normal anatomy. Foot Ankle. 1985;6(1):29–33.

83. Drez Jr D, Guhl JF, Gollehon DL. Ankle arthroscopy: technique and indications. Foot Ankle. 1981;2(3):138–43.
84. Ferkel RD, Fasulo GJ. Arthroscopic treatment of ankle injuries. Orthop Clin North Am. 1994;25(1):17–32.
85. Ferkel RD, Heath DD, Guhl JF. Neurological complications of ankle arthroscopy. Arthroscopy. 1996;12(2):200–8.
86. Guhl JF. New concepts (distraction) in ankle arthroscopy. Arthroscopy. 1988;4(3):160–7.
87. Unger F, Lajtai G, Ramadani F, Aitzetmuller G, Orthner E. Arthroscopy of the upper ankle joint. A retrospective analysis of complications. Unfallchirurg. 2000;103(10):858–63.
88. van Dijk CN. Hindfoot endoscopy. Foot Ankle Clin 2006;11(2):391–414, vii
89. Parisien JS, Vangsness T, Feldman R. Diagnostic and operative arthroscopy of the ankle. An experimental approach. Clin Orthop Relat Res. 1987;224:228–36.
90. Stone J, Guhl JF. Diagnostic arthroscopy of the ankle. In: Andrews JR, Tinnerman LA, editors. Diagnostic and operative arthroscopy. Philadelphia: WB Saunders; 1997. p. 423–30.
91. Voto SJ, Ewing JW, Fleissner Jr PR, Alfonso M, Kufel M. Ankle arthroscopy: neurovascular and arthroscopic anatomy of standard and trans-achilles tendon portal placement. Arthroscopy. 1989;5(1):41–6.
92. Lijoi F, Lughi M, Baccarani G. Posterior arthroscopic approach to the ankle: an anatomic study. Arthroscopy. 2003;19(1):62–7.
93. Amendola A, Petrik J, Webster-Bogaert S. Ankle arthroscopy: outcome in 79 consecutive patients. Arthroscopy. 1996;12(5):565–73.
94. Baums MH, Kahl E, Schultz W, Klinger HM. Clinical outcome of the arthroscopic management of sports-related “anterior ankle pain”: a prospective study. Knee Surg Sports Traumatol Arthrosc. 2006;14(5):482–6.
95. van Dijk CN, Tol JL, Verheyen CC. A prospective study of prognostic factors concerning the outcome of arthroscopic surgery for anterior ankle impingement. Am J Sports Med. 1997;25(6):737–45.
96. Sitler DF, Amendola A, Bailey CS, Thain LM, Spouge A. Posterior ankle arthroscopy: an anatomic study. J Bone Joint Surg Am. 2002;84-A(5):763–9.
97. de Leeuw PAJ, Golano P, van Dijk CN. A 3-portal endoscopic groove deepening technique for recurrent peroneal tendon dislocation. Techn Foot Ankle Surg. 2008;7(4):250–6.