Chapter 4
Surgical Treatment Paradigms of Ankle Lateral Instability, Osteochondral Defects and Impingement

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Abstract Ankle sprain is amongst the most frequent musculoskeletal injuries, particularly during sports activities. Chronic ankle instability (CAI) resulting from an ankle sprain might have severe long-lasting consequences on the ankle joint.

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Despite the fact that most patients will respond favourably to appropriate conservative treatment, around 20% will develop symptomatic CAI with sense of giving away and recurrent sprains leading to functional impairment. “Classical” surgical repair by Brostrom-like surgery in one of its many modifications has achieved good results over the years. Recently, major advances in surgical techniques have enabled arthroscopic repair of ankle instability with favourable outcome while also enabling the treatment of other concomitant lesions: loose bodies, osteochondral defects (OCDs) or ankle impingement. Moreover, when the tissue remnant does not permit a repair technique, anatomic reconstruction by means of using a free graft has been developed. In many cases, OCDs occur as a consequence of CAI. However, traumatic and non-traumatic aetiologies have been described. There is no evidence favouring any surgical treatment over another concerning OCDs. Considering lower cost and limited aggression, microfracture is still the most frequent surgical approach. Herein, the authors describe their algorithm in the treatment of these conditions. Similarly, anterior or posterior impingement might be linked with CAI. These are clinical syndromes based on clinical diagnosis which are currently managed arthroscopically upon failure of conservative treatment.

Keywords Ankle impingement syndromes · Ankle sprain · Chronic lateral ankle instability · Osteochondral defects

Top 10 Evidence-Based References

1. Doherty C, Bleakley C, Delahunt E, Holden S (2017) Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis. Br J Sports Med 51:113–125
2. Hunt KJ, Fuld RS, Sutphin BS, Pereira H, D’Hooghe P (2017) Return to sport following lateral ankle ligament repair is under-reported: a systematic review. J ISAKOS Joint Disorders Orthop Sports Med EPub ahed of Print. https://doi.org/10.1136/jisakos-2016-000064
3. Hélder Pereira, Gwen Vuurberg,f Nuno Gomes, Joaquim Miguel Oliveira, Pedro L. Ripoll, Rui Luís Reis, João Espregueira-Mendes, C. Niek van Dijk (2016) Arthroscopic repair of ankle instability with all-soft knotless anchors. Arthrosc Tech 5(1):e99–e107. Published online 2016 Feb 1. https://doi.org/10.1016/j.eats.2015.10.010

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4. Guillo S, Takao M, Calder J, Karlson J, Michels F, Bauer T, Ankle Instability Group (2016) Arthroscopic anatomical reconstruction of the lateral ankle ligaments. Knee Surg Sports Traumatol Arthrosc 24(4):998–1002. https://doi.org/10.1007/s00167-015-3789-z. Epub 2015 Sep 25. PMID: 26408309
5. Michels F, Pereira H, Calder J, Matricali G, Glazebrook M, Guillo S, Karlsson J, ESSKA-AFAS Ankle Instability Group (2017) Searching for consensus in the approach to patients with chronic lateral ankle instability: ask the expert. Knee Surg Sports Traumatol Arthrosc. https://doi.org/10.1007/s00167-017-4556-0. [Epub ahead of print]
6. Jari Dahmen, Kaj TA Lambers, Mikel L Reilingh, Christiaan JA van Bergen, Sjoerd AS Stufkens, Gino MMJ Kerkhoffs (2017) No superior treatment for primary osteochondral defects of the talus. Knee Surg Sports Traumatol Arthrosc. https://doi.org/10.1007/s00167-017-4616-5. [Epub ahead of print]
7. Zengerink M, Struijs PAA, Tol JL et al (2010) Treatment of osteochondral lesions of the talus: a systematic review. Knee Surg Sports Traumatol Arthrosc 18:238. https://doi.org/10.1007/s00167-009-0942-6
8. VIDEO: Athletic Injuries of the Ankle - Anterior ankle impingement ESSKA Academy. Pereira H. Jul 14, 2014; 58936 Topic: Ankle: https://academy.esska.org/esska/2014/dvds/58936/helder.pereira.athletic.injuries.of.the.ankle.-.anterior.ankle.impingement.html?f=topic=7059*media=1
9. van Dijk CN1, van Bergen C (2008) Advancements in ankle arthroscopy J Am Acad Orthop Surg 16(11):635–46.
10. Ross KA, Murawski CD, Smyth NA, Zwiers R, Wiegerinck JI, van Bergen CJ, Dijk CN, Kennedy JG (2017) Current concepts review: arthroscopic treatment of anterior ankle impingement. Foot Ankle Surg 23(1):1–8.

Fact Box 1 – Ankle Injury Epidemiology

- Inversion ankle sprain most frequent mechanisms: often during landing on the lateral border of the foot, or if the foot gets locked on the ground, while the body continues to turn.
- Isolated lesions of the ATFL occur in 65% of all injuries, while combined rupture of the ATFL and CFL occurs in approximately 20%.
- Despite adequate conservative treatment, approximately 20% of patients develop chronic lateral ankle instability.
- Nonanatomic reconstruction techniques significantly change ankle and subtalar biomechanics
- Upon failure of conservative treatment, anatomic repair or reconstruction techniques have achieved high percentage of good results.

Fact Box 2 – Surgical Options for Treatment of Lateral Ankle Instability

- The so-called anatomic techniques include isolated repair of ATFL remnant and combined ATFL and CFL repair, with or without Gould augmentation by pants-over-vest reinforcement with inferior extensor retinaculum.
- If the remnant tissues are considered as irreparable, or in revision surgeries, anatomic reconstruction by using a tendon graft (e.g. gracilis tendon) either open, percutaneous or arthroscopic has produced favourable outcome.
- Arthroscopic surgical techniques are under development with promising results (at least similar to open techniques while enabling treatment of comorbidities), but more studies are required, particularly in in high-level athletes.

Fact Box 3 – Most Frequent Risk Factors for Surgical Treatment of Lateral Ankle Instability

- Stiffness <5% (reduced ROM >5°)
- Re-rupture
- Nerve damage
- Complications with skin closure
- Risk factors for worst surgical outcome:
- Patients with hyperlaxity
- Very long-standing ligamentous injury (over 10 years)
- Previous surgery for ankle ligament repair

Fact Box 4 – Osteochondral Defects (OCDs) of the Ankle

- Traumatic and non-traumatic aetiologies have been described.
- Ankle sprain or chronic ankle instability might be implicated in the aetiology of OCD.
- Fixation of a large fragment shall be performed whenever possible.
- Microfracture is still the most popular treatment once it has favourable results, low aggression and low cost.
- Moreover, no surgical treatment has proven superiority over any other in this field so far.
- Tissue engineering and regenerative medicine approaches promise new options for the future.

Fact Box 5 – Ankle Anterior and Posterior Impingement

- Both are based on clinical diagnosis while imaging might be helpful in preoperative planning.
- Arthroscopic approach of bony or soft tissue impingement is the rule upon failure of conservative treatment.
- Both are treated in outpatient clinic with immediate range of motion and weightbearing. Full return to activity is usually achieved between 4 and 6 weeks.
- It is very important to start active dorsiflexion-plantarflexion exercises from day one to avoid stiffness.

4.1 Introduction

Ankle lateral instability is a very frequent injury which might cause functional limitations in both athletes and in the general population. It has been stated that ankle sprain is one of the most frequent injuries during sports activity; however, criteria for return to activity are under-reported [1]. The rapid direction and step's changes in addition to landings from falls, collisions and jumps present players with high injury risk during sports. These manoeuvres, which are key elements of the sport at the top level, produce high loads to the hindfoot, frequently exceeding the mechanical resistance of the ankle joint [2, 3].

An inversion ankle sprain is the most frequent cause of acute ankle injury in sports [4]. This typically occurs after a jump, when landing on the lateral border of the foot, but might also occur if the foot gets locked on the ground, while the body continues to turn.

This sudden increase in inversion and internal rotation forces, combined with either dorsi- or plantarflexion, produces sufficient strains to rupture the ankle lateral ligaments, causes concomitant osteochondral lesions or aggravates anterior or posterior joint impingement [5, 6]. The anterior talofibular ligament (ATFL) is injured first; then with increased inversion and rotation, the calcaneofibular ligament (CFL) is also torn (Fig. 4.1) [7]. In about 65% of cases, an isolated lesion of the ATFL will occur, while combined ruptures of the ATFL and CFL happen in around 20% [8, 9]. The posterior talofibular ligament (PTFL) is rarely injured during inversion sprain [10, 11]. In approximately 10–15% of all inversion injuries, there is a total rupture of the lateral ankle ligaments [12]. Moreover, 50% of these cases have concomitant other injuries in the joint (medial ligament injuries, syndesmotic injuries, loose bodies, osteochondral defects (OCDs)) [13].

If not treated adequately and in due time, these injuries will lead to chronic ankle instability (CAI) and might have severe consequences such as osteochondral defects, ankle impingement, synovitis and post-traumatic ankle arthrosis (given the recurrence of ankle sprains) [14–17]. Furthermore, patients with CAI have altered joint kinematics which in turn lead to an increased chance on recurrent ankle sprains

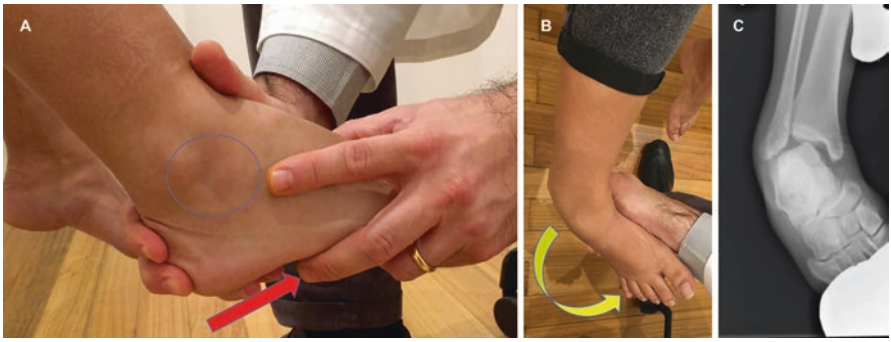

Fig. 4.1 (**A**) Anterior drawer test in which the surgeon induces anterior translation force (red arrow). The anterior dislocation of the talus makes visible a sulcus sign (blue circle). (**B**) Tilt test in which a rotational force (yellow arrow) is induced suggesting calcaneofibular ligament injury. (**C**) Varus stress X-ray reproducing the tilt test and demonstrating impingement of the talus within the ankle mortise

[18]. These persistent "microtraumatisms" will increase the possibility for osteochondral injuries as well as anterior or posterior impingement. In case of failure of conservative treatment, patients who suffer from recurrent ankle sprains can be effectively treated by means of surgical stabilization [19–21]. With the objective to minimize surgical aggression and enable immediate treatment of comorbidities, arthroscopic techniques have been developed and optimized, providing at least similar outcome as open techniques [20].

In order to preserve joint kinematics and optimize clinical results, present surgical techniques aim to restore the "normal" anatomy [22]. Use of peroneal tendons as used in the past is therefore not advised unless this is considered to be the last option [22]. The two most popular techniques include anatomic repair and anatomic reconstruction [22]. A third technique, receiving less attention in current literature, is capsular shrinkage [23]. By use of radiofrequency, the joint capsule is heated which induces shrinkage of collagenous structures aiming to tighten the ATFL (without any foreign or allogeneic material such as suture anchors or tendon grafts) [24]. Despite overall good results, de Vries et al. [23] reported the technique to be unable to modify objective ankle joint laxity.

4.2 From Ankle Sprain to Chronic Lateral Ankle Instability

Although the natural history of ankle sprains is not completely understood, the inherent stability of the ankle mortice and its congruency might contribute to the fact that complete but isolated ATFL ruptures have good prognosis. Most patients are successfully treated with functional treatment [25]. In some selected cases,

especially in elite athletes, it has been proposed that early surgery can be considered as a first-line treatment to achieve a faster return to play [26, 27].

If no ligament rupture occurs, functional rehabilitation treatment will enable to resume activities in few days/weeks. Pain is used as a guide for patients and doctors. Ruptured lateral ankle ligaments usually require a period of rigid/semi-rigid immobilization followed by soft brace protection or taping (taping has some risk of skin irritation) [28].

Despite adequate conservative treatment, around 20–30% of patients will develop CAI with persistent symptoms (fear of reinjury limiting activity, sense of giving away, and recurrent sprains) [26, 29, 30]. Standardized and reproducible criteria for reporting return to play for athletes are scarce in literature, and there are no objective guidelines to assist us in this determinant decision [1].

CAI derives from several functional and mechanical factors [7, 31, 32]. These include lower-leg proprioceptive deficits, disturbance of normal reflexes and (peroneal) muscle weakness which are relevant contributors to the persistence of the symptoms [31]. Subsequently, a thorough rehabilitation programme that emphasizes proprioceptive, neuromuscular control and balance training must always be followed. Available data report success rates up to 80% after functional rehabilitation programmes [10, 26].

4.2.1 Principles of Surgical Treatment of Lateral Ankle Instability

Surgery is indicated to restore functional stability upon failure of conservative treatment [25, 30]. The surgical options to treat CAI range from anatomic repair to nonanatomic reconstructions.

Currently, there is insufficient evidence to support any specific superior surgical intervention in the treatment of chronic ankle instability [29, 33].

Nevertheless, nonanatomic reconstruction, as the classic Evans, Watson-Jones or Chrisman-Snook procedures, has been shown to significantly alter the normal biomechanics of the ankle complex, particularly the subtalar joint [8, 9, 34, 35]. Given these concerns [33], and the favourable outcome of anatomic techniques, the former are currently the first line of surgical treatment [36–38].

Anatomic open repair was first described in 1966 by Bröstrom et al. [39]. This technique respects the original anatomy by tightening the torn ATFL and CFL to the distal fibula (Fig. 4.2). Two modifications were introduced over time by Gould et al. [40] that advises to suture the inferior retinaculum extensorum (RE) over the proximal ATFL end to augment the repair, and the modification by Karlsson et al. [41] advises to shorten the ligaments were often not disrupted but elongated.

The functional outcomes of these techniques in its many modifications have been excellent, with success rates reported as high as 87–95% [12, 40, 41]. Retrospective case series of arthroscopic repair techniques have shown successful postoperative

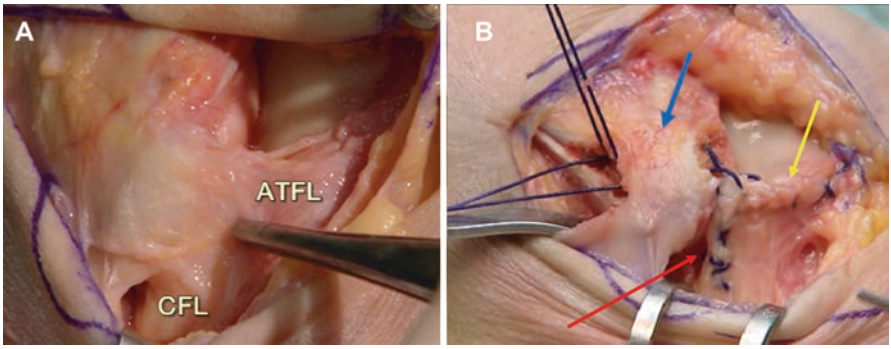

Fig. 4.2 (**A**) Open surgery where anterior tibiofibular (ATFL) and calcaneofibular ligament (CFL) are visible. (**B**) Open Brostrom repair with repair of the anterior tibiofibular (yellow arrow, ATFL) and calcaneofibular ligament (red arrow, CFL) is reattached to the fibula (blue arrow)

results with a high rate of self-reported satisfaction (94.5%), with low rate of complications (0.5–3%) [42–45].

The rehabilitation protocol after anatomic repair of the lateral ligament follows the functional treatment for acute ligament rupture, with a lower-leg cast for 1 or 2 weeks, followed by 2–4 weeks in a functional brace [37]. To encourage earlier return to play, range of movement exercises and protected loading are recommended after 2 weeks as tolerated. Inversion and rotational exercises should be limited during the first 4–6 weeks. Return to sport is usually possible between 10 and 12 weeks; dynamic postural control tests are considered valuable functional assessment tools to progress in return to full activities [4, 33, 46].

4.2.2 Recent Advances in Surgery for Ankle Instability

All the anatomic repair techniques depend on the quality of the ligaments' remnant in order to achieve an effective repair [36]. Karlsson et al. determined risk factors for worst outcome: hyperlaxity, long-standing injuries and previous surgical treatment [41].

When the tissue remnant is considered inadequate for repair, then anatomic reconstruction using a free tendon graft (autograft or allograft), usually the gracilis tendon, has been proposed with favourable outcome [47, 48]. Available clinical data suggest that these anatomic free graft-based reconstructions, either by arthroscopic, percutaneous or open techniques [49], enable favourable outcome in properly selected cases: inadequate remnant or as a salvage/revision procedure [47, 48, 50, 51].

Graft-based reconstructions may lead to increased stiffness once the graft is much stronger than the native tissue [47]. Usually a more aggressive rehabilitation is possible, depending on the intraoperative achieved tension and graft fixation [52].

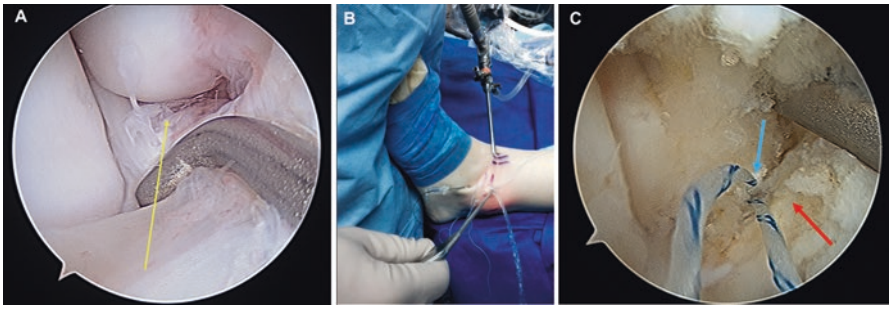

Fig. 4.3 (**A**) Arthroscopic view of the ATFL remnant detached from the fibula (yellow arrow); (**B**) outside view of arthroscopic ATFL repair; (**C**) arthroscopic view of reattachment of the ATFL remnant (red arrow) to the fibula and knot tying (light blue arrow)

Song et al. recently showed a midterm better ankle joint function in patients who received an ATFL reconstruction, compared with the Broström procedure [51], but this finding requires further research with larger series and uniform selection criteria followed by randomized studies.

The current trend is on the pursuit of minimally invasive arthroscopic techniques (Fig. 4.3). Based on the favourable outcome of open ligament repair, several authors have described repair techniques aiming to replicate what has been learnt with open surgery and achieve similar repairs with arthroscopic anchor-based approaches [36–38, 42, 49, 53]. This might lower the surgical morbidity and shorten the time of recovery [54, 55]. Arthroscopy also enables the treatment of concomitant intra-articular lesions in addition to ankle stabilization [14, 56]. Considering the aforementioned retrospective series, comparative studies for open and arthroscopic anatomic lateral ligament repair have shown similar clinical and biomechanical outcome [20, 54, 55].

4.3 Ankle Osteochondral Defects

An osteochondral defect (OCD) of the talus is a lesion involving the talar articular cartilage and its subchondral bone. Several classifications have been used over time, but the first comes from 1959 from Berndt and Harty [57]. OCDs are usually caused by a single or multiple traumatic events, but non-traumatic, idiopathic OCDs of the ankle have been described [58–61]. No classification fully addresses the problem, but the anatomic grid proposed by Raikin and Elias has proven to be useful both in the talus and the tibial plafond [62, 63]. The defect initially may involve only superficial cartilage damage caused by shearing stresses, without damage to the underlying subchondral bone, but a bony injury after a high-impact force also can cause a defect [64]. Ankle trauma associated with an OCD often develops leading to the formation of subchondral bone cysts. These cysts are related with persistent

deep ankle pain thereby causing functional impairment. Most OCDs of the talus are found on the anterolateral or posteromedial talar dome [65]. Lateral lesions are usually shallow oval shaped, and a shear mechanism has been proposed to be more frequently implicated. This opposes to medial lesions which are usually deeper, and cup shaped, suggesting a mechanism of torsional impaction and axial loading [58, 60]. Despite several theories and basic science studies concerning OCDs of the talus, its aetiology and pathogenesis are still not fully comprehended.

An OCD might have an acute onset. However, the process leading to subchondral cyst formation requires some time, and it's a slower process [66]. The reason why some OCDs remain asymptomatic is still unclear, while others with apparently similar features cause pain on weightbearing (aggravated by effort), show persistent bone oedema on magnetic resonance imaging and ultimately lead to a subchondral cyst. Understanding this process would be critical in order to prevent progressive joint damage [66].

A traumatic event is commonly accepted as the most important aetiologic factor of an OCD of the talus. For lateral talar defects, trauma has been implicated in 93–98% and for medial defects in 61–70% [67]. OCD aetiology can be divided in non-traumatic and traumatic defects [60]. Vascular aetiology, ischemia, subsequent necrosis, and genetics have been accepted as aetiologic factors [58]. Moreover, OCDs have been found in identical twins and siblings [68]. OCDs are bilateral in 10% of patients [69]. Traumatic cartilage lesions include three categories: microdamage or blunt trauma, chondral fractures and osteochondral fractures [70].

Ankle sprains have a predominant role in the aetiology of traumatic OCDs, once these are probably the most frequent traumatic events leading to these injuries [13]. When a talus twists inside its "bony mortice" during an ankle sprain, the cartilage covering of the talus can be damaged by direct impactions causing a real OCD, bone bruise, cartilage crack or delamination. Shearing forces might cause separation in superficial layer of the cartilage [60]. Loose bodies can be created (and cause even more cartilage damage), or OCDs might remain partially stable in its position (Fig. 4.4). The lesions can either heal and remain asymptomatic, or progress to deep ankle pain on weightbearing and form subchondral bone cysts. IBerndt and Harty were able to reproduce lateral ankle OCDs under laboratory conditions by intensely inverting a dorsiflexed ankle. As the foot was inverted, the lateral border of the talar dome was compacted against the face of the fibula, and when the lateral ligament ruptured it lead to cartilage avulsion. During application of excessive inverting force, the talus rotated laterally in the frontal plane within the mortise, thus impacting and compressing the lateral talar margin against the articular surface of the fibula. With this mechanism, a portion of the talar margin was sheared off from the main body of the talus, causing a lateral OCD. A medial lesion was reproduced by plantarflexing the ankle in combination with slight anterior displacement of the talus on the tibia and inversion and internal rotation of the talus on the tibia [57, 60].

For this reason, one can assume a tight connection between most ankle OCDs and CAI which is the topic for reflection in the herein presented paper.

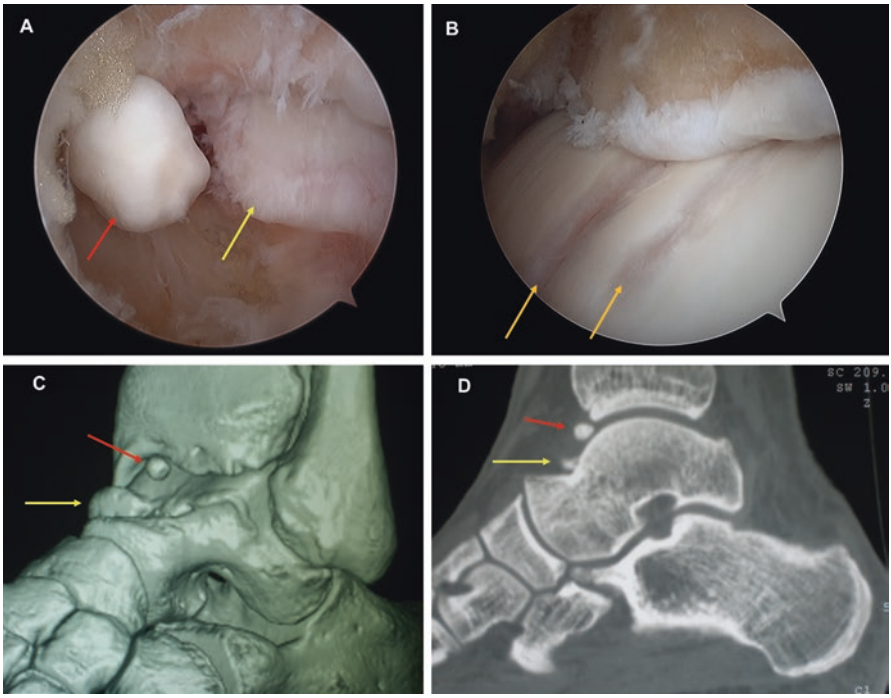

Fig. 4.4 (**A**, **B**) Arthroscopic view of loose body (red arrow) and talar spur (yellow arrow), causing osteochondral ridge defects (orange arrow on the talar dome). (**C**, **D**) CT view of the loose body (red arrow) and talar spur (yellow arrow)

4.3.1 Principles of Surgical Treatment of Osteochondral Defects

Asymptomatic incidental findings of the ankle are not infrequent, including within athletic population [71].

Asymptomatic and/or low symptomatic OCDs can usually be treated conservatively, even if kept under clinical and/or image surveillance. Conservative treatment includes orthobiologics, physiotherapy, periods of rest or immobilization (e.g. Walker Boot) [59, 65].

Regarding the symptomatic ankle OCDs, several approaches are possible depending on the characteristics of the lesion and patient profile. There is no current consensus in literature of clear superiority of any surgical treatment over another either in primary or secondary ankle OCDs [65, 72, 73].

Preoperative planning is of paramount relevance, and it should always include X-rays for alignment assessment and global evaluation. The computed tomography (CT) is a critical method since it provides a relatively more reliable assessment of bone defects, which can be overestimated by the MRI oedema around the defect

Table 4.1 Practical algorithm for surgical treatment of osteochondral defects of the ankle

Type of osteochondral defect	Treatment option
Asymptomatic/low-symptomatic lesions	Conservative: periods of rest/walker boot
Symptomatic lesions ≤ 15 mm	Excision, curettage and bone marrow stimulation (ECBMS)
Symptomatic lesions ≥ 15 mm	Fixation* / OATS Consider ECBMS
Large talar cystic lesion	Retrograde drilling ± bone transplant Consider ECBMS
Secondary lesions	OATS/ACI/Hemicap ®/Osteotomy Consider ECBMS

ECBMS excision, curettage and bone marrow stimulation, *OATS* osteochondral autologous transplantation surgery, *ACI* autologous chondrocyte implantation (last generation); Hemicap®, metallic implant for partial replacement of the medial talar dome. ECBMS is considered in most cases given the outcome possibilities and lower aggression and cost. Lower percentage of good/excellent results is to be expected in larger lesions and revision surgery

mainly in T2 sequences. However, the presence of such oedema in T2 suggests activity around the lesion. Moreover, CT lateral view in plantar flexion or dorsiflexion is helpful to determine if it's possibly an anterior or posterior arthroscopic approach or if an open approach is required (medial malleolar osteotomy for medial defects or lateral ligament detachment and afterwards reinsertion for lateral defects). Arthroscopic approach is currently the preferred and most frequently used for both anterior and posterior compartments [74]. Moreover, when no fixed distraction is used, the percentage of complications is extremely low [75].

Given the lack of evidence of any superior treatment, the author's approach favours to prefer the less aggressive options. More aggressive, thus more prone to complications or higher cost procedures are considered for secondary or revision surgeries (Table 4.1).

Whenever possible, an ankle OCD which is possible to fix in place (with sufficient size and preferably with some underlying bone) will constitute our first option (Fig. 4.5). Either open or arthroscopic, the "lift, drill, fill, fix" technique should always be considered once it is the one who preserves the most of the native tissue and hyaline cartilage [76] (lift, the defect; drill, by making microfracture or bone marrow stimulation; fill, the defect with bone graft; and fix, the fragment with metallic or bioabsorbable screws or pins).

In OCDs smaller than 15 mm, excision, curettage and bone marrow stimulation, usually by microfractures (Fig. 4.6), aims to stimulate the underlying subchondral bone bringing "blood" containing growth factors (GFs) and mesenchymal stem cells (MSCs) which will promote fibrocartilage coverage of the defect and provide around 85% of successful outcome at a 5-year follow-up [77]. Given the satisfactory results with minimal aggression, depending on the patient profile and injury characteristics, this approach can also be considered in bigger lesions unable for fixation or secondary injuries [65, 72, 73].

Large cystic lesions, including tibial OCDs, can be addressed by retrograde drilling to lower the pressure within the cyst and filling with bone graft when possible or required.

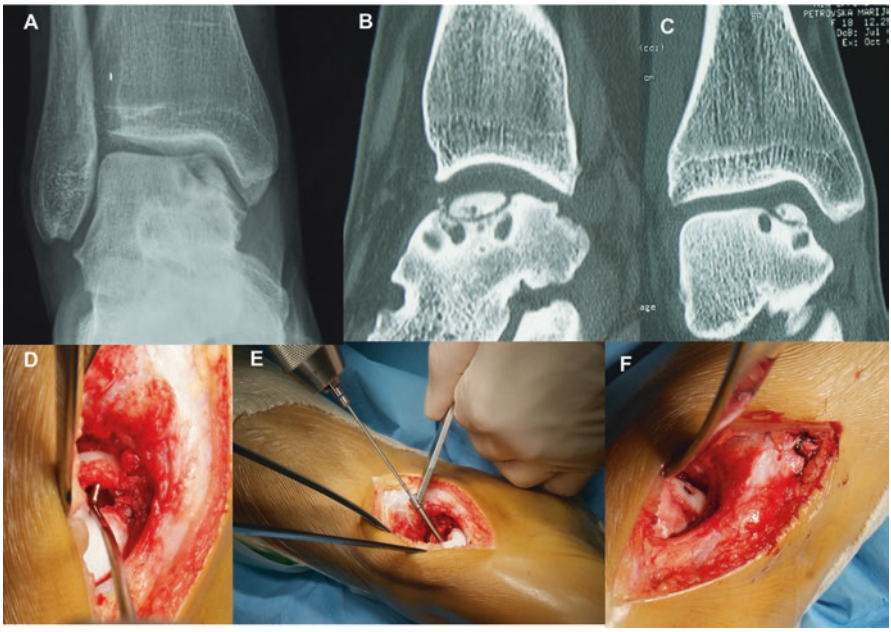

Fig. 4.5 (**A**) X-ray with visible medial OCD on the talar dome. (**B, C**) CT confirms OCD with underlying bone and cystic lesions around it. (**D**) After medial malleolus osteotomy, the OCD is lifted, submitted to bone marrow stimulation and filled with bone autograft. (**E**) The fragment is fixed. (**F**) Final view with fixation with compression screw

The osteochondral autologous transplantation surgery (OATS) consists in harvesting osteochondral cylinders from the knee to fill an ankle defect. Despite a high rate of successful outcome stated by the promoters, a systematic review has shown that this technique is linked to a high percentage of complication [78]. So, in our algorithm it remains a salvage procedure for large OCDs or secondary lesions (after failure of previous surgeries).

Cell-based therapies, scaffolds and augmentation with hydrogels, despite being quite promising, have not been able to consistently present superiority to the previously described techniques on the clinical setting. For this reason, and considering their high cost, they remain options for revision surgeries or large injuries without possibility for fixation and not amenable by any of the previous techniques [79–95]. However, we strongly believe in advanced tissue engineering and regenerative medicine approaches for the future.

When all biologic surgical treatments fail, a novel metallic implant designed for secondary defects of the medial talar dome (Hemicap®) has provided favourable outcome [96].

Finally, realignment by means of the osteotomy (calcaneal sliding (Fig. 4.7) or supramalleolar) is a powerful tool to provide a more favourable biomechanical environment for OCD healing by unloading the affected site [97, 98].

As a last resource, ankle fusion or ankle arthroplasty in very selective cases might be the end line treatment [98].

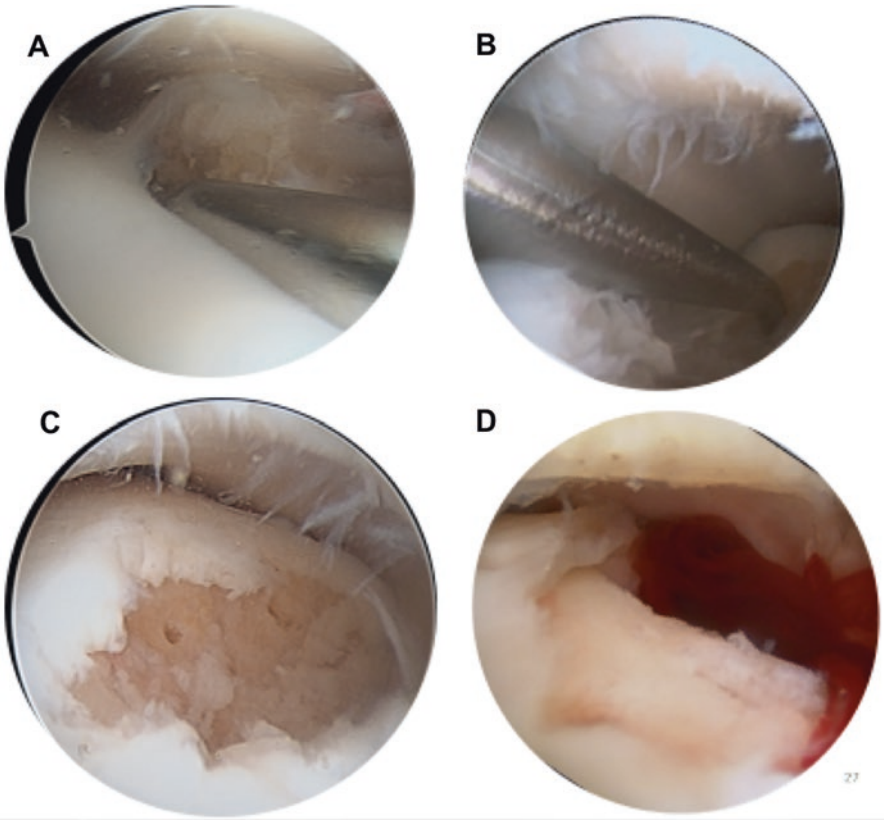

Fig. 4.6 (**A**) Ankle OCD arthroscopic view and removal of unstable fragment; (**B**) microfracture probe; (**C**) final look after microfractures; (**D**) blood coming from the microfracture holes after reliving the tourniquet

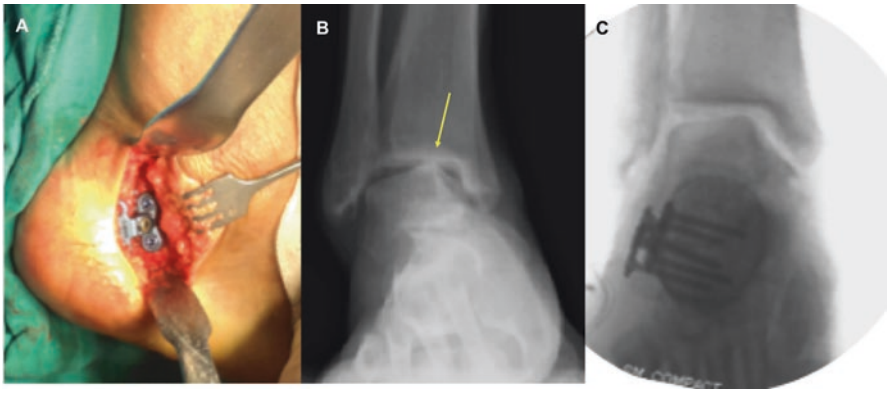

Fig. 4.7 (**A**) Surgical procedure of calcaneal sliding osteotomy; (**B**) preoperative X-ray demonstrating severe varus with impingement of the talus on the tibial plafond; (**C**) final position achieved with improved alignment enabling better load distribution

4.4 Ankle Impingement Syndromes

Repetitive microtrauma to the anterior aspect of the ankle joint might lead to bony spur formation ultimately causing anterior impingement syndrome [99]. This microtrauma might be linked to CAI or repetitive direct impact force (e.g. kicking a ball) [100]. About one third of patients with CAI will experience pain related to ankle impingement. Injury of the anterior-inferior talofibular ligament might lead to the development of a "meniscoid lesion" which might cause soft tissue anterolateral impingement [99]. Impingement is considered as a syndrome, meaning that it is basically a clinical diagnosis in which the key sentence is superficial recognizable pain on palpation. Patients complain of persistent pain in walking, aggravated by climbing stairs (dorsiflexion or local pressure might cause entrapment of soft tissue/synovitis between two hard surfaces). Anterior or anteromedial impingement is usually caused by osteophytes, which are not enthesophytes (Fig. 4.8). They do not result traction once they are included in the limits of the capsule [101]. X-ray (including the AMIC view –anteromedial oblique view) [102] or CT (less frequently MRI) can be useful for preoperative planning and identification of concomitant loose bodies or painful broken osteophytes.

Posterior impingement syndrome concerns a mechanical conflict due to hyperplantarflexion [103]. It can be either acute (*os trigonum* or Stieda process fracture or dislocation) after trauma [104] or chronic, caused by repetitive microtrauma (which might also be linked to CAI) (Fig. 4.9). Chronic cases can be linked to hypertrophic os trigonum or posterior talar process as well as related fractures or soft tissue impingement (e.g. cysts). It is often observed in footballers, cyclers, swimmers, acro-gymnasts and ballet dancers [105, 106]. It is also a syndrome, where posterior impingement test is most helpful and imaging is used for preoperative planning in most cases [107]. Upon failure of conservative treatment (physiotherapy, injections, shoe wear), surgical treatment is recommended.

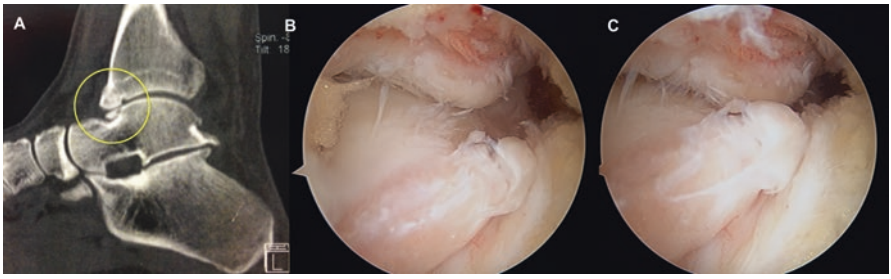

Fig. 4.8 (**A**) CT demonstrating anterior impingement (yellow circle); (**B**, **C**) arthroscopic view in neutral position and dorsiflexion where bony impingement is confirmed

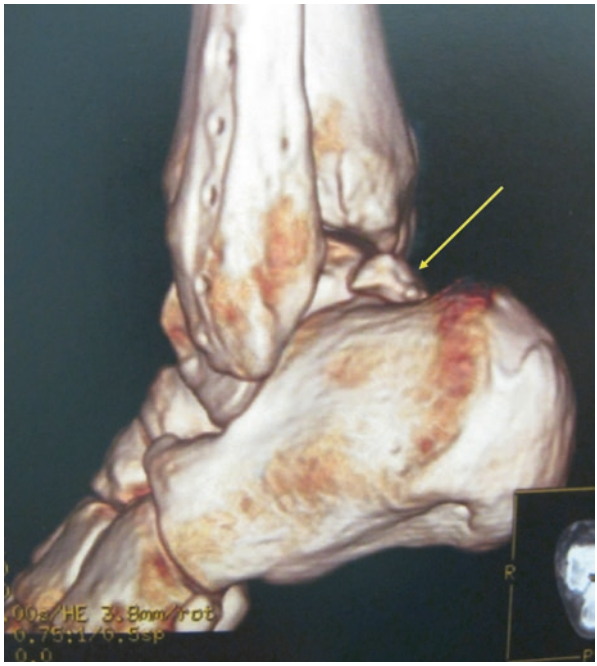

Fig. 4.9 CT 3D view of plantarflexion ankle with posterior impingement with os trigonum (yellow arrow)

4.4.1 Principles of Surgical Treatment of Anterior Impingement

The treatment of anterior, anteromedial, anterolateral, bony or soft tissue ankle impingement is nowadays achieved mainly by arthroscopic approach. The medial portal is created in dorsiflexion, medial to the crossing line between the anterior tibialis tendon and the joint line [108]. This way the cartilage surface is protected under the tibial plafond, and the working space is "opened". The lateral portal is performed under transillumination and again in dorsiflexion to avoid nerve damage (the superficial peroneal nerve moves posteriorly). The tibial osteophyte shall be removed from superior to inferior and the talar osteophyte from distal to proximal to fully control the bone morphology [101, 107]. It is recommended to minimize aggression which will ultimately lead to a faster recovery and avoid secondary instability due to loss of bony contact (if too much bone is removed) [101, 107]. This is an outpatient procedure, and the patient can weight bear from day 1 if tolerated. It is very important to start active dorsiflexion-plantarflexion exercises from day 1 to avoid stiffness. Stiches are removed at 2 weeks, and full return to activity is possible within 4–6 weeks. Satisfactory results have been published around 85–90% at a 5-year follow-up, and around 80% remain asymptomatic at an 8-year follow-up [101, 107].

4.4.2 *Principles of Surgical Treatment of Posterior Impingement*

The two-portal endoscopic approach for the hindfoot described by Van Dijk et al. created a revolution in the treatment of these conditions [109], either bony or soft tissue impingement. It lowered dramatically the surgical aggression as it is an outpatient procedure, and the patient can weight bear from day 1 if tolerated. Once more, it is very important to start active dorsiflexion-plantarflexion exercises from day 1. Stiches are removed at 2 weeks, and full return to activity is possible within 4–6 weeks for isolated procedures [103]. The flexor hallucis longus tendon is used as a medial landmark to define a safe working area to avoid the medial neurovascular bundle.

The knowledge of anatomy is fundamental, and the step-by-step technique has been described elsewhere [110]. Effort shall be made to remove the *os trigonum* in one piece to avoid living small loose bodies behind.

4.5 Final Remarks

- The majority of inversion ankle sprains are effectively managed with functional conservative treatment, even in the case of ligament rupture.
- There is increasing evidence on the effectiveness of arthroscopic approach for CAI treatment. So far, the reported outcomes are at least equivalent to open techniques. However, more high-level studies are still needed.
- When repair of the remnant tissue is no longer possible, anatomic reconstruction by using a free graft (auto- or allograft) has provided good results and is also suitable for revision cases. Moreover, replication of the anatomy may facilitate to overcome the limitations of previous nonanatomic techniques.
- Osteochondral defects can have traumatic and non-traumatic aetiology. CAI is a major cause of traumatic OCDs.
- Fixation of an OCD should be performed whenever possible. Besides this, the most frequent surgical treatment remains bone marrow stimulation (e.g. microfractures). This relies on the high percentage of satisfactory results and lower aggression, as well as the fact that no surgical procedure has, so far, demonstrated consistent advantage over the former.
- Tissue engineering and regenerative medicine promises to provide new more effective options for the future.
- Anterior and posterior impingement syndromes are based on clinical diagnosis while imaging is helpful in preoperative planning.
- Aetiology can be traumatic with the contribution of repeated microtrauma connected to CAI.

- Arthroscopic/endoscopic approaches for both these entities enable high percentage of good results with minimal complications and fast return to activity.
- CAI, as herein described, is a major entity which can cause further damage through time in the ankle joint. Effective and timely treatment will avoid further joint damage.

References

1. Hunt KJ, Fuld RS, Sutphin BS, Pereira H, D'Hooghe P (2017) Return to sport following lateral ankle ligament repair is under-reported: a systematic review. J ISAKOS Joint Disorders Orthop Sports Med. EPub ahed of Print. https://doi.org/10.1136/jisakos-2016-000064
2. Lindner M, Kotschwar A, Zsoldos RR, Groesel M, Peham C (2012) The jump shot - a biomechanical analysis focused on lateral ankle ligaments. J Biomech 45(1):202–206. https://doi.org/10.1016/j.jbiomech.2011.09.012
3. Kristianslund E, Krosshaug T (2013) Comparison of drop jumps and sport-specific sidestep cutting: implications for anterior cruciate ligament injury risk screening. Am J Sports Med 41(3):684–688. https://doi.org/10.1177/0363546512472043
4. D'Hooge P, Giza E, Longo G Torn ankle ligaments in elite handball: does a player require surgery? Aspetar Sports Medicine Journal N.A. 186–194. http://www.aspetar.com/journal/upload/PDF/2014410115142.pdf
5. Fong DT, Ha SC, Mok KM, Chan CW, Chan KM (2012) Kinematics analysis of ankle inversion ligamentous sprain injuries in sports: five cases from televised tennis competitions. Am J Sports Med 40(11):2627–2632. https://doi.org/10.1177/0363546512458259
6. Kristianslund E, Bahr R, Krosshaug T (2011) Kinematics and kinetics of an accidental lateral ankle sprain. J Biomech 44(14):2576–2578. https://doi.org/10.1016/j.jbiomech.2011.07.014
7. Brostroem L (1964) SPRAINED ANKLES. I. ANATOMIC LESIONS IN RECENT SPRAINS. Acta Chir Scand 128:483–495
8. Pereira H, D'Hooghe P, Anderson N, Fuld R, Kelley JZ, Baldini TH, Isakos Laf Committee, Hunt K (2017) Ankle and subtalar joint kinematics following lateral ligament repair-implications for early surgical treatment. Arthroscopy J Arthrosc Relat Surg 33(10):e101. https://doi.org/10.1016/j.arthro.2017.08.106
9. Hunt K, D'Hooghe P, Kelley JZ, Anderson N, Fuld R, Baldini TH, Isakos Laf Committee, Pereira H (2017) The role of calcaneofibular ligament (CFL) injury in ankle instability: implications for surgical management. Arthroscopy J Arthrosc Relat Surg 33(10, Supplement):e51–e52 (10). https://doi.org/10.1016/j.arthro.2017.08.024
10. Baumhauer JF, O'Brien T (2002) Surgical considerations in the treatment of ankle instability. J Athl Train 37(4):458–462
11. Lynch SA (2002) Assessment of the injured ankle in the athlete. J Athl Train 37(4):406–412
12. Brostroem L (1966) Sprained ankles. V. Treatment and prognosis in recent ligament ruptures. Acta Chir Scand 132(5):537–550
13. van Dijk CN, Bossuyt PM, Marti RK (1996) Medial ankle pain after lateral ligament rupture. J Bone Joint Surg 78(4):562–567
14. Ferkel RD, Chams RN (2007) Chronic lateral instability: arthroscopic findings and long-term results. Foot Ankle Int 28(1):24–31. https://doi.org/10.3113/fai.2007.0005
15. Lee J, Hamilton G, Ford L (2011) Associated intra-articular ankle pathologies in patients with chronic lateral ankle instability: arthroscopic findings at the time of lateral ankle reconstruction. Foot Ankle Spec 4(5):284–289
16. Liszka H, Depukat P, Gadek A (2016) Intra-articular pathologies associated with chronic ankle instability. Folia Med Cracov 56(2):95–100

17. Harrington KD (1979) Degenerative arthritis of the ankle secondary to long-standing lateral ligament instability. J Bone Joint Surg Am 61(3):354–361
18. Kobayashi T, Gamada K (2014) Lateral ankle sprain and chronic ankle instability: a critical review. Foot Ankle Spec 7(4):298–326. https://doi.org/10.1177/1938640014539813
19. Guillo S, Takao M, Calder J, Karlson J, Michels F, Bauer T (2015) Arthroscopic anatomical reconstruction of the lateral ankle ligaments. Knee Surg Sports Traumatol Arthrosc Off J ESSKA. https://doi.org/10.1007/s00167-015-3789-z
20. Drakos MC, Behrens SB, Paller D, Murphy C, DiGiovanni CW (2014) Biomechanical comparison of an open vs arthroscopic approach for lateral ankle instability. Foot Ankle Int 35(8):809–815. https://doi.org/10.1177/1071100714535765
21. Struijs PA, Kerkhoffs GM (2010) Ankle sprain. BMJ Clin Evid 2010:1115
22. Ferran NA, Oliva F, Maffulli N (2009) Ankle instability. Sports Med Arthrosc Rev 17(2):139–145. https://doi.org/10.1097/JSA.0b013e3181a3d790
23. de Vries JS, Krips R, Blankevoort L, Fievez AW, van Dijk CN (2008) Arthroscopic capsular shrinkage for chronic ankle instability with thermal radiofrequency: prospective multicenter trial. Orthopedics 31(7):655
24. Maiotti M, Massoni C, Tarantino U (2005) The use of arthroscopic thermal shrinkage to treat chronic lateral ankle instability in young athletes. Arthroscopy J Arthrosc Relat Surg Off Publ Arthrosc Assoc North Am Int Arthrosc Assoc 21(6):751–757. https://doi.org/10.1016/j.arthro.2005.03.016
25. Michels F, Pereira H, Calder J, Matricali G, Glazebrook M, Guillo S, Karlsson J, Group E-AAI, Acevedo J, Batista J, Bauer T, Calder J, Carreira D, Choi W, Corte-Real N, Glazebrook M, Ghorbani A, Giza E, Guillo S, Hunt K, Karlsson J, Kong SW, Lee JW, Michels F, Molloy A, Mangone P, Matsui K, Nery C, Ozeki S, Pearce C, Pereira H, Perera A, Pijnenburg B, Raduan F, Stone J, Takao M, Tourne Y, Vega J (2017) Searching for consensus in the approach to patients with chronic lateral ankle instability: ask the expert. Knee Surg Sports Traumatol Arthrosc Off J ESSKA. https://doi.org/10.1007/s00167-017-4556-0
26. Kerkhoffs GM, van den Bekerom M, Elders LA, van Beek PA, Hullegie WA, Bloemers GM, de Heus EM, Loogman MC, Rosenbrand KC, Kuipers T, Hoogstraten JW, Dekker R, Ten Duis HJ, van Dijk CN, van Tulder MW, van der Wees PJ, de Bie RA (2012) Diagnosis, treatment and prevention of ankle sprains: an evidence-based clinical guideline. Br J Sports Med 46(12):854–860. https://doi.org/10.1136/bjsports-2011-090490
27. White WJ, McCollum GA, Calder JD (2016) Return to sport following acute lateral ligament repair of the ankle in professional athletes. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 24(4):1124–1129. https://doi.org/10.1007/s00167-015-3815-1
28. Kemler E, van de Port I, Schmikli S, Huisstede B, Hoes A, Backx F (2015) Effects of soft bracing or taping on a lateral ankle sprain: a non-randomised controlled trial evaluating recurrence rates and residual symptoms at one year. J Foot Ankle Res 8:13. https://doi.org/10.1186/s13047-015-0069-6
29. de Vries JS, Krips R, Sierevelt IN, Blankevoort L (2006) Interventions for treating chronic ankle instability. Cochrane Database Syst Rev 4:CD004124. https://doi.org/10.1002/14651858.CD004124.pub2
30. Doherty C, Bleakley C, Delahunt E, Holden S (2017) Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis. Br J Sports Med 51(2):113–125. https://doi.org/10.1136/bjsports-2016-096178
31. Hertel J (2002) Functional Anatomy, Pathomechanics, and Pathophysiology of Lateral Ankle Instability. J Athl Train 37(4):364–375
32. McKay GD, Goldie PA, Payne WR, Oakes BW (2001) Ankle injuries in basketball: injury rate and risk factors. Br J Sports Med 35(2):103–108
33. de Vries JS, Krips R, Sierevelt IN, Blankevoort L, van Dijk CN (2011) Interventions for treating chronic ankle instability. Cochrane Database Syst Rev 8:CD004124. https://doi.org/10.1002/14651858.CD004124.pub3

34. Karlsson J, Bergsten T, Lansinger O, Peterson L (1989) Surgical treatment of chronic lateral instability of the ankle joint. A new procedure. Am J Sports Med 17(2):268–273.; discussion 273-264. https://doi.org/10.1177/036354658901700220
35. Vuurberg G, Veen OC, Pereira H, Blankevoort L, van Dijk CN (2017) Tenodesis reconstruction in patients with chronic lateral ankle instability is associated with a high risk of complications compared with anatomic repair and reconstruction: a systematic review and meta-analysis. J ISAKOS Joint Disorders Orthop Sports Med. https://doi.org/10.1136/jisakos-2016-000121
36. Vega J, Golano P, Pellegrino A, Rabat E, Pena F (2013) All-inside arthroscopic lateral collateral ligament repair for ankle instability with a knotless suture anchor technique. Foot Ankle Int 34(12):1701–1709. https://doi.org/10.1177/1071100713502322
37. Pereira H, Vuurberg G, Gomes N, Oliveira JM, Ripoll PL, Reis RL, Espregueira-Mendes J, Niek van Dijk C (2016) Arthroscopic repair of ankle instability with all-soft knotless anchors. Arthrosc Tech 5(1):e99–e107. https://doi.org/10.1016/j.eats.2015.10.010
38. Takao M, Matsui K, Stone JW, Glazebrook MA, Kennedy JG, Guillo S, Calder JD, Karlsson J, Ankle Instability G (2016) Arthroscopic anterior talofibular ligament repair for lateral instability of the ankle. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 24(4):1003–1006. https://doi.org/10.1007/s00167-015-3638-0
39. Brostrom L (1966) Sprained ankles. VI. Surgical treatment of "chronic" ligament ruptures. Acta Chir Scand 132(5):551–565
40. Gould N, Seligson D, Gassman J (1980) Early and late repair of lateral ligament of the ankle. Foot Ankle 1(2):84–89
41. Karlsson J, Bergsten T, Lansinger O, Peterson L (1988) Reconstruction of the lateral ligaments of the ankle for chronic lateral instability. J Bone Joint Surg Am 70(4):581–588
42. Matsui K, Burgesson B, Takao M, Stone J, Guillo S, Glazebrook M, Group EAAI (2016) Minimally invasive surgical treatment for chronic ankle instability: a systematic review. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 24(4):1040–1048. https://doi.org/10.1007/s00167-016-4041-1
43. Acevedo JI, Mangone P (2015) Arthroscopic Brostrom technique. Foot Ankle Int 36(4):465–473. https://doi.org/10.1177/1071100715576107
44. Lui TH (2016) Modified arthroscopic brostrom procedure with bone tunnels. Arthrosc Tech 5(4):e775–e780. https://doi.org/10.1016/j.eats.2016.03.003
45. Prissel MA, Roukis TS (2014) All-inside, anatomical lateral ankle stabilization for revision and complex primary lateral ankle stabilization: a technique guide. Foot Ankle Spec 7(6):484–491. https://doi.org/10.1177/1938640014548418
46. Pearce CJ, Tourne Y, Zellers J, Terrier R, Toschi P, Silbernagel KG, Group E-AAI (2016) Rehabilitation after anatomical ankle ligament repair or reconstruction. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 24(4):1130–1139. https://doi.org/10.1007/s00167-016-4051-z
47. Takao M, Oae K, Uchio Y, Ochi M, Yamamoto H (2005) Anatomical reconstruction of the lateral ligaments of the ankle with a gracilis autograft: a new technique using an interference fit anchoring system. Am J Sports Med 33(6):814–823. https://doi.org/10.1177/0363546504272688
48. Coughlin MJ, Schenck RC Jr, Grebing BR, Treme G (2004) Comprehensive reconstruction of the lateral ankle for chronic instability using a free gracilis graft. Foot Ankle Int 25(4):231–241. https://doi.org/10.1177/107110070402500407
49. Guillo S, Takao M, Calder J, Karlson J, Michels F, Bauer T, Ankle Instability G (2016) Arthroscopic anatomical reconstruction of the lateral ankle ligaments. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 24(4):998–1002. https://doi.org/10.1007/s00167-015-3789-z
50. Okuda R, Kinoshita M, Morikawa J, Jotoku T, Abe M (1999) Reconstruction for chronic lateral ankle instability using the palmaris longus tendon: is reconstruction of

the calcaneofibular ligament necessary? Foot Ankle Int 20(11):714–720. https://doi.org/10.1177/107110079902001107
51. Song B, Li C, Chen N, Chen Z, Zhang Y, Zhou Y, Li W (2017) All-arthroscopic anatomical reconstruction of anterior talofibular ligament using semitendinosus autografts. Int Orthop 41(5):975–982. https://doi.org/10.1007/s00264-017-3410-9
52. Glazebrook M, Stone J, Matsui K, Guillo S, Takao M, Group EAAI (2016) Percutaneous ankle reconstruction of lateral ligaments (Perc-Anti RoLL). Foot Ankle Int 37(6):659–664. https://doi.org/10.1177/1071100716633648
53. Corte-Real NM, Moreira RM (2009) Arthroscopic repair of chronic lateral ankle instability. Foot Ankle Int 30(3):213–217. https://doi.org/10.3113/FAI.2009.0213
54. Yeo ED, Lee KT, Sung IH, Lee SG, Lee YK (2016) Comparison of all-inside arthroscopic and open techniques for the modified brostrom procedure for ankle instability. Foot Ankle Int 37(10):1037–1045. https://doi.org/10.1177/1071100716666508
55. Matsui K, Takao M, Miyamoto W, Matsushita T (2016) Early recovery after arthroscopic repair compared to open repair of the anterior talofibular ligament for lateral instability of the ankle. Arch Orthop Trauma Surg 136(1):93–100. https://doi.org/10.1007/s00402-015-2342-3
56. Hintermann B, Boss A, Schafer D (2002) Arthroscopic findings in patients with chronic ankle instability. Am J Sports Med 30(3):402–409. https://doi.org/10.1177/03635465020300031601
57. Berndt AL, Harty M (1959) Transchondral fractures (osteochondritis dissecans) of the talus. J Bone Joint Surg Am 41-A:988–1020
58. Schachter AK, Chen AL, Reddy PD, Tejwani NC (2005) Osteochondral lesions of the talus. J Am Acad Orthop Surg 13(3):152–158
59. O'Loughlin PF, Heyworth BE, Kennedy JG (2010) Current concepts in the diagnosis and treatment of osteochondral lesions of the ankle. Am J Sports Med 38(2):392–404. https://doi.org/10.1177/0363546509336336
60. van Dijk CN, Reilingh ML, Zengerink M, van Bergen CJ (2010) Osteochondral defects in the ankle: why painful? Knee Surgery Sports Traumatol Arthrosc Off J ESSKA 18(5):570–580. https://doi.org/10.1007/s00167-010-1064-x
61. Ventura A, Terzaghi C, Legnani C, Borgo E (2013) Treatment of post-traumatic osteochondral lesions of the talus: a four-step approach. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 21(6):1245–1250. https://doi.org/10.1007/s00167-012-2028-0
62. Elias I, Raikin SM, Schweitzer ME, Besser MP, Morrison WB, Zoga AC (2009) Osteochondral lesions of the distal tibial plafond: localization and morphologic characteristics with an anatomical grid. Foot Ankle Int 30(6):524–529. https://doi.org/10.3113/FAI.2009.0524
63. Elias I, Zoga AC, Morrison WB, Besser MP, Schweitzer ME, Raikin SM (2007) Osteochondral lesions of the talus: localization and morphologic data from 424 patients using a novel anatomical grid scheme. Foot Ankle Int 28(2):154–161. https://doi.org/10.3113/FAI.2007.0154
64. Vellet AD, Marks PH, Fowler PJ, Munro TG (1991) Occult posttraumatic osteochondral lesions of the knee: prevalence, classification, and short-term sequelae evaluated with MR imaging. Radiology 178(1):271–276. https://doi.org/10.1148/radiology.178.1.1984319
65. Zengerink M, Struijs PA, Tol JL, van Dijk CN (2010) Treatment of osteochondral lesions of the talus: a systematic review. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 18(2):238–246. https://doi.org/10.1007/s00167-009-0942-6
66. Durr HD, Martin H, Pellengahr C, Schlemmer M, Maier M, Jansson V (2004) The cause of subchondral bone cysts in osteoarthrosis: a finite element analysis. Acta Orthop Scand 75(5):554–558. https://doi.org/10.1080/00016470410001411
67. Verhagen RA, Struijs PA, Bossuyt PM, van Dijk CN (2003) Systematic review of treatment strategies for osteochondral defects of the talar dome. Foot Ankle Clin 8(2):233–242. viii-ix
68. Woods K, Harris I (1995) Osteochondritis dissecans of the talus in identical twins. J Bone Joint Surg 77(2):331
69. Hermanson E, Ferkel RD (2009) Bilateral osteochondral lesions of the talus. Foot Ankle Int 30(8):723–727. https://doi.org/10.3113/FAI.2009.0723

70. Frenkel SR, DCP E (1999) Degradation and repair of articular cartilage. Front Biosci 4:671–685
71. Saxena A, Luhadiya A, Ewen B, Goumas C (2011) Magnetic resonance imaging and incidental findings of lateral ankle pathologic features with asymptomatic ankles. J Foot Ankle Surg 50(4):413–415. https://doi.org/10.1053/j.jfas.2011.03.011
72. Dahmen J, Lambers KTA, Reilingh ML, van Bergen CJA, Stufkens SAS, Kerkhoffs G (2017) No superior treatment for primary osteochondral defects of the talus. Knee Surg Sports Traumatol Arthrosc Off J ESSKA. https://doi.org/10.1007/s00167-017-4616-5
73. Lambers KTA, Dahmen J, Reilingh ML, van CJA B, Stufkens SAS, Kerkhoffs G (2017) No superior surgical treatment for secondary osteochondral defects of the talus. Knee Surg Sports Traumatol Arthrosc Off J ESSKA. https://doi.org/10.1007/s00167-017-4629-0
74. van Dijk CN, van Bergen CJ (2008) Advancements in ankle arthroscopy. J Am Acad Orthop Surg 16(11):635–646
75. Zengerink M, van Dijk CN (2012) Complications in ankle arthroscopy. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 20(8):1420–1431. https://doi.org/10.1007/s00167-012-2063-x
76. Kerkhoffs GM, Reilingh ML, Gerards RM, de Leeuw PA (2016) Lift, drill, fill and fix (LDFF): a new arthroscopic treatment for talar osteochondral defects. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 24(4):1265–1271. https://doi.org/10.1007/s00167-014-3057-7
77. Doral MN, Bilge O, Batmaz G, Donmez G, Turhan E, Demirel M, Atay OA, Uzumcugil A, Atesok K, Kaya D (2012) Treatment of osteochondral lesions of the talus with microfracture technique and postoperative hyaluronan injection. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 20(7):1398–1403. https://doi.org/10.1007/s00167-011-1856-7
78. Ferreira C, Vuurberg G, Oliveira JM, Espregueira-Mendes J, Pereira H, Reis RL, Ripoll P (2016) Assessment of clinical outcome after osteochondral autologous transplantation technique for the treatment of ankle lesions: a systematic review. J Isakos. doi:jisakos-2015-000020.R2
79. Bhattarai N, Gunn J, Zhang M (2010) Chitosan-based hydrogels for controlled, localized drug delivery. Adv Drug Deliv Rev 62(1):83–99. https://doi.org/10.1016/j.addr.2009.07.019
80. Brittberg M (2010) Cell carriers as the next generation of cell therapy for cartilage repair: a review of the matrix-induced autologous chondrocyte implantation procedure. Am J Sports Med 38(6):1259–1271. https://doi.org/10.1177/0363546509346395
81. Candrian C, Miot S, Wolf F, Bonacina E, Dickinson S, Wirz D, Jakob M, Valderrabano V, Barbero A, Martin I (2010) Are ankle chondrocytes from damaged fragments a suitable cell source for cartilage repair? Osteoarthr Cartil/OARS Osteoarthr Res Soc 18(8):1067–1076. https://doi.org/10.1016/j.joca.2010.04.010
82. Caron MMJ, Emans PJ, Coolsen MME, Voss L, Surtel DAM, Cremers A, van Rhijn LW, Welting TJM (2012) Redifferentiation of dedifferentiated human articular chondrocytes: comparison of 2D and 3D cultures. Osteoarthr Cartil 20(10):1170–1178. https://doi.org/10.1016/j.joca.2012.06.016
83. Centeno CJ, Schultz JR, Cheever M, Robinson B, Freeman M, Marasco W (2010) Safety and complications reporting on the re-implantation of culture-expanded mesenchymal stem cells using autologous platelet lysate technique. Curr Stem Cell Res Ther 5(1):81–93
84. Che JH, Zhang ZR, Li GZ, Tan WH, Bai XD, Qu FJ (2010) Application of tissue-engineered cartilage with BMP-7 gene to repair knee joint cartilage injury in rabbits. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 18(4):496–503. https://doi.org/10.1007/s00167-009-0962-2
85. Clar C, Cummins E, McIntyre L, Thomas S, Lamb J, Bain L, Jobanputra P, Waugh N (2005) Clinical and cost-effectiveness of autologous chondrocyte implantation for cartilage defects in knee joints: systematic review and economic evaluation. Health Technol Assess 9 (47):iii-iv, ix-x, 1–82. doi:03-65-01 [pii]
86. Dhollander AA, De Neve F, Almqvist KF, Verdonk R, Lambrecht S, Elewaut D, Verbruggen G, Verdonk PC (2011) Autologous matrix-induced chondrogenesis combined with platelet-rich

plasma gel: technical description and a five pilot patients report. Knee Surg Sports Traumatol Arthrosc Off J ESSKA 19(4):536–542. https://doi.org/10.1007/s00167-010-1337-4
87. DiGiovanni CW, Lin SS, Baumhauer JF, Daniels T, Younger A, Glazebrook M, Anderson J, Anderson R, Evangelista P, Lynch SE (2013) Recombinant human platelet-derived growth factor-BB and beta-tricalcium phosphate (rhPDGF-BB/beta-TCP): an alternative to autogenous bone graft. J Bone Joint Surg Am 95(13):1184–1192. https://doi.org/10.2106/JBJS.K.01422
88. Enea D, Gwynne J, Kew S, Arumugam M, Shepherd J, Brooks R, Ghose S, Best S, Cameron R, Rushton N (2012) Collagen fibre implant for tendon and ligament biological augmentation. In vivo study in an ovine model. Knee Surg Sports Traumatol Arthrosc Off J ESSKA. https://doi.org/10.1007/s00167-012-2102-7
89. Gurkan UA, Tasoglu S, Kavaz D, Demirci U (2012) Emerging technologies for assembly of microscale hydrogels. Adv Healthc Mater 1:149–158
90. Harris JD, Siston RA, Pan X, Flanigan DC (2010) Autologous chondrocyte implantation: a systematic review. J Bone Joint Surg Am 92(12):2220–2233. https://doi.org/10.2106/JBJS.J.00049
91. Nagura I, Fujioka H, Kokubu T, Makino T, Sumi Y, Kurosaka M (2007) Repair of osteochondral defects with a new porous synthetic polymer scaffold. J Bone Joint Surg Br 89(2):258–264. https://doi.org/10.1302/0301-620X.89B2.17754
92. Pereira D, Silva-Correia J, Pereira H, Espregueira-Mendes J, Oliveira JM, Reis RL (2012) Gellan gum-based bilayered scaffolds for application in osteochondral tissue engineering. J Tissue Eng Regen Med 6(1):185
93. Shive MS, Stanish WD, McCormack R, Forriol F, Mohtadi N, Pelet S, Desnoyers J, Methot S, Vehik K, Restrepo A (2015) BST-CarGel(R) treatment maintains cartilage repair superiority over microfracture at 5 years in a multicenter randomized controlled trial. Cartilage 6(2):62–72. https://doi.org/10.1177/1947603514562064
94. Stanish WD, McCormack R, Forriol F, Mohtadi N, Pelet S, Desnoyers J, Restrepo A, Shive MS (2013) Novel scaffold-based BST-CarGel treatment results in superior cartilage repair compared with microfracture in a randomized controlled trial. J Bone Joint Surg Am 95(18):1640–1650. https://doi.org/10.2106/JBJS.L.01345
95. Vinatier C, Mrugala D, Jorgensen C, Guicheux J, Noel D (2009) Cartilage engineering: a crucial combination of cells, biomaterials and biofactors. Trends Biotechnol 27(5):307–314. https://doi.org/10.1016/j.tibtech.2009.02.005
96. Ettinger S, Stukenborg-Colsman C, Waizy H, Becher C, Yao D, Claassen L, Noll Y, Plaass C (2017) Results of HemiCAP(R) implantation as a salvage procedure for osteochondral lesions of the talus. J Foot Ankle Surg 56(4):788–792. https://doi.org/10.1053/j.jfas.2017.04.001
97. Pagenstert GI, Hintermann B, Barg A, Leumann A, Valderrabano V (2007) Realignment surgery as alternative treatment of varus and valgus ankle osteoarthritis. Clin Orthop Relat Res 462:156–168. https://doi.org/10.1097/BLO.0b013e318124a462
98. Badekas T, Takvorian M, Souras N (2013) Treatment principles for osteochondral lesions in foot and ankle. Int Orthop 37(9):1697–1706. https://doi.org/10.1007/s00264-013-2076-1
99. Ross KA, Murawski CD, Smyth NA, Zwiers R, Wiegerinck JI, van Bergen CJ, Dijk CN, Kennedy JG (2017) Current concepts review: arthroscopic treatment of anterior ankle impingement. Foot Ankle Surg 23(1):1–8. https://doi.org/10.1016/j.fas.2016.01.005
100. Tol JL, Slim E, van Soest AJ, van Dijk CN (2002) The relationship of the kicking action in soccer and anterior ankle impingement syndrome. A biomechanical analysis. Am J Sports Med 30(1):45–50. https://doi.org/10.1177/03635465020300012101
101. Tol JL, Verheyen CP, van Dijk CN (2001) Arthroscopic treatment of anterior impingement in the ankle. J Bone Joint Surg 83(1):9–13
102. van Dijk CN, Wessel RN, Tol JL, Maas M (2002) Oblique radiograph for the detection of bone spurs in anterior ankle impingement. Skelet Radiol 31(4):214–221. https://doi.org/10.1007/s00256-002-0477-0
103. Miyamoto W, Miki S, Kawano H, Takao M (2017) Surgical outcome of posterior ankle impingement syndrome with concomitant ankle disorders treated simultaneously in

patient engaged in athletic activity. J Orthop Sci 22(3):463–467. https://doi.org/10.1016/j.jos.2016.12.017
104. Kose O, Okan AN, Durakbasa MO, Emrem K, Islam NC (2006) Fracture of the os trigonum: a case report. J Orthop Surg (Hong Kong) 14(3):354–356. https://doi.org/10.1177/230949900601400326
105. Walls RJ, Ross KA, Fraser EJ, Hodgkins CW, Smyth NA, Egan CJ, Calder J, Kennedy JG (2016) Football injuries of the ankle: a review of injury mechanisms, diagnosis and management. World J Orthop 7(1):8–19. https://doi.org/10.5312/wjo.v7.i1.8
106. Lees A, Asai T, Andersen TB, Nunome H, Sterzing T (2010) The biomechanics of kicking in soccer: a review. J Sports Sci 28(8):805–817. https://doi.org/10.1080/02640414.2010.481305
107. Niek van Dijk C (2006) Anterior and posterior ankle impingement. Foot Ankle Clin 11(3):663–683. https://doi.org/10.1016/j.fcl.2006.06.003
108. de Leeuw PA, Golano P, Clavero JA, van Dijk CN (2010) Anterior ankle arthroscopy, distraction or dorsiflexion? Knee Surg Sports Traumatol Arthrosc Off J ESSKA 18(5):594–600. https://doi.org/10.1007/s00167-010-1089-1
109. van Dijk CN, Scholten PE, Krips R (2000) A 2-portal endoscopic approach for diagnosis and treatment of posterior ankle pathology. Arthroscopy J Arthrosc Relat Surg Off Publ Arthrosc Assoc North Am Int Arthrosc Assoc 16(8):871–876. https://doi.org/10.1053/jars.2000.19430
110. Haverkamp D, Bech N, de Leeuw P, d'Hooghe P, Kynsburg A, Calder J, Ogut T, Batista J, Pereira H (2016) Posterior compartment of the ankle joint: a focus on arthroscopic treatment (ICL 17). In: Becker R, Kerkhoffs GMMJ, Gelber PE, Denti M, Seil R (eds) ESSKA instructional course lecture book. Springer, Berlin/Heidelberg. https://doi.org/10.1007/978-3-662-49114-0_15