Osteochondral talar lesions and ankle biomechanics
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Citation for published version (APA):

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Introduction

Osteochondral defects (OCDs) of the talus are a common cause of chronic ankle pain and disability. They often occur in a young, active and athletic population. Arthroscopic surgery by means of debridement and bone marrow stimulation (BMS) is the primary treatment of choice, leading to a good to excellent result in the majority of patients. Results are less predictable in larger OCDs. Moreover, results tend to deteriorate over time.

This thesis aims to evaluate current treatment methods for osteochondral talar defects. Since most talar OCDs are treated by means of arthroscopy, ankle arthroscopy was studied more extensively. Complications of ankle arthroscopy were evaluated, and the technique of ankle arthroscopy that was used was described in detail.

This thesis also aims to describe normal patterns of range of motion of the ankle. These kinematic data can be used for discerning pathological motion. Pathological motion may lead to injury, and subsequently to the development of an OCD.

Ankle motion is important as well during ankle arthroscopy. To access a talar OCD during anterior arthroscopy, the proximal talar surface is revealed from underneath the distal tibia by plantar flexion. The same goes for posterior arthroscopy and dorsal flexion. The acquired kinematic data were used to quantify arthroscopic access to the talar dome.

For secondary OCDs a metal implant for focal resurfacing was developed. For development of this implant lesion size was measured as well as talar geometry at the location of the lesion. The accuracy and reproducibility of implantation were evaluated.

Current concepts

The literature was reviewed and the three currently most used treatment methods were described (Chapter 2). The surgical treatment involving arthroscopic debridement and bone marrow stimulation was identified as the first treatment option for primary osteochondral lesions of the talus up to 15 mm. Osteochondral autograft transfer system (OATS) and autologous chondrocyte implantation (ACI) are alternative treatment options. The results for arthroscopic debridement and bone marrow stimulation, OATS and ACI are respectively 83%, 92% and 82% good to excellent. These are the results of single case series with medium term follow up. This emphasized the need for a more thorough investigation of results concerning the outcome of these techniques.

Systematic review

A systematic review was performed concerning all previous and current treatment methods in order to summarize their success rates (Chapter 3). Small studies were excluded. Lack of sufficiently sized long-term follow up studies is a challenge in orthopaedic literature, leading to a low level of evidence. This was apparent when performing the systematic review. Many case series were identified that contained less than 10 patients. No randomized clinical trials (RCTs) were identified. The quality of the primary studies included ultimately reflects the quality of the pooled
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data from the meta-analysis [9]. Besides the lack of sufficiently powered high quality studies, another challenge of a systematic review on this subject is the heterogeneity of the group of patients with a symptomatic talar OCD. The OCDs vary in size, depth, location, and containment, and these characteristics influence outcome [3, 18, 19, 21-23]. Concerning age, there is some debate about its prognostic significance [20, 31]. A high body mass index, a history of trauma, and the presence of osteophytes negatively influence outcome [22].
The lack of RCTs, the heterogeneity within OCD pathology, the wide availability of case series of lesser quality and the publication bias of these, necessitate the need for a critical appraisal of future study designs on the topic.

Obviously, it is wise to join forces between institutions to set up larger scaled studies. However, even though a systematic review of RCTs remains key in practicing evidence-based medicine, orthopaedic medicine has not proven to be able to produce them. Only 3% of orthopaedic literature consists of RCTs [10, 61, 64]. In view of this, it is interesting to analyze contributing factors to the lack of RCTs. First of all, lack of volume is an important factor. Furthermore, funding, blinding, and preference by the surgeon for a certain procedure play a role.

It is unknown how many osteochondral talar lesions are treated each year, but volumes like those obtained in arthroplasty surgery are far from those obtained in OCD surgery. Additionally, not all treatment methods are suitable for every symptomatic OCD, because of specific lesion and / or patient characteristics. The challenge of volume may be tackled by the cooperation between several hospitals, and by assigning certain hospitals to be centers of expertise on certain treatments.

The challenge of funding may also be tackled by cooperation. When surgeons are working together in clinical trials, they may organize their lobby to raise funds. The already existing Work Groups / Associations, like the Dutch Orthopaedic Foot and Ankle Association, may serve as a platform in this [33].

Blinding of treatment is obviously not possible to the surgeon, but blinding treatment to the patient may face challenges as well. For instance comparing a one-stage procedure (arthroscopic microfracturing) to a two-stage procedure (ACI) or to a procedure where osteochondral plugs are harvested from the knee (OATS) can be difficult. The number of surgeries, the duration of surgery and the location of surgery differ between the procedures. It is hard to blind these to the patient.

Finally, the surgeon often has a preference for a certain surgical procedure. He or she is best skilled for one surgical procedure, and it has ethical consequences when also another procedure has to be performed. Orthopaedic RCTs should therefore mostly be expertise based, as was advocated by Devereux et al. [32].

In spite of the above mentioned arguments, the goal should still be to perform an RCT which meets its criteria. To further improve quality of orthopaedic research and care, a critical attitude should be adopted towards the formulation of clinical research questions. In other words: the answer to which clinical problem would be of most benefit to the patient? In the case of talar OCDs good progress has been made. Several treatments have proven their value, but they also
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have a 10 to 20% failure rate. Studies were carried out to define which OCD or patient characteristics predict the failures. The outcomes of these studies make it possible to offer more individual patient care in the treatment of talar OCDs. Work in this field was performed by Choi et al. concerning lesion size, containment and age [18-21], but can be expanded.

No systematic review has been performed concerning treatment of osteochondral talar lesions since the study described in Chapter 3. However, new studies were published concerning treatment results of osteochondral lesions [7, 25, 35, 47, 63, 75, 77]. Therefore it is valuable to update the review in the near future. To use it as a tool in making decisions on treatment, it can be decided to only include those treatment methods that are currently practiced. To limit publication bias also mainly larger studies should be selected, as publication bias is a bigger problem in smaller sized studies [57].

Complications in ankle arthroscopy

The type and percentage of complications related to ankle arthroscopy were examined. Half of the complications were of neurovascular origin. Posterior ankle arthroscopy showed a complication rate that compares favourably to that of anterior ankle arthroscopy. The rate that was found was substantially lower than the rates that are mentioned in literature (Chapter 4). This may have to do with the dorsiflexion method that is used. Key in this is the use of the anterior working space, which develops when the foot is placed in dorsal flexion. It is thought that nerves, vessels and other soft tissues are less prone to be injured because they are not under tension when using and changing instruments. Since the study was published a few other studies on the topic have been reported. Blazquez Martin et al. evaluated their complications after ankle and hindfoot arthroscopy and found a higher percentage of overall complications (12%) and of nerve lesions (almost 6%). In 4% there was persistent drainage through the portals [11]. This emphasizes the room for improvement.

To further study complications of ankle arthroscopy in relation to the dorsiflexion method one could examine this method in comparison to other techniques in an expertise based clinical trial. However, the described complications are diverse, and the rate is low. This implies practical challenges for such a study, as study size would have to be enormous.

It was rightfully discussed by dr. Golanó that anatomy was little exposed in the study on complications in ankle arthroscopy (Chapter 5). He underlines the importance of knowledge of extra- intra-articular anatomy, and marking the important landmarks on the skin. It is agreed on this point. In the near past, more reports were published concerning complications related to anatomical structures [1, 6, 16, 59]. Most of these complications, like iatrogenic nerve damage to the posterior tibial nerve, to the sural nerve, and the development of pseudoaneurysms of the anterior tibial artery and peroneal artery, can be avoided by anatomical knowledge and execution of the right arthroscopic technique. In this respect it is promising that anatomical studies related to ankle arthroscopy are increasing [4, 5, 12, 24, 26, 62]. Nerve patterns are mapped and the distance of nerves and arteries to the path the arthroscope and instruments follow during the
procedure are studied more precisely. These publications on arthroscopic ankle anatomy seem to go hand in hand with the increase in the number of ankle arthroscopy procedures [8]. This increase is due to the fact that worldwide more surgeons become familiar with the technique of ankle arthroscopy, as well as to the fact that the number of indications for ankle arthroscopy is increasing. Lately many studies have been published on arthroscopy-assisted surgery for acute ankle fractures [13, 14, 17, 28, 37, 39, 60], and there is a trend in performing ankle ligament repair arthroscopically [2, 48, 53-55, 74]. Also, posterior ankle arthroscopy is increasingly used to accomplish a tibiotalar fusion [27, 43, 50]. When adopting these new indications the importance of knowledge of the anatomy of the bones, tendons, ligaments and neurovascular structures should be acknowledged. Only this way many potential complications can be avoided and new techniques have a higher chance to become successful.

Ankle biomechanics

Since the late sixties, ankle biomechanics were studied extensively [44, 58, 66]. These studies described ankle motion in relation to gait analysis. The function of the ankle within the lower limb kinetic chain was analyzed and described. Later, the consequences for motion within the kinetic chain for certain ankle pathologies were described, as well as the implications for gait pattern after surgery, like ankle arthrodesis [56]. Previous methods to determine motion in vivo, like roentgen stereophotogrammetric analysis (RSA), were limited by the impossibility to 3-dimensionally (3D) define the involved articulating bones. It was not possible to take into account the complete bony surface. The current method using a 3D computed tomography (CT) stress-test for measuring motion is able to determine the position of two articulating bones in 3D space, taking into account the complete bony surface (Chapter 6). This leads to accurate measurements and is less invasive. In healthy subjects, eversion dorsal flexion – inversion plantar flexion (EVDF–INPF) movement showed the most consistent orientation of finite helical axes (FHAs) and smallest variation in rotation for both the ankle and subtalar joint. Dorsal flexion – plantar flexion (DF–PF) motion is restricted to the talocural joint and shows high consistency in FHA orientation. The general orientation of the FHAs leads to coupling of inversion to internal rotation and eversion to external rotation in both joints, and absence of this coupling may indicate pathology.

The need to describe motion patterns of the ankle in detail remains valid up until today. Movement dysfunction may lead to injury. Only by accumulating baseline biomechanical data, pathological motion can be determined. In 1971, Glick already mentioned that football players with a talus tilt of 5° or more experienced the highest incidence of ankle injuries [38]. Since ankle injuries are the main etiological factor in sustaining an osteochondral talus lesion, and the difference between pathological and non-pathological motion is so small, precise measurement of this motion is key for improving treatment and prevention of injury. Research in the field of ankle joint kinematics should now be aimed at making this technique possible for individual patients, so they may benefit directly. But in addition to this, the value of the 3D computed tomography stress-test extends beyond measuring individual range of motion. It has recently
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Proven its value in determining the functionality of the EXO-L ankle brace. It was confirmed that under static and passive testing conditions, the new ankle brace limits the inversion-plantar flexion motion that is responsible for most ankle sprains without limiting plantar flexion or dorsal flexion [46].

**Arthroscopic access to the ankle joint**

The technique of bone contour segmentation and matching using CT was used to determine arthroscopic accessibility of the ankle joint (Chapter 7). The position and the orientation of the distal tibia and talus could be precisely registered. In each extreme position of the ankle the coverage of the talus by the distal tibia could be determined. This gave information on the surface of the talus that can be reached by anterior arthroscopy, by posterior arthroscopy, and on which part cannot be reached at all. Nearly the entire talar dome is accessible through either anterior or posterior arthroscopy, dependent on the diameter of the instrument that is used. However, the part of the talus between 10 and 11 o’clock (viewed from lateral, where the anterior border of the talar dome is 3 o’clock) may be hard to reach. Most osteochondral talar lesions occur in the midportion (medial or lateral) of the talus [34], and this involves the part of the talus that is hard to reach. The lesions in this posterocentral may need open surgery.

The arthroscopic access was measured and calculated in 20 healthy subjects. Due to the laborious nature of the technique, it is not available for individual patients yet. To develop this technique for the clinical setting would be of great benefit to the surgeon and patient, when there is doubt whether the OCD can be reached arthroscopically. Moreover, the arthroscopic reach may be increased by the use of alternative instruments. The development of steerable instruments will increase access to the joint, since the curvature of the talus is a limitation in combination with the use of rigid instruments. These instruments, like a steerable punch, are currently being developed [68, 69]. For drilling, the availability of a flexible waterjet, instead of a rigid chondral pick, could be beneficial. With this instrument it is possible to follow the curvature of the talar dome. If the nozzle of the waterjet is flat and it has a small diameter hose the narrow joint space can be entered. This way also more posteriorly located OCDs can be arthroscopically drilled. A prototype has now been developed [29, 30].

**Future perspectives**

It is known that results of arthroscopic debridement and bone marrow stimulation tend to decline over time [63, 70]. The resultant fibrocartilage is thought to be of lower quality and to be less sustainable [49]. Furthermore, lesion size is an outcome predictor for the arthroscopic microfracture procedure. In several studies it was found that excellent results are obtained for lesions smaller than 15 mm or 150 mm², and that larger lesions have a high failure rate [21-23].

More recently, lesion depth was added to antero-posterior and medio-lateral size as being significantly negatively correlated with outcome of arthroscopic microfracturing [3]. This may indicate we have to revise the guideline that arthroscopic microfracturing is always a good initial
Alternative treatment method for talar OCDs

An alternative treatment method was developed by measuring size and location of OCDs of the ankle in relation to talar geometry (Chapter 8). It was found that coronal angle, median diameter and height of a focal metal implant to cover the OCD are larger for medial than lateral defects. A focal metal implant was developed for the treatment of secondary medial OCDs and its accuracy and reproducibility concerning implantation was tested (Chapter 9). It was shown the implant could be slightly recessed below cartilage level, and that contact pressures in the joint were not increased. Initial results are promising, but long-term results are needed to define its value [71, 72]. The current implant is available with varying offset sizes, but comes with a standard diameter of 15 mm. If its value in lesions up to 15 mm has been proven, a larger HemiCAP could be developed, to tackle the treatment dilemma of lesions larger than this.

Many other studies on new treatment methods have been carried out, and variations on existing treatments have been developed in an attempt to increase its success rates. The arthroscopic lift drill fill fix (LDFF) technique has been described by Kerkhoffs as an extension of the arthroscopic microfracture treatment for talar OCDs [45]. It is advocated for an osteochondral lesion with an intact or nearly intact cartilage layer, and the presence of sufficient vital subchondral bone. The theoretical advantages of the LDFF technique are restoration of the subchondral bone and the preservation of hyaline cartilage. In the first report of Kerkhoffs et al. on seven patients treated by the LDFF method excellent short term clinical outcome was shown. More patients and longer follow up results are needed to evaluate its value.

Also, new methods to evaluate the results of treatment were developed and are increasingly used, like the magnetic resonance observation of cartilage repair tissue (MOCART) score [35, 36, 51, 52]. The results of platelet rich plasma (PRP), hyaluronic acid (HA) and pulsed electromagnetic fields (PEMF) as additional treatment of arthroscopic microfracturing of talar OCDs initially seemed promising, but up until today have not been able to unquestionably prove their success in randomized clinical trials [15, 40-42, 65, 67, 73]. On the contrary: no clear benefit was demonstrated for any of them.

The treatment of osteochondral injury therefore remains challenging, and there is no golden standard. Progress is being made by research on what treatment works best for what particular lesion, but the search for the ultimate solution in cartilage repair treatment remains ongoing.
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Conclusions

1. Based on the current best available evidence, arthroscopic debridement and bone marrow stimulation is the most effective treatment strategy for symptomatic primary talar OCDs up to 15 mm. ACI and OATS are indicated for secondary and larger lesions.

2. The use of the dorsiflexion method for anterior ankle arthroscopy is related to a relatively low rate of complications. Posterior ankle arthroscopy by means of a two-portal hindfoot approach is a safe procedure with a complication rate that compares favourably to that of anterior ankle arthroscopy.

3. Half of the complications that occur in ankle arthroscopy are of neurovascular origin. Knowledge of intra- and extra-articular anatomy is mandatory in preventing these complications.

4. In healthy subjects, eversion dorsal flexion – inversion plantar flexion (EVDF–INPF) movement show the most consistent orientation of finite helical axes (FHAs) and smallest variation in rotation for both the ankle and subtalar joint. Dorsal flexion – plantar flexion (DF–PF) motion is restricted to the talocrural joint and shows high consistency in FHA orientation.

5. The general orientation of the FHAs leads to coupling of inversion to internal rotation and eversion to external rotation in both joints, and absence of this coupling may indicate pathology.

6. Nearly the entire talar dome is accessible through either anterior or posterior arthroscopy, dependent on the diameter of the instrument that is used.

7. Because of their location, most osteochondral lesions can be arthroscopically reached, without the need for arthrotomy or osteotomy. However, lesions between 10 and 11 o’clock, viewed from lateral, where the anterior border of the talar dome is 3 o’clock, may require open surgery.

8. Coronal angle, median diameter and height of a focal metal implant to cover the OCD are larger for medial than lateral defects.

9. Accurate and reproducible implantation of the talar HemiCAP can be achieved, preventing excessive prosthetic pressure.
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