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CHAPTER 9

Summary

Introduction

The aim of this thesis was firstly to obtain insight in the normal subtalar joint range of motion. Secondly, to provide knowledge of the subtalar joint range of motion following two different surgical procedures for flexible adult acquired flatfoot deformity. And finally, to enhance endoscopic treatment options for subtalar joint pathology. Advancement in imaging techniques allows us to study joint motion in detail. Our group has developed a bone contour segmentation and registration technique using CT images (CT-BCM), to measure relative bone to bone motions in-vivo to gain insight in the normal subtalar joint range of motion. A study was performed to compare the accuracy of the CT-BCM method with the current gold standard for detailed measurements of bone to bone motion, the roentgen stereophotogrammetric analysis (RSA). To gain insight in the normal subtalar joint range of motion, the CT-BCM method was then used to study the subtalar joint range of motion in 20 healthy volunteers. CT-BCM can also be used to assess bone to bone motion in postoperative situations. The ankle and subtalar joint range of motion following two different surgical procedures for lateral column lengthening in patients with flexible adult acquired flatfoot deformity was assessed using the CT-BCM method to provide knowledge on this topic.

The subtalar arthrodesis techniques were analysed through a literature review and the problems with the surgical techniques were analysed. Possible solutions based on the literature review were provided for the problems with subtalar arthrodesis. To provide an overview on the aspects of the surgical technique for subtalar joint arthroscopy, a literature review was presented. Finally, to enhance treatment options for symptomatic subtalar joint pathology, the technique and results of the arthroscopic subtalar arthrodesis technique in patients with a symptomatic talocalcaneal coalition using the posterior hindfoot approach with an accessory sinus tarsi portal were presented. The results of these studies and overviews are summarized in the sections below.

Chapter 2

In comparison to the ankle joint or tibiotalar joint, detailed information on subtalar joint kinematics is relatively scarce. The lack of external landmarks of the talus in combination with the complex subtalar joint geometry has made the subtalar joint kinematics difficult to investigate in living subjects. The disadvantages of the roentgen stereophotogrammetric analysis (RSA) to study bone to bone motion are its invasiveness and the risk of infection, joint cartilage damage and malpositioning of the bone markers. Our group developed a bone contour segmentation and registration technique using CT images (CT-BCM) to measure

relative bone to bone motions in-vivo. The purpose of this CT-based technique was to acquire data of the three-dimensional position and orientation of the ankle and hindfoot bones in the CT images in an accurate way. Therefore, the CT-based bone contour registration technique was compared to the current gold standard technique, the RSA in Chapter 2. Tantalum bone markers were placed in the distal tibia, talus and calcaneus of one cadaver specimen. With a fixed lower leg, the cadaveric foot was held in a neutral position and subsequently loaded in eight extreme foot positions. Immediately after acquiring a CT-scan with the foot in a certain position, RSA radiographs were made. Following CT-BCM and RSA, helical axis parameters were calculated for talocrural and subtalar joint motion from neutral to extreme positions and between opposite extreme positions. Firstly, the overall root mean square differences between the CT-BCM and RSA for rotations around and translations along the helical axis for talocrural and subtalar joint motion were similar to those reported for the RSA method. Secondly, the root mean square differences between the CT-BCM and RSA of the position and direction of the helical axes were also similar to those reported for the RSA method. It was concluded that CT-BCM is an accurate and accessible alternative for studying bone to bone motion in-vivo.

Chapter 3

In this chapter, the normal ranges of motion of the subtalar joint were studied using the validated CT-BCM technique. In 20 healthy volunteers, an external load was applied to a footplate and forced the otherwise unconstrained foot in eight extreme positions. CT images were acquired in a neutral foot position and each extreme position separately. After bone segmentation and contour matching of the CT data sets (CT-BCM), the helical axes were determined for the motion of the calcaneus relative to the talus between four pairs of opposite extreme foot positions. The helical axis was represented in a coordinate system based on the geometric principal axes of the talus of the concerning subject. The greatest relative motion between the calcaneus and the talus was calculated for foot motion from extreme eversion to extreme inversion with a mean rotation about the helical axis of $37.3 \pm 5.9^\circ$ and a mean translation of 2.3 ± 1.1 mm. The helical axes that represented the range of motion of the subtalar joint between two opposite extreme foot positions, were consistent in the group of 20 subjects, except for the subtalar joint motion between extreme dorsiflexion and extreme plantarflexion. We concluded that for extreme positions of the foot with a considerable eversion and inversion component, the helical axis parameters were highly consistent between the 20 subjects in our series. We found the helical axis of the subtalar joint running from

postero-lateral-inferior to antero-medial-superior. There was relatively little variation in the inclination angle, and moderate variation in the deviation angle of the mean helical axis for extreme foot positions with an eversion and inversion component. The CT-BCM technique can be used as a quantitative outcome measure for analysing changes in subtalar range of motion before and after operative interventions in the hindfoot.

Chapter 4

Lateral column lengthening (LCL) has become an accepted surgical procedure for the treatment of the symptomatic flexible adult acquired flatfoot deformity. Chapter 4 described the outcome of two commonly used LCL techniques for flatfoot deformity correction in terms of postoperative ankle and subtalar joint range of motion. The calcaneocuboid distraction arthrodesis (CCDA) or the anterior calcaneal open wedge osteotomy (ACDO) technique was used in two groups of five patients with flexible adult acquired flatfoot deformity. These bony procedures were combined with an augmentation of the posterior tibial tendon and other procedures. The hypothesis was that the ACDO procedure is preferred in these patients as the CCDA procedure has the possible disadvantage of restricting hindfoot motion with surgical fusion of the calcaneocuboid joint as there is a interdependency of motion of the tarsal bones (i.e. immobilization of one joint limits the mobility of others as the bones of the hindfoot are considered as a closed kinematic chain). The CT-BCM method that was validated in Chapter 2 was used. CT scanning was performed with the foot in eight extreme positions in five ACDO and five CCDA patients. With the small number of patients in both groups no statistical analyses were performed. The maximum mean finite helical axis (FHA) rotation of the talocrural joint (for extreme dorsiflexion to extreme plantarflexion) after ACDO was $52.2^\circ \pm 12.4^\circ$ and after CCDA $49.0^\circ \pm 12.0^\circ$. Subtalar joint maximum mean FHA rotation (for extreme eversion to extreme inversion) following ACDO was $22.8^\circ \pm 8.6^\circ$, and following CCDA $24.4^\circ \pm 7.6^\circ$. It was concluded that our study yielded comparable results for the postoperative ranges of talocrural and subtalar joint motion in the ACDO and CCDA patients.

Chapter 5

Subtalar joint arthrodesis is the treatment of choice for severe symptomatic osteoarthritis of the subtalar joint unresponsive to conservative treatment. Although subtalar joint arthrodesis is considered a routine orthopaedic surgical procedure, authors have described peri-operative problems with this procedure. In Chapter 5 a literature review was performed of papers that presented subtalar arthrodesis techniques. The aspects of the different subtalar arthrodesis

procedures were analysed. A meta analysis, including statistical analyses by data pooling was not possible, since the published series were invariably retrospective reviews of small heterogenous groups of hindfoot pathologies. An additional restriction was that only recently, operative techniques and evaluation protocols have been described in sufficient detail that allow for clear interpretation and evaluation. Five separate stages of the general technique of subtalar joint arthrodesis were identified; surgical approach, cartilage removal, bone graft use, hindfoot deformity correction, and, fixation. The following pitfalls were identified: complications related to the use of large incisions in open subtalar arthrodesis procedures, insufficient cartilage removal, improper bone graft selection and fixation techniques that could all possibly lead to a non-union of the arthrodesis. Furthermore; morbidity caused by bone graft harvesting and late screw removal, under- or overcorrection of the hindfoot malalignment, and difficulties with the postoperative assessment of the state of bony fusion of the arthrodesis. Literature also provided possible solutions to overcome these pitfalls with the remark that some are still under development: (1) if applicable use an arthroscopic approach in combination with burrs and distraction devices, (2) when possible use local bone graft or allografts, (3) fixation of the subtalar arthrodesis should be done by using two screws to prevent rotational micromotion, and (4) if doubt exists on solid bony fusion of the subtalar arthrodesis, a CT-scan of the subtalar joint is recommended. Further efforts should be taken to perform long-term follow-up studies to assess the effects of the many proposed adjustments to the subtalar arthrodesis operative techniques.

Chapter 6

Arthroscopic subtalar management has been credited with clear advantages for the patient, including a faster postoperative recovery period, decreased postoperative pain, and fewer complications. In Chapter 6 an overview of the aspects of the surgical technique for subtalar joint arthroscopy was provided. Subtalar joint arthroscopy may be applied as a diagnostic and therapeutic instrument. Therapeutic indications include intra-articular subtalar joint pathology such as chondromalacia or loose bodies, and extra-articular pathology such as an os trigonum. More recently, the indication for subtalar arthroscopy has expanded to include the arthroscopic subtalar arthrodesis. A noninvasive soft-tissue distractor was advised to open the subtalar joint during arthroscopic surgery. The lateral and posterior portals that are routinely used in subtalar joint arthroscopy are considered safe with regard to the important anatomical structures in the proximity of the portals. The safety of these portals has been assessed in cadaveric specimens. The literature on arthroscopic treatment and results of sinus tarsi

syndrome, os trigonum syndrome and subtalar arthrodesis demonstrated the use of subtalar joint arthroscopy. It was concluded that the technique of subtalar joint arthroscopy has slowly evolved as an alternative to open subtalar surgery. In addition, there is a need for prospective clinical studies to provide detailed information on the results and complications of subtalar joint arthroscopy.

Chapter 7

In Chapter 7 we reported on the technique and outcome of the arthroscopic subtalar arthrodesis in patients with a symptomatic talocalcaneal coalition using the posterior hindfoot approach and an accessory sinus tarsi portal. The prone position of the posterior hindfoot approach allows the use of the standard posterolateral and posteromedial portals. It also allows for accurate control of hindfoot alignment during surgery. Furthermore, the introduction of talocalcaneal lag screws is convenient with the patient in the prone position. Arthroscopic subtalar arthrodesis in patients with a talocalcaneal coalition presents a technical challenge as the subtalar joint space is limited and the workspace in the hindfoot is reduced. An accessory portal at the level of the sinus tarsi is created to introduce a large diameter blunt trocar to open up the subtalar joint and providing more workspace for an arthroscopic subtalar joint arthrodesis. Due to the curved geometry of the posterior subtalar joint, removal of the anterior articular cartilage is impossible by means of the posterior portals only. An advantage of the 3-portal approach is that ring curettes can be introduced through the accessory sinus tarsi portal to remove the articular cartilage of the anterior part of the posterior talocalcaneal joint. In all 3 patients with a symptomatic talocalcaneal coalition it was possible to carry out a successful arthroscopic subtalar arthrodesis using the 3-portal technique. Bony fusion of the subtalar arthrodesis was achieved and no complications occurred. It was concluded that with the 3-portal technique, a safe and time-efficient arthroscopic subtalar arthrodesis can be performed even in cases with limited subtalar joint space such as in symptomatic talocalcaneal coalition.

Samenvatting