Summary

The most common temporomandibular joint (TMJ) disorder involves a combination of degenerative alterations (osteoarthritis, OA) and articular disk displacement (internal derangement, ID). Deviations in position, form, and function of the TMJ articular disk play an important role in the clinical signs and symptoms. A displaced articular disk may cause clicking, locking, restriction of movement, and pain, and may have severe consequences for jaw function. Besides anamnesis and clinical examination, diagnostic imaging plays an important role in diagnosing TMJ disorders.

Chapter 1 gives an overview of current TMJ imaging techniques. Traditionally, conventional X-ray examination is performed, revealing degenerative changes of the bony articular surfaces in varying extent and severity, especially in the later stages of OA. However, conventional X-ray examination has an important limitation: it produces an image of only the bony parts, and does not provide insight into the condition and position of the articular disk. Visualization of the disk may be achieved by arthrography, but this imaging technique is invasive. Rather, there is a need for non-invasive imaging techniques that can visualize the position, form, and function of the TMJ disk. Initially computed tomography (CT) seemed to be the method that could satisfy this requirement. However, since magnetic resonance imaging (MRI) became available, this technique appeared to be preferable over CT for articular disk visualization.

The primary aim of this investigation was to evaluate the specific indication and suitability of these techniques in the examination of TMJ disorders in general and TMJ internal derangements in particular.

Chapter 2 describes the development of a scanning technique for direct sagittal CT imaging of the TMJ. As CT provides imaging of bone and soft tissues, it may be suitable for visualization of the articular disk. Therefore, CT may be useful for making a diagnosis in patients suspected for internal derangements and other disorders of the TMJ.

To achieve a sagittal view of the TMJ, direct sagittal scanning appears superior to scanning in other directions (axial or coronal) with subsequent reconstruction for the sagittal plane. Direct sagittal scanning requires special positioning of the patient and a sophisticated scanning technique, which had to be developed first. To this end, a special patient table and an internal light visor were used for proper patient positioning in the apparatus. To define the planes of scanning, an overview image (scanogram) was used, allowing precise correction of the condylar axis and exact slice level selection. This new technique provides several advantages over other techniques for sagittal scanning of the TMJ. Because no other structures than the patient's head are involved in the imaging process, misleading artifacts from the arm or the shoulder are avoided.

Chapter 3 describes the influence of the wide range of modalities that play a role in CT image reconstruction and image processing especially in relation to articular disk visualization. Among others, techniques that extensively influence brightness and contrast of the CT image (window-width and window-level variation) are widely used. A quantitative evaluation of the X-ray attenuation of the different parts of the TMJ is also possible. The use of techniques that brighten up or blink structures with a certain, more or less specific X-ray attenuation ("Level-detection", "Blink-mode") is often described in the literature. Findings from our study as well as data from the literature indicate that not all available image processing modalities can unrestrictedly be applied in the examination of internal derangements of the TMJ. Application of the most basic techniques (especially window-variation) offers the most reliable possibilities regarding articular disk visualization. The application of "Level-detection" and allied techniques carries substantial risks of erroneous (false-positive) findings regarding disk and disk position. Optimal values for the setting of the CT system for the different image reconstruction and image processing techniques are discussed.

Chapter 4 describes the evaluation of the reliability of direct sagittal CT for TMJ articular disk visualization. The TMJs of 73 patients were examined with direct sagittal CT. The CT images of 20
randomly selected joints were evaluated by four independent observers in two sessions. A closed- and an open-mouth image of each joint was available. For each CT image, each observer had to decide whether the articular disk could be identified in the image or not (interpretability), and to assess the relative position of the articular disk (interpretation). Nominal scale analysis was used for calculation of chance-corrected intra- and inter-observer agreement (Kappa) on interpretability and interpretation of articular disk position.

In the majority of the CT images, the articular disk could not be identified (not interpretable). Further on, the agreement on interpretability among the observers was very low. Because the observers were forced to give a judgment about articular disk position, agreement on interpretation could be determined. Surprisingly, this appeared to be higher than agreement on interpretability. So, while the images did not display the articular disk, the observers agreed on its position. Apparently, secondary factors played a major role in the (artificially high) agreement on interpretation.

The results indicate that direct sagittal CT is not a reliable technique for diagnosing TMJ internal derangements, for which several factors may be responsible. In particular, the small dimensions of the TMJ, the specific anatomy of the articular disk, its position between the bony structures, and the limitations of the performance of the CT equipment (too low resolution) play a role.

Chapter 5 describes the verification of the disappointing results of direct sagittal CT for articular disk visualization.

The interpretation of patient-related factors and equipment-related factors may determine the success or failure of direct sagittal CT in the clinical situation. To eliminate these factors, an autopsy study was performed for histological verification of articular disk visualization by CT in anatomical specimens. Ten TMJ s were dissected while the teeth were placed in intercuspal position. The TMJ was deep frozen and kept frozen during subsequent processing. All TMJ s were CT scanned, and subsequently processed histologically.

The validity of the CT appearance of articular disk position and form was assessed by superimposition of CT and histological pictures, using bony structures and other reference markers for orientation. To study the influence of the specifications of the CT equipment on the visualization of the TMJ articular disk, the results of two different CT units were compared.

The interpretability of the articular disk visualization in the CT images of the specimens also appeared to be low. However, for CT images judged to be interpretable there was a good degree of matching between the diagnosed articular disk position and the findings in the histological pictures. Regarding articular disk visualization, no significant differences in the performance of the two different CT units were noted.

The failure of direct sagittal CT to routinely visualize the TMJ articular disk appears not to result from patient- or equipment-factors. CT primarily offers a too low contrast resolution. Nevertheless, whenever the articular disk is visible in the CT image despite its limitations, its appearance represents the true position and form within the joint.

Chapter 6 presents an overview of the differential diagnostic potential of (direct sagittal) CT.

Despite the fact that CT is not the technique of choice for articular disk visualization, it appeared during the course of the investigation that it is useful in the diagnosis of a range of disorders of the TMJ.

This chapter follows the nowadays commonly used classification of TMJ disorders. Sixteen examples of TMJ disorders are presented. In the differential diagnosis of all cases, CT played a decisive role. CT is especially successful in imaging cases of intra- and extra-capsular hard tissue pathology of the TMJ. CT was superior to other techniques for diagnostic imaging in the described cases.

Chapter 7 describes the evaluation of the reliability of TMJ articular disk visualization using MRI. The design of the study was similar to the study of the reliability of CT.

The MR images of 28 joints, examined at the Center of Diagnostic Imaging, St. Louis Park/Minneapolis, were evaluated by four independent observers. Of each joint, a closed-mouth image was available, and of 14 joints also an open-mouth image had been made.

The articular disk could be identified in 31 out of 42 images (74%). Nevertheless, the agreement on interpretability was not really high because of the effects of unfavorable distribution of the findings on the statistical procedures. Because the majority of the images was interpretable, non-interpretable images could be kept out of consideration in the determination of agreement on interpretation, which appeared to be high. Based on the presented results, MRI can be considered to be a reliable technique for TMJ articular disk visualization.
In chapter 8, direct sagittal CT and MRI of the TMJ were compared to each other. The reliability of articular disk visualization of CT and MRI was determined. Chance-corrected nominal scale analysis revealed that MRI is superior to CT for diagnosing TMJ internal derangements. MRI proved to be a reliable technique for determining articular disk position, and has a considerable number of advantages over other techniques for articular disk visualization. MRI nowadays is considered to be the non-invasive technique of choice for visualization of the TMJ articular disk.

The influence of factors concerning the patient, the examiner, the equipment, and the imaging technique on the possibilities of application of CT and MRI for articular disk visualization, are discussed. CT and MRI are valuable in the examination of TMJ disorders. Both techniques have their own area of application.

Chapter 9 deals with X-ray doses and risks of transcranial, transpharyngeal, arthrographic, tomographic and CT TMJ imaging techniques.

In the literature, different reports on patient dose in general radiology as well as in dental radiology have been published. However, the great variation in imaging techniques, in dosimetric methods, and in presentation of results complicates comparison of the presented data. Furthermore, very few reports are available specifically comparing radiation doses from TMJ X-ray imaging techniques, including CT. Especially, the transpharyngeal projection according to Parma was suspected for irresponsibly high radiation dose.

The effective dose equivalent of one transcranial projection is comparable to that of three routine dental X-rays. The transpharyngeal projection can be compared to ten dental X-rays, equivalent to one-third of one panoramic X-ray. Even more important were the findings concerning arthrography, especially concerning the application of fluoroscopy. The dose during 60 seconds of fluoroscopy was equivalent to 30 dental films or one panoramic X-ray. Diagnostic imaging of the TMJ is considered safe using the techniques described. The transpharyngeal projection can responsibly be applied from the point of view of radiation dose. Fluoroscopy should be applied as brief as possible.

In chapter 10, the general discussion, the findings of the different parts of the study are interrelated. The following general conclusions can be drawn.

- Direct sagittal scanning of the TMJ requires special adaptations to the technique. A useful technique for direct sagittal scanning was developed, offering a number of advantages over alternative sagittal techniques.

- CT image reconstruction and image processing parameters have important influences on interpretation. Image processing modalities offer extensive possibilities to enhance interpretation, but should in TMJ imaging only be used with respect to its limitations and risks. Application of basic techniques (window-variation) is most reliable, whereas application of "Level-detection" and allied techniques may lead to erroneous (false-positive) findings.

- Articular disk visualization by direct sagittal CT in vivo and in vitro is unreliable. Hence, CT is very useful in diagnosing bony and calcifying disorders.

- MRI can reliably be used for diagnostic imaging of the TMJ.

- Comparing CT and MRI for TMJ examination, CT is suitable for imaging of fine bony details, and MRI is suitable for articular disk visualization and some other specific indications. In differential diagnosis of a wide range of different TMJ disorders, CT and MRI can be considered complementary techniques.

- The X-ray dose of generally used radiological TMJ imaging techniques is not high in comparison to dental radiology. Therefore, radiological imaging techniques, including the transpharyngeal projection according to Parma, can be applied safely in the examination of TMJ disorders.