Application of cone beam computed tomography in bone quality assessment prior to implant placement

The aim of this dissertation was to assess the potential of cone beam computed tomography in bone quality assessment prior to implant placement. The emphasis was on radiographic bone density measurement as one of the most important criteria of bone quality.

In chapter 1, the definition of bone quality and its relation with implant treatment success was explained. The application of different modalities in bone density measurement were compared, but the main focus was on MSCT as the gold standard for radiographic bone density measurement and CBCT as the modality under study. Previous efforts on assessing the usefulness of CBCT in bone density measurements were also mentioned. The last part of chapter 1, which is based on a published literature review, briefly introduced the evaluation of bone micro structures, as the second criteria of bone quality.

In chapter 2, as the first step of the evaluation of CBCT usefulness in bone quality assessment, the possible correlation between CBCT gray value and MSCT HU were studied. The CBCT machine used for this study was the NewTom 5G (QR, Verona, Italy). Although the actual CBCT gray values deviated from calibrated HU, an excellent correlation was found between these measurements ($r=0.96$). The correlation of voxel gray values derived from another CBCT scanner (3D Accuitomo 170, J.Morita, Kyoto, Japan) and the calibrated HU was further discussed in chapter 4 and a strong correlation was observed ($r=0.89$). Therefore, the results showed the potential reliability of the NewTom 5G and 3D Accuitomo 170 in radiographic bone density measurements.

The aim of chapter 3 was to determine the accuracy of CBCT (3D Accuitomo 170, J.Morita, Kyoto, Japan) for measuring trabecular bone microstructure using micro CT as
gold standard. As the bone microstructural parameters the number of trabeculae (Tb.N), the thickness (Tb.Th) and the separation (Tb.Sp) were assessed. CBCT bone microstructural measurements using the highest resolution showed high correlations with micro CT. We could conclude from this chapter that CBCT can be an accurate tool for bone microstructure analysis, taking into account that due to the voxel size CBCT introduced overestimation of the measurements of Tb.Sp and Tb.Th. The bone volume fraction (BV/TV) which is the most important histomorphometric bone parameter was not considered in this chapter. Therefore the next chapter mainly focused on this parameter.

Chapter 4 aimed to analyze the correlation between bone volume fraction and the calibrated HU, derived from micro-CT and MSCT respectively, and also the accuracy of CBCT (3D Accuitomo 170, J.Morita, Kyoto, Japan) in evaluating BV/TV using micro-CT as the gold standard. An excellent correlation was shown between bone volume fraction and bone density as assessed by micro-CT and MSCT, respectively. This suggested that bone density measurements could be used to estimate bone microstructural parameters. A strong correlation also was found between CBCT BV/TV and its gold standards, suggesting the potential of this modality in bone volume fraction assessment at implant sites.

Although a strong correlation was found between CBCT gray values and calibrated HU, in chapter 2 and 4, the CBCT scans were done with identical scanning protocols. Therefore in chapter 5, we determined the gray values variation at implant sites with different scan settings including field of view (FOV), spatial resolution, number of projections, exposure time and dose selections in the two cone beam computed tomography systems that had been applied in previous chapters. Gray values derived from the CBCT machines deviated from each other. In both CBCT systems, the FOV and the selected spatial resolution had a statistically significant influence on gray value measurements and number of projections as well in 3D Accuitomo 170 system. We concluded from this chapter that gray level values from CBCT images are influenced by device and scanning setting. So assessing of voxel gray values from CBCT in evaluating bone mineral density should be conducted with consideration to the scanning parameters.
In chapter 6, another possible limitation of CBCT (3D Accuitomo 170 and NewTom 5G) bone density assessment was studied. This chapter was aiming at the evaluation of the variation of gray values at implant sites with different object location within the selected field of view. In both CBCT systems object location had a statistically significant influence on the gray value measurements. Thus, although in the previous chapters CBCT seems to be suitable for gray value assessment, the effect of object location within the CBCT device is a serious limitation of use for the evaluation of bone density.

Chapter 7 investigated if the metal artifact reduction (MAR) tool used in the software of the ORTHOPANTOMOGRAPH® OP300 (Instrumentarium Dental, Tuusula, Finland) can improve the measurement of gray value levels in post-operative implant scans. This ex-vivo study showed that gray voxel values around an implant significantly deviate from the original range regardless of the application of the MAR tool. No differences in gray value ranges at peri-implant sites were found with and without the application of the MAR tool in the CBCT scanner mentioned in this study. Thus, the conclusion of this chapter was that the MAR tool in the ORTHOPANTOMOGRAPH® OP300 CBCT scanner will not lead to correction of the original voxel gray values in the vicinity of an implant.

In conclusion, although gray level values from CBCT images show a high correlation with calibrated HU, the effect of object position as well as type of the device and scanning parameters on CBCT gray values make this imaging modality (as it currently stands) unsuitable for the evaluation of bone density.