The reliability of cone-beam computed tomography to analyze trabecular and cortical bone structures: an in-vitro study

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Background

The microarchitecture of bone plays crucial role in acquiring primary implant stability. In the previous studies, microarchitectural characteristics of trabecular bone have been intensively investigated by examining 2D sections of bone biopsies, combined with calculation of 2D morphometric parameters using stereologic methods. Nevertheless, considering the invasiveness of this method and related ethical issues, alternate and reliable imaging modality has become a necessity. Cone-beam CT (CBCT), as a new emerging radiographic approach, may possess plenty of benefits regarding radiation dose, cost-effectiveness and 3D modalities in evaluating the trabecular and cortical bone structures in a clinically objective and quantitative way. Although the application of morphometric parameters for the assessment of trabecular bone structure has already been extensively studied in MSCT and μCT, the use of CBCT for prediction of these measures remains relatively unexplored.

Aim

The purpose of this study was to evaluate the reliability of various CBCT devices for measuring the trabecular and cortical bone microstructure in comparison to MSCT and μCT systems.

Materials and methods

Six dentate and 8 edentulous human mandibular bone samples underwent 6 CBCT scanning (3D Accuitomo 170, i-CAT Next Generation, Planmeca ProMax 3D Classic, Scanora 3D, Cranex 3D and NewTom) and one MSCT system respectively (Somatom Definition Flash) using the clinical exposure protocol with the highest resolution. Next, all the samples were scanned by μCT (SkyScan 1174). After image acquisition, similar volumes of interest (VOI)

of the trabecular and cortical structures captured with CBCT, MSCT and µCT were aligned to each other. Segmentation was then applied and the morphometric qualification were made by CTAn software within the VOIs in the trabecular and cortical bone. Edentulous and dentate 3D bone parameters were compared among the different devices. Statistical analysis was performed in R software.

Results

The morphometric analysis showed that CBCT bone parameters are comparable to MSCT even though variability exists among the different CBCT systems. A more detailed comparison of all analysis techniques showed that radiographic CBCT and MSCT analysis tended to slightly overestimate morphometric indices compared to µCT. Reliability of segmentation was therefore checked for all scanning systems. Pearson's correlation coefficients demonstrated a statistically significant linear correlation between CBCT, MSCT and µCT bone parameters, not only in the trabecular bone but also in the cortical bone.

Conclusions and clinical implications:

The present study demonstrated the potential of low-dose CBCT for quantitative 3D bone morphometry, offering an ideal clinical way, instead of MSCT or µCT, to determine the bone quality. However, not all CBCT machines have been proven to have sufficient resolution in the accurate depiction of the trabecular bone or cortical bone; and the overestimation of morphometric bone parameters needs to be taken into account.