Does low dose provide sufficient quality? Optimization of CBCT scanning protocols for volumetric analysis of tooth extraction sockets

Van Dessel J[1,2], Nicolielo LFP[1,2], Stratis A[1], Ma H[1], Benchimol D[2], Lambrichts I[3], Politis C[1], Jacobs R[1,2]

[1]OMFS-IMPATH Research Group, KU Leuven, Leuven, Belgium
[2]Deparment of Dental Medicine, Karolinska Institutet, HuddingeSweden
[3]Morphomogy Group, Biomedical Research Institute, Hasselt University, Hasselt, Belgium

Background: Nowadays, cone-beam computed tomography (CBCT) can be considered as the method of choice in preoperative planning of dental implant sites. During the healing process after tooth removal, bone is deposited and remodelling takes place causing a reduction of the extraction socket (ES) volume. Unfortunately, current radiographic evaluations have not yet fully exploited the advantage of three dimensional (3D) bone analysis. Measurements on the width and height of the alveolar ridge are mostly limited to subjective linear measurements performed on arbitrary chosen 2D slices of a 3D dataset. Overall, 3D assessment of the socket morphology and volume is deemed crucial to provide a robust basis for comparing and evaluating socket preservation techniques and surgical implant protocols. In the present study, a new easy-to-use imaging method was developed that can semi-automatically calculate socket volumes from CBCT scans. The accuracy of this technique was estimated for different CBCT machines and clinical scanning protocols compared to the gold standard micro-CT. Finally, the most optimal CBCT protocol for reliable clinical evaluation of socket healing was determined.

Material and methods:
Teeth were atraumatically extracted from eight cadaver mandibles to be able to measure the ES volume while still preserving the socket anatomy. Specimens were scanned using a predetermined randomization list in three different CBCT devices (3D Accuitomo 170, NewTom VGI Evo, ProMax 3D Max) using four protocols (high-resolution, standard, low dose, ultra-low dose) and a field-of-view of 10x5cm. Subsequently, the mandibles were sectioned perpendicular to the lower arch totalizing in sixty-four edentulous bone samples and scanned in a high-resolution (35µm) SkyScan 1174 micro-CT system. CBCT scans were spatially aligned on the corresponding micro-CT scan to minimize the errors generated by comparing different anatomical structures. The ES were selected using an automatic boundary extraction. The alveolar bone was segmented to allow an automatic and objective 3D quantification. Next, 3D models were generated for the ES and alveolar bone. Obtained CBCT ES volumes were statistically compared with micro-CT values using mixed effect modelling. General linear model rankings were made to classify the CBCT machines and protocols according to the better balance between accurate measurements and radiation dose.

Results
The largest measured effective dose was 364 µSv for the high-resolution protocol of ProMax 3D Max HD. While the ultra-low dose protocol of ProMax 3D Max achieved the lowest effective dose of 24 µSV. All CBCT machines and scanning protocols were able to accurately assess the socket morphology and volume compared to micro-CT, except for the ultra-low dose protocols of ProMax 3D Max and 3D Accuitomo 170. Standard and high-resolution scanning protocols provided the best balance between administered dose to the patient and measurement error.

Conclusion
CBCT assessment of the socket morphology and volume is deemed crucial for objective socket healing follow-up. This new automatic volume analysis method provides an excellent alternative for subjective 2D measurements. Although low-dose CBCT scan protocols greatly reduce the administered radiation dose to the patient, these protocols underestimate the socket volume.