Artifact Reduction in three-dimensional Dental Imaging using Micro Computed Tomography

M. Luckow[1,2,3], D. Berndt[2], J.T. Lambrecht[2], F. Beckmann[4], H. Deyhle[1,3], J. Ratia[1], and B. Müller[1,3]

[1]*Biomaterials Science Center, University of Basel, 4031 Basel, Switzerland*
[2]*Department of Oral Surgery, Oral Radiology and Oral Medicine, University of Basel, 4056 Basel, Switzerland*
[3]*Materials Science Institute of Dental School, University of Basel, 4056 Basel, Switzerland*
[4]*Institute of Materials Research, GKSS-Research Center, 21502 Geesthacht, Germany*

Introduction

Metal implants for accurate restorations in dentistry have been widely accepted to treat patients, who need a tooth root replacement. Dental cone beam computed tomography (CBCT) is an effective tool for pre-operative planning and implant selection. The cross-sectional images allow the selection of the appropriate implant length and diameter as well as the appropriate implantation site. CBCT can not be utilized likewise for the post-operative imaging because huge artifacts appear as dark bands and streaks around the metal objects. In order to understand the related phenomena and finally to reduce the artifacts, dental CBCT scans of a porcine mandible with two commercial available titanium implants were performed varying the accelerating voltage, the beam current and the position of the mandible with respect to source and detection unit. In order to determine a baseline for comparison, micro computed tomography (µCT) and synchrotron radiation-based micro computed (SRµCT) data were generated, which did not contain these huge artifacts.

The patient's head between X-ray source and detection unit is oriented that the strongly absorbing teeth and implants are in a single plane. This is the worst case, since all highly X-ray absorbing components in line cause the strongest artifacts. We hypothesize that tilting the patient's head will significantly reduce artifacts. The effect should be especially clear for patients with multiple implants, because the tilting can prevent the overlapping of the strongly X-ray absorbing materials.

Sample Preparation and Tomography Imaging

For the current study, two titanium-implants (Institut Straumann AG, Villeret, Switzerland) each 4.1 mm in diameter and 10 mm in length were inserted into a porcine mandible. The dental CBCT 3D Accuitomo 60 (Accuitomo, Morita, Japan) provided the volumetric data. For the µCT measurements with the Skyscan 1172 (Skyscan, Kontich, Belgium) a cylinder (30 mm in diameter) hosting the two implants was extracted from the mandible.

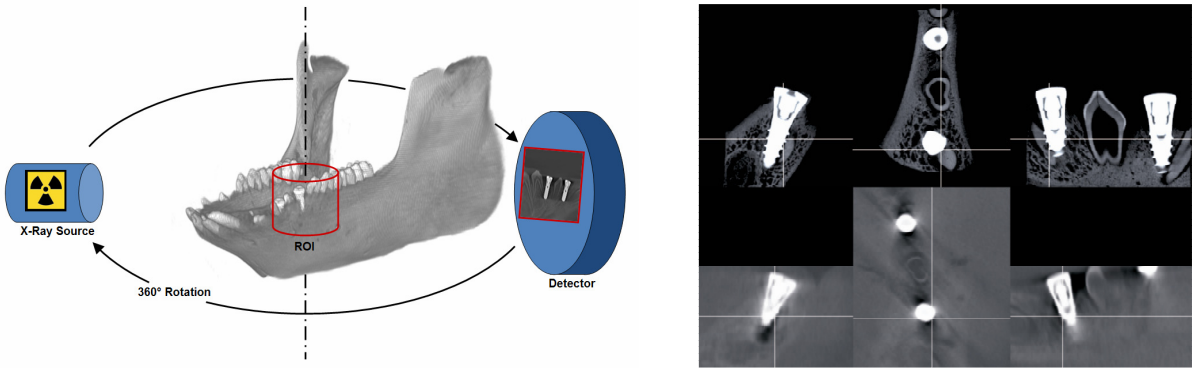

Figure 1: Left: Set up for dental CBCT (Accuitomo 60). The region of interest is marked in red. Right: For comparison, all tomography data were pre-registered via the manual selection of 3 non-collinear anatomical landmarks. (Top: µCT Skyscan 1172; bottom: dental CBCT data).

SRµCT Measurements

SRµCT measurements were performed at the beamline W 2 (HASYLAB at DESY, Hamburg, Germany) using the photon energy of 76 keV. The 30 mm sample was larger than the field of view of the X-ray detection unit. Therefore, scans for four lateral and two vertical sample positions were reassembled. The resulting reconstructed volume of $(1199 \times 1199 \times 332)$ voxels corresponds to $32.3\ \text{mm} \times 32.3\ \text{mm} \times 8.9\ \text{mm}$.

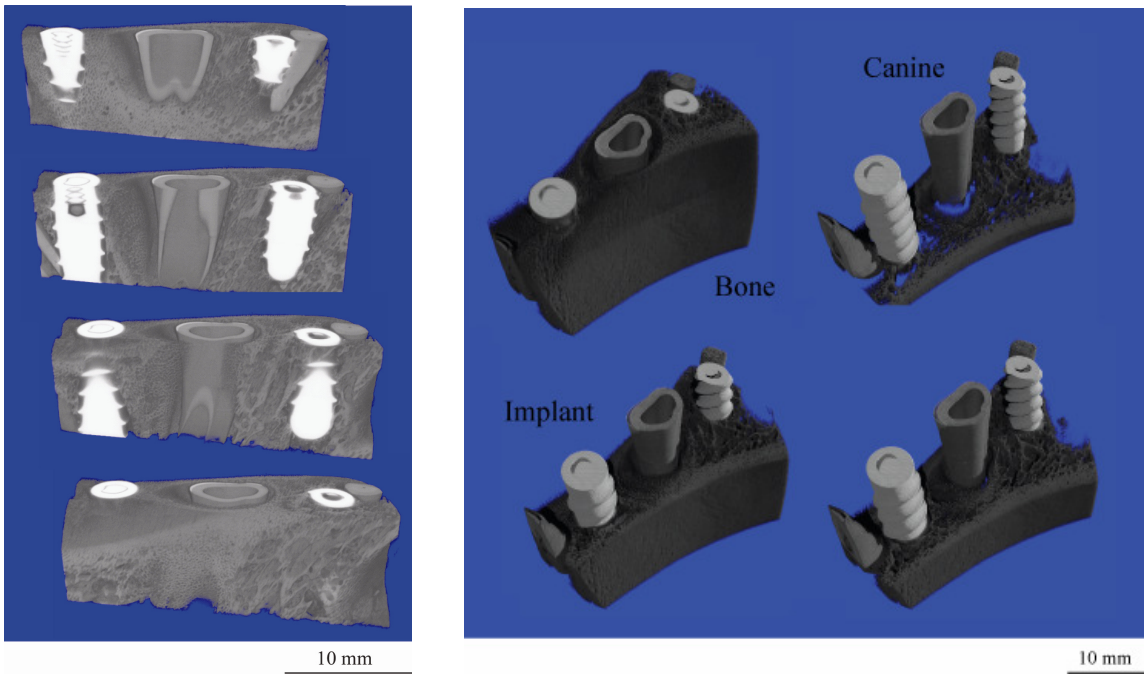

Figure 2: Left: Volume renderings of the total volume with different sagittal cuts (step size: 1.5 mm). Right: 3D representation of the segmented implants and teeth. The position is shown by different horizontal cuts of the mandible.

Conclusion

The µCT data provide the baseline to be used for the quantification of artifacts in clinical CT [1]. Because of the improved image quality and the artifact-free visualization of additional features, SRµCT yields an even better defined standard for the optimization purposes. In both cases, the clinical CT data acquired at different accelerating voltages, beam currents and geometrical arrangements can be directly compared for the empirical optimization. As expected, the increase in the accelerating voltage from 70 to 80 kV in CBCT improves the image quality [1]. The dark bands at the bone-implant interfaces become weaker, the white streaking artifacts in the axial planes are significantly reduced. Preliminary results indicate that tilting the patient's head permit a significant reduction of artifacts [2]. Further data evaluation is necessary to finally instruct the CBCT operator how to image the human mandible in position, which mainly supports the accurate post-operative evaluation.

The authors thank HASYLAB at DESY, Hamburg, Germany for beam-time allocation (II-20060035 EC). The support of Julia Herzen, GKSS, at the beam-line is gratefully acknowledged.

References

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