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Optimization of clinical CT by means of micro computed tomography

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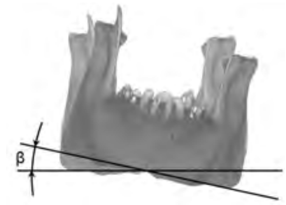
INTRODUCTION

Metal implant supported 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 selecting the appropriate implant length and diameter as well as the desired implant position. CBCT cannot be utilized likewise for the post-operative imaging because huge artifacts appear as dark bands and streaks around the metal implant. In order to understand the related phenomena and finally to reduce the artifacts, dental CBCT scans of a pig jaw with two conventional titanium implants were performed varying the accelerating voltage, the beam current and the position of the jaw with respect to source and detection unit. Furthermore, microCT and SRµCT scans were performed to define an artifact free measurement.

SAMPLE PREPARATION AND CBCT

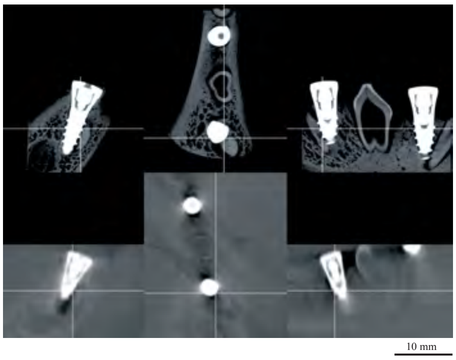
The head of the patient is oriented that teeth, potential implants, X-ray source and detection unit are arranged in a single plane. This is the worst case, since highly X-ray absorbing components in line causes the strongest artifacts. We hypothesize that tilting the patient's head will reduce artifacts. The effect should be clear for patients with multiple implants, because the tilting can prevent the overlapping of the strongly X-ray absorbing materials.
For the investigation, two titanium implants (Straumann AG, Villeret, Switzerland) each 4.1 mm in diameter and 10 mm in length were inserted into the pig jaw. The dental CBCT 3D Accuitomo 60 (Accuitomo, Morita, Japan) provided the volumetric data.



The data acquisition implies the 360° rotation of X-ray source and detector around the specimen within about 18 s. Besides tilting the jaw in a frontal and sagital plane in steps of about 5 degrees (α, β) we also varied the accelerating voltage from 70 kV to 80 kV and cathode current from 1 mA to 10 mA.

REGISTRATION

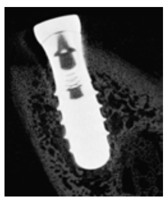
For comparison, all tomography data were cropped to the common volume. For this purpose, the data were pre-registered via the manual selection of 3 non collinear anatomical landmarks. Pre-registration ensures a reasonable estimate for the automatic registration procedure.



The three images in the top row are slices perpendicular to each other obtained from the microCT (Skyscan 1172), whereas the slices below are dental CBCT data.

MICRO-CT

For the microCT measurements with the Skyscan 1172 (Skyscan, Kontich, Belgium) a cylinder of 30 mm diameter was extracted from the pig jaw.

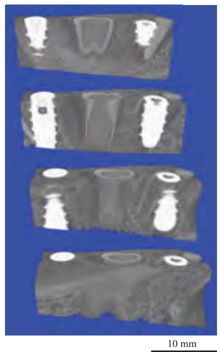


The exposure times of 80 min, the accelerating voltage of 100 kV and the beam current of 100 mA permit the almost artifact-free data acquisition by the implants and the surrounding mineralized bone.

SRµCT

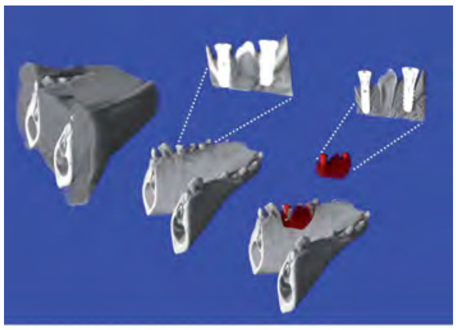
SRµCT mesurements were performed at the beamline W 2 (HASYLAB at DESY, Hamburg, Germany) using the photon energy of 76 keV.

The prepared sample (cylinder of 30 mm diameter) was larger than the field of view of the X-ray detector. Therefore, eight tomographical scans (four lateral and two vertical sample positions) were combined, resulting in a reconstructed volume of 1199x1199x332 voxels representing 32.3x32.3x8.9 mm³.



OVERVIEW BY CLINICAL CT

The entire specimen was visualized by the multi-slice CT Somatom Sensation 16 scanner (Siemens Medical Solutions, Erlangen, Germany). The accelerating voltage corresponded to 120 kV and the beam current to 80 mA.



The multi-slice CT allows visualizing the pig jaw (on the left). Making the soft tissues transparent, the shape of the hard tissues and the implants become visible. The microCT data are represented in red. The virtual cuts of the implants and the tooth in-between demonstrate the much better resolution of microCT with respect to the multi-slice CT.

CONCLUSION AND ACKNOWLEDGEMENT

The SRµCT measurements provide the baseline that can be used to quantify the artifacts generated in clinical CT. Therefore, the clinical CT data acquired at different accelarating voltages, beam currents and geometrical arrangements can be directly compared for optimization purposes. As expected, the increase in the accelerating voltage from 70 to 80 kV in the CBCT improves the image quality. The dark bands at the bone-implant interfaces become weaker, the white streaking artifacts in the axial planes are significantly reduced. (Berndt D, et al., Proc. SPIE 7078 (2008) 7080N) The preliminary results indicate that slight rotations of the patients head permit a significant reduction of artifacts. Further data evaluation is necessary to finally instruct the CBCT operator how to image the patients jaw in an optimized manner.
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