Clinical micro-CT for dental imaging

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Introduction

Motivation
- Implant treatments and/or diagnosis of diseases sometimes require histologic evaluations.
- This histologic evaluation can only be achieved with high-resolution images.
- Conventional dental CT cannot serve micro scale images.

Objective
- We exploit the development of a clinical computed micro-tomography (micro-CT) system for dental imaging using magnification.
- In order to determine the optimal magnification factor, we measured the imaging detector and tomographic performances and referenced clinician’s opinion.

System description

Micro dental CT system consists of
- Micro-focus x-ray source (Ulbralight™, Oxford Instruments X-ray Technology, Inc., USA)
- Variable focal spot size form 13 to 40 μm 10–90 kVp within 80 W power
- Motor-controlled rotational object holder
- 0.09° minimum step angle
- X-ray imaging detector (C925/DOP, Hamamatsu, Japan)
  - Pixel pitch: 200 μm
  - Field of view: 122 x 122 mm²
  - Readout frame speed: 30 fps

Dose measurement
- Dose at a certain distance was estimated by the inverse-squares law.
- Doses at the detector and at the object, imply the estimations at the entrance surface of the detector and at the AOR.
- While keeping the other geometric variables fixed, the magnification factor is given by
  \[ M = \frac{d_{on}}{d_{os}} \]

MTF is calculated by slice image of bone.

3D MTF
- MTF measured from tomographic images for the thin wire phantom are shown in Figure.
- Little improvement in the MTF performance at M = 4 compared to that at M = 3.
- It is similar to the MTF results based on radiography.

Uniformity
- Because of the magnification the photon fluence incident on the detector was reduced in a fashion of the inverse squares of distance.
- Lower photon fluence accentuates quantum noise in images.

As the applied magnification factor increases, the decreasing dose at AOR reduces both the SNR and CNR in tomography because of the enhanced quantum noise.

Characteristics of CT system

A water-filled cylindrical acrylic vessel having a diameter of 30 mm was used for evaluating the signal uniformity.

The contrast was evaluated with the contrast phantom which consists of six low-contrast inserts.

SNR and CNR are calculated by

\[ \text{SNR} = \frac{M \cdot \sigma}{\sqrt{M \cdot \nu}} \]

As the magnification factor increases, ring artifacts are more apparent.

Dose at the detector decreases as the applied magnification increased. → contrast worsens according to the increase in magnification.

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Results

Overall detector characteristics

MTF and uniformity of CT system

CNR and SNR of CT system

Conclusions

With the micro-focus x-ray source having a focal spot size of ~32 μm and the flat-panel detector with a pixel pitch of 200 μm, the best MTF and DQE performances were achieved at the magnification factor of 3.

MTF in tomography was also limited at the magnification factor of 3.

Tomographic image qualities, such as SNR and CNR, of the low-contrast phantom and the skull phantom were mainly restricted by the quantum mottle in the detector because of the inefficient x-ray exposure.

However, the potential image quality is promising for a clinical application. With the system investigated in this study, the magnification factor of 3 would be the upper limit for high-resolution imaging and thus histologic evaluation.

For the practical use of the system, the patient dose should be evaluated considering the quantum mottle in the detector.