# CMOS Flat-Panel CBCT for Dental Imaging

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## 1. Introduction

Computed tomography (CT) has become one of the most frequently used imaging modalities for the preoperative evaluation of the jaw for dental implants. Sometimes dental Implant surgery needs histologic information of the regeneration of bone structure However conventional dental CT cannot serve these information because of its resolution limit. Hence we suggest dental CT which has micro scale resolution with high magnification factor. In these regards, We investigated micro dental CT with optimal magnification factor about our hardware system and evaluated along the 2D and 3D performance experimentally.

## 2. Methods and Results

### *2.1 Hardware description*

The main components for the micro-CT system are a microfocus x-ray source (Ultrabright[TM], Oxford Instruments X-ray Technology, Inc., USA), and an x-ray imaging detector (C9250DP, Hamamatsu, Japan) with rotational stage. The x-ray source has a variable focal spot size from 13 to 40 μm, which is dependent on the applied power. And The detector is based on photodiode array coupled to a CsI:Tl scintillator. The photodiode array was fabricated by a CMOS (complementary metal-oxide-semiconductor) process. It has 122 × 123 mm$^2$ active area with 200μm pixel pitch. Geometric magnification of the micro-CT system was provided by adjusting one of two distance parameters; the source-to-detector distance, $d_{SD}$, and source-to-object distance, $d_{SO}$, while keeping the other fixed. The magnification factor is given by $M = d_{SD} / d_{SO}$.

### *2.2 2D performance evaluation*

The performance of an imaging detector is mostly responsible for the image quality and eventually the quality of tomography. Imaging characteristics of the detector used in this study were evaluated by measuring MTF, NPS and DQE[1]. The irradiation conditions were 80 kVp and 1 mA, which yields a focal spot size of ~32 μm. To consider the beam quality attenuated from a human head, we measured HVL for the beam transmitted from a water vessel having a diameter of 150 mm, and the measured HVL was 12-mm-Al-

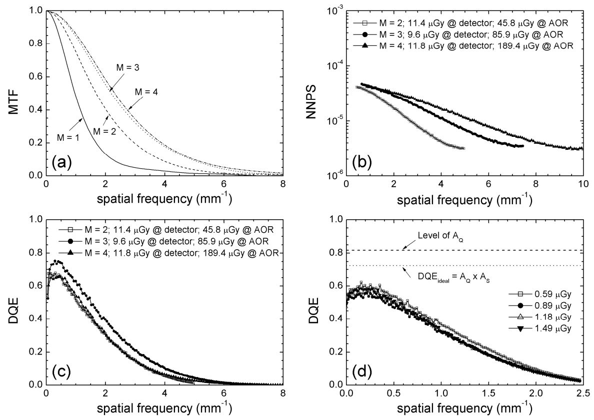


Fig. 1. Fourier analyses of the imaging performances of the detector with respect to magnification. (a) MTF, (b) Normalized NPS, and (c) DQE. (d) DQE with respect to dose at the entrance surface of the detector without magnification (or $M$ = 1).

equivalent. So, all the measurements were performed with the beam tailored by the additional Al filtration of 12 mm in this study (including 3D performance evaluation). The detector performance was evaluated as a function of magnification. Neglecting x-ray scatter, the DQE accounting for magnification can be calculated by [2]

$$\mathrm{DQE}(f') = \frac{M^4 \bar{q}_0 \bar{G}^2 \mathrm{MTF}^2(f/M)}{\mathrm{NPS}(f/M)} = \frac{\mathrm{MTF}^2(f/M)}{\bar{q}_0 \mathrm{NNPS}(f/M)}$$

where $f$ and $f'$ denote the spatial frequencies in the image plane and the object plane, respectively.

Fig. 1. shows the result of 2D performance evaluation. The effect of magnification is stretching the frequency bin. Hence ideal system should show better performance for more magnification. But the best performance with respect to the results is $M$=3. We can

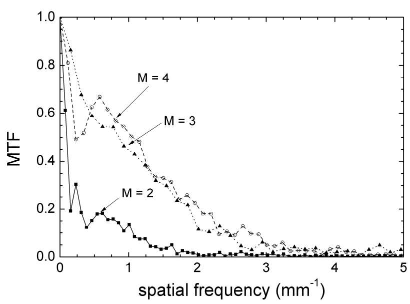


Fig. 2. MTF in CT images with respect to $M$. MTF results were estimated based on Hankel transform of transaxial images reconstructed from the wire phantom.

deduce that focal spot blur is came out more reasonable

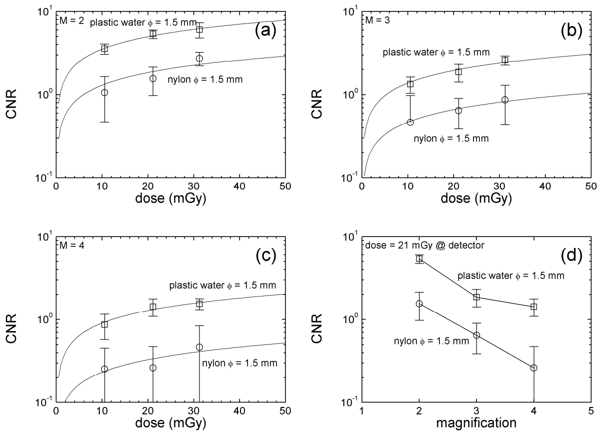


Fig. 3. Calculated CNRs for the contrast phantom with respect to dose and magnification.

at more than $M$=3.

*2.3 3D performance evaluation*

Tomographic imaging performance of the micro-CT system was evaluated with homemade quantitative phantoms. The contrast was evaluated with the contrast phantom which consists of six-low-contrast inserts. The contrast phantom is completed when the inserts are immersed in the water vessel. Each insert was made of commercial electronic density phantoms (Model 76-430, Nuclear Associates, NY, USA). CNR of each insert material for the background water was calculated[3]. MTF in the tomography was evaluated by using a wire phantom (Au with a diameter of 25 μm). A transaxial image of the reconstructed wire phantom was analyzed by Hankel transform considering circular symmetry.

Fig. 2 is calculated CNRs using contrast phantom. CNRs are increase for more dose (more number of views) and it is decrease for more magnification. This result means that the decreasing dose at AOR lowers the CNR as the magnification factor increases. And Fig. 3 shows the result of the 3D MTF. It shows similar result compared with 2D MTF result.

*2.5 Phantom study*

A humanoid skull phantom (PUT-2, Kyotokagaku,

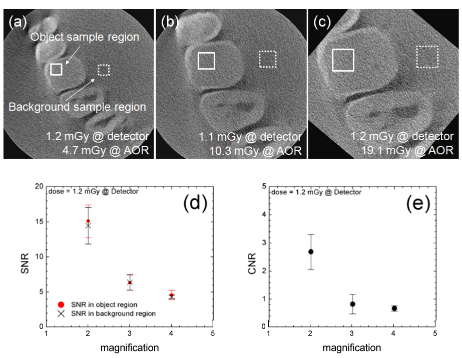


Fig. 4. Transaxial images of teeth region of the skull phantom for the magnification of factor of 2, 3 and 4 and calculated CNRs and SNRs [(d), (e)]

Japan) was scanned with respect to various magnification factors. For all the image reconstructions, we applied the Feldkamp's cone-beam algorithm to the projection data filtered with the Ram-Lak filter.

Fig. 4. show the result of CNRs and SNRs for skull phantom data. Calculated CNR between two regions are plotted in Fig. 4(e). 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. As the magnification factor increases, the image noise becomes more severe due to the quantum mottle in the detector.

## 3. Conclusions

We have investigated the feasibility of micro tomography for clinical dental imaging application. 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.

## AKNOWLAGEMENTS

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