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Analytical dose estimation in dental cone-beam CT

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1. Introduction

In dentistry, it is important to acquire exact information on dental arches, surrounding tissues, maxillary and mandible. Cone beam computed tomography (CBCT) is widely adopted diagnosis tool due to its characteristic which offers the three-dimensional volumes of objects. However, there are risks of radiation induced diseases and the public attention and concern on them. Despite these risks and concerns, patient clinical studies on dose in dental CBCT are scarce [1, 2].

In this paper, we introduce an analytical algorithm to estimate the absorbed dose in dental CT. The algorithm contains the calculation of dose distributions due to the primary and scattered photons separately.

2. Materials and Methods

This study considers different types of CBCT scan methods.. One is a typical full-scan CBCT and the other is a half-scan CBCT, which implies the CBCT from width-truncated projections [3]. Typically, in the actual half-beam scan, a wider beam than the half-beam is used to avoid the abrupt truncation in the sonogram. To distinguish this from the half-beam scan, we call it the overlapping half-beam scan.

2.1 Dose estimation

The absorbed dose due to primary x-ray at each voxel in the reconstructed volume image is estimated accounting for the attenuation along the ray, which connects the focal spot of x-ray tube and the voxel of interest:

$$D_p(r_v) = \sum_E \sum_\beta \sum_z \varphi(E; r_f)\Omega(r_f \to r_v)$$
$$\alpha(r_f \to r_v)\mathrm{A}(r_f \to r_v)\varepsilon(\Delta v)$$

where $\varphi(E; r_f)$ represents the fluence at the source position $r_f(\beta, \mathrm{z})$, and $\Omega(r_f \to r_v)$, $\alpha(r_f \to r_v)$ and $\mathrm{A}(r_f \to r_v)$ are the solid angle subtended by r_f by a voxel at r_v, the effective voxel area at r_v by a voxel at r_f, the attenuation along the vector $r_f \to r_v$,

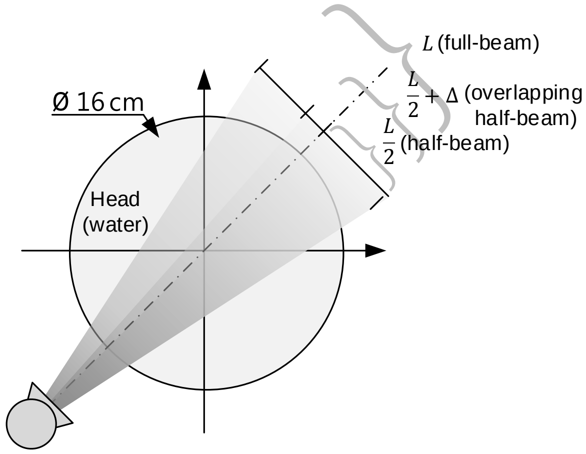

Fig. 1. The phantom and the calculation geometry

respectively. $\varepsilon(\Delta v) = \{\mu_{pe}(r_v)/\mu_{tot}(r_f)\}E$ is the energy deposition at a voxel at r_v.

Calculated voxel-dose values combined with the scatter-to-primary ratio then become the sources of secondary dose at surrounding voxels due to scatted photons:

$$D_s(r_v) = \sum_{r_v' \in R} D_p(r_{v'})\mathrm{f_s}(r_{v'})\Omega(r_v \to r_{v'})$$
$$\times A(r_v \to r_{v'})\mathrm{F}(r_v)$$
$$D_s(r_{v'}) = D_p(r_{v'}) + \mathrm{f_s}(r_{v'})(1 \to \mathrm{F}(r_v))\varepsilon(r_{v'})$$

where $\mathrm{f_s}(r_{v'})$ represents the scatter fraction and $\mathrm{F}(r_v)$ is E'/E. Similar to the primary dose calculations, the scatter dose is calculated accounting for the attenuation along the ray, which connect at this time the scatter-source voxel and the voxel of interest.

2.2 Phantom

The phantom and the calculation geometry are shown in Fig.1. The dimension of the numerical phantom is based on the typical CT dose index (CTDI) head phantom, of which outer diameter 16 cm. The phantom is filled with water.

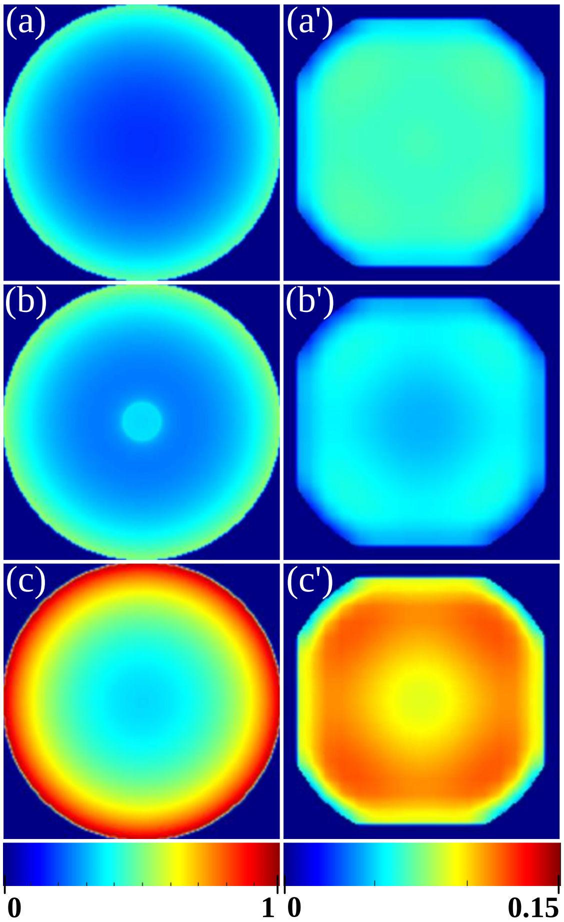

Fig. 2. Absorbed dose in phantom. dose distributions due to the primary and scattered photons. (a) and (a') show primary and scatter dose distributions at half-scan, (b) and (b') at overlapping half-scan, (c) and (c') at full-scan condition respectively.

3. Preliminary results

Preliminary calculations were conducted on full scan, half scan, and half scan with overlapping. The results are shown in Fig. 2. Fig. 3. Compares the profiles extracted from Fig. 2. Although the dose due to scatted photons is small compared to that due to primary, it affects the spatial distribution of the absorbed dose. The half-beam scan results in less dose then the full-beam scan. The overlapping half-beam scan adds the dose around the central region of the head phantom.

4. Ongoing and Further Studies

More quantitative analysis of the absorbed dose distributions in dental CBCT will be addressed.

To verify the algorithm, the Monte Carlo simulation to measure dose in CTDI head phantom will be carried out. The CTDI measurement will also be performed.

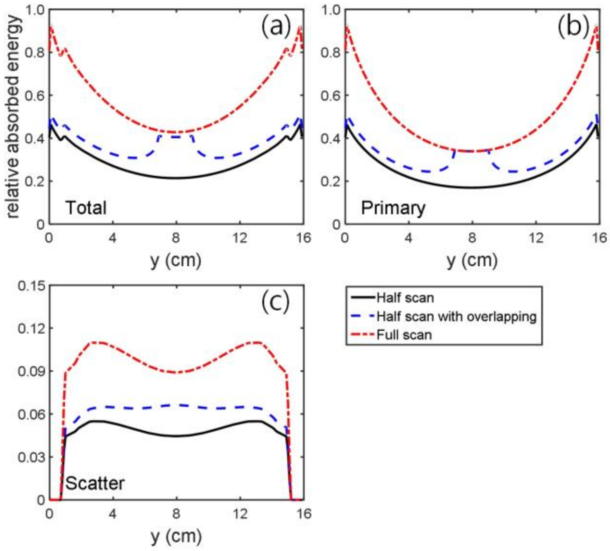

Fig. 3. the profiles extracted from Fig.2.

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