A survey of organ and effective doses for seven dental cone beam computed tomography (CBCT) units.

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Introduction

Cone Beam Computed Tomography (CBCT) imaging is accomplished by using a rotating gantry to which an x-ray source and an imaging detector are attached. A pyramidal or cone-shaped x-ray beam is used instead of the conventional CT fan beam. The x-ray source and the detector perform a full or half rotation around a point fixed within the centre of region of interest. During the rotation multiple planar projections of the field of view are acquired and reconstructed.

CBCT offers three-dimensional images with high level of accuracy. Dental CBCT has been associated with higher radiation risk compared to conventional dental imaging and lower radiation risk compared to multi-slice CT (MSCT). Several studies have reported on radiation doses for dental CBCT examinations [1-4].

Three dimensional imaging

Dental CBCT unit

Accuitomo 170, Morita

The majority of the studies have used thermoluminescent dosimeters (TLD) in tissue-equivalent anthropomorphic phantoms. There is a wide variation in terms of methodology, type of phantoms, number of TLDs and positioning. The effect of positioning and number of TLDs on the accuracy of the effective dose has not been assessed. The effective doses for dento-alveolar examinations ranged from 34 μSv to 652 μSv . For craniofacial examinations, the effective doses ranged from 30 μSv to 1073 μSv.

Aim

The aim of this study was to measure the adult organ and effective doses for seven dental CBCT units.

Methods and Materials

Radiation absorbed doses were measured using two adult ART head and neck phantoms (slices 1-10) and two types of TLDs (TLD-100 and TLD100-H). The TLD uncertainty was < 10%. On average, 150 TLDs were uniformly positioned in the two phantoms in order to measure the absorbed doses to the brain (~30), red bone marrow (~30), bone surface (~30), salivary glands (~20), skin (~30) and thyroid (~10). Correction factors were applied to the skin, bone surface and red bone marrow doses for each phantom slice to account for the fraction of the total mass of the specified organ in the phantom. The effective doses were calculated using the ICRP 103 tissue equivalent factors. Measurements were done on seven dental CBCTs: a) Galileos (Sirona), Promax 3D (Planmeca), NewTom VG (AFP Imaging), i-CAT Next Generation (i-CAT), Picasso Trio (E-woo), Scanora 3D (Soredex) and Kodak 9000 (Kodak).

Male adult ART phantom

Results

Table 1. Exposure factors* and clinical indications used in this study

	kV	mAs	Voxel size (mm)	Field of View (cm)	Clinical Indication
Galileos	85	28	0.3	15	Dento-alveolar
Promax 3D	84	114	0.16	8	Mandible + half maxilla
Picasso Trio	85	53	0.2	12 Ø x 7	Mandible
Kodak 9000	70	105	0.076	5 Ø x 3.7	Mandible Front
NewTom VG	110	10	0.3	15 Ø	Dento-alveolar
i-CAT Next Generation	120	19	0.4	16 Ø x 6	Mandible
Scanora 3D	85	30	0.2	10 Ø x 7.5	Mandible, Maxilla, Dento-alveolar

*Exposure factors as used for standard patients by departments

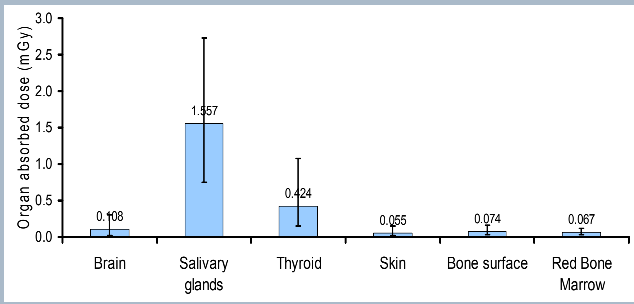

Figure 1. Average, minimum and maximum absorbed organ doses

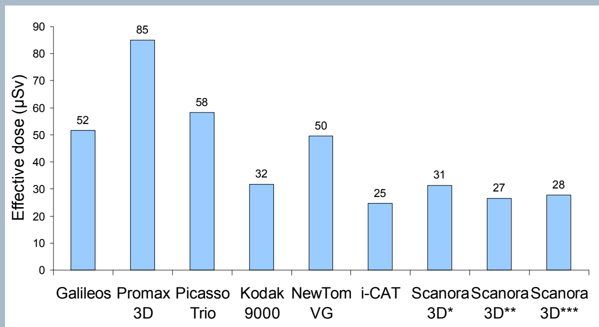

Figure 2. Effective doses for seven dental CBCT units

Discussion and Conclusions

Figure 1 shows that the salivary and thyroid glands receive the highest organ doses. They are positioned between slices 5 and 8 and between slices 9 and 10 respectively. The salivary glands are either partially or fully irradiated by the primary beam depending on the clinical examination. The thyroid gland is either exposed to scattered radiation and/or is partially irradiated by the primary beam. The absorbed doses to skin, red bone marrow and bone surface were rather small due to the fact that only a fraction of the total mass of these organs is located in the head and neck region of the phantom. Figure 1 shows that there is a wide variation in the absorbed doses for all the organs. This is due to a) clinical area being imaged and b) the wide range of exposure factors set by the manufacturers and clinical staff, as shown in table 1.

The salivary glands, thyroid gland and the red bone marrow are the three organs that contribute the most to the effective doses for all the CBCT units and clinical examinations. Although the dose to the red bone marrow is much smaller than the salivary and thyroid glands doses, its contribution to the effective dose is significant due to its high radiosensitivity.

Figure 2 shows that there is a wide range of effective doses even for the same clinical indication with an average value of 43 μSv. This is mainly due to the exposure factors set by the manufacturers and clinical staff. The highest and lowest effective doses correspond to the Promax 3D and i-CAT Next Generation units. Galileos, Picasso Trio and NewTom VG use relatively high FOVs resulting in effective doses greater than 50 μSv. It should be noted that the exposure factors used for this study were those selected by the users to give acceptable image quality for a standard patient.

This study reported and compared organ and effective doses for seven dental CBCT units. In addition, this study confirmed that CBCT radiation doses are one-twentieth of published MSCT radiation doses [4] but four times higher than the average panoramic dose (10μSv) published by the Health Protection Agency (UK) [5].

References

1. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofac Radiol 2006; 35: 219-26.
2. Loubele M, Jacobs R, Maes F, Schutyser F, Debaveye D, Bogaerts R, Coudyzer W, Vandermeulen D, van Cleynenbreugel J, Marchal G, Suetens P. Radiation dose vs. image quality for low-dose CT protocols of the head for maxillofacial surgery and oral implant planning. Radiat Prot Dosimetry 2005; 117: 211-216.
3. Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. Br J Radiol 2009; 82: 35-40
4. Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P, Marchal G, Sanderink G, Jacobs R. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol. 2008; Jul 16.[Epub ahead of print]
5. NRPB-W4, Radiation Exposure of the UK Population from Medical and Dental X-ray Examinations, National Radiological Protection Board, 2002

It should be noted the doses quoted in the study might not apply to newer versions of CBCT equipment with the same name.

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