ORGAN DOSES AND AIR KERMA-AREA PRODUCT FROM DENTAL CONE BEAM COMPUTED TOMOGRAPHY SCANNERS

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Abstract

The aim of this paper was to determine absorbed doses to relevant organs and the air kerma-area product for implant planning cone beam computed tomography (CBCT) examinations, performed with two scanners (i-CAT and PreXion) using two types of acquisition protocols. The air kerma-area product (P_{KA}) was measured for standard (S) and high resolution (HR) protocols. Organ doses were measured with TLD rods inside an ALDERSON RANDO phantom. Results: For both protocols, organ doses measured for the i-CAT scanner were smaller than those measured for the PreXion 3D scanner. For both CBCT scanners, eye absorbed doses due to the HR protocol were two times higher than corresponding values measured for the standard protocol. Using the HR protocol, the eyes received three times more absorbed dose from the PreXion than from the i-Cat scanner.

1. INTRODUCTION

Radical changes for dental and maxillofacial radiology occurred after the introduction of the Cone Beam Computed Tomography (CBCT) technology, that allows the acquisition of 3-D volume data in one rotation of the X ray equipment. CBCT is capable of providing sub-millimetre resolution images of high diagnostic quality, with short scanning times (10–70 seconds) [1]. CBCT is most frequently used for planning of implant placement to replace teeth. In the area of diagnostic imaging, radiological procedures have to be justified and optimized to ensure that an image with the best clinical information possible is obtained with the lowest patient absorbed doses necessary. It is known that in the area of dental radiography patients absorbed doses from CBCT examinations are higher than doses from single panoramic radiography but, at the same time, are much lower than those delivered by conventional CT scans [2]. Patient absorbed dose depends on the type of radiation detector (flat panel or conventional image intensifiers), on the irradiation parameters, especially the size of the field of view (FOV) and the current-time product (mAs), which is selected by the operator depending on the desired spatial resolution.

The British Health Protection Agency [3] recommends the use of the air kerma-area product (P_{KA}) as the quantity for determining the National Dose Reference Levels. Although these levels have not yet been determined, this Agency recommends a maximum achievable P_{KA} for new CBCT scanners of 250 mGy•cm^2 (25 µGy•m^2) for the clinical protocol used for the placement of an upper first molar implant. On the other hand, recent studies are also concerned about the eye lens and salivary glands doses, which were evidenced by ICRP 103 [4] as important tissues with respect to the induction of cancer.

In Brazil the use of CBCT for dental implant has quickly increased and new CBCT technology equipment has been introduced all over the country, with the PreXion CBCT scanner being the most recent equipment to provide high-resolution 3D images. The objectives of this paper were to determine absorbed doses to relevant organs and the air kerma-area product for implant planning CBCT examinations, performed with two scanners (i-CAT and PreXion) and using two types of acquisition protocols.

2. MATERIALS AND METHODS

This study was carried out with two CBCT scanners installed in Recife, Brazil, applying scanning parameters used by the technicians of the institution for dental-implant planning acquisition for 2 arches (maxilla and mandible). Table 1 presents the scanning parameters used for each acquisition protocol for both CBCT scanners. The measurements were made with two protocols: standard (S) and high-resolution (HR) for adult patients.

TABLE 1. ACQUISITION PARAMETERS USED FOR EACH SCANNER FOR THE ACQUISITION OF IMAGE FOR THE DENTAL-IMPLANT PLANNING.

Scanner model	Acquisition protocol *	kV	mAs	Scan time (s)	FOV (mm)	No. images	Voxel size (mm)
ISI i-CAT	HR	120	46.72	40.0	80×160	599	0.20
(*classic*)	S	120	23.87	20.0	80×160	306	0.30
PreXion 3D	HR	90	148.0	33.5	81×76	1024	0.10
	S	90	76.0	16.85	81×76	512	0.15

* HR – High-resolution; S – Standard.

Measurements of the air kerma-area product (P_{KA}) were performed with a transmission ion chamber (PTW Diamentor E2) positioned at the tube exit. The anthropomorphic RANDO® phantom was used to simulate the patient. P_{KA} was registered after each complete acquisition with the anthropomorphic phantom and three measurements were performed for each protocol. The in site calibration factor of the PTW Diamentor was initially determined and used to correct the P_{KA} values.

Organ doses were measured using TLD-100 (LiF:Mg,Ti) rods inserted in pairs inside the adult anthropomorphic head and neck of the RANDO® phantom in the region of relevant organs and tissues presented at Table 2. The dosimeters' readings were carried out using a Harshaw-Bicron 3500 TLD reader. Table 2 also presents the fraction of the organ or tissue irradiated due to CBCT procedure for implant planning. These fractions were based on those used by Ludlow et al. [5] and Roberts et al. [6], for an 8 cm Field of View (FOV).

TABLE 2. NUMBER OF PHANTOM SLICES WHERE THE TLD RODS WERE INSERTED AND THE PERCENTAGE OF THE ORGAN IRRADIATED IN EXAM PERFORMED WITH FOV= 80mm

Organ	Phantom slices	Fraction irradiated
Brain	3, 4	40%
Pituitary gland	4	100%
Eye lens	4	100%
Bone surface	5, 6, 7	7.3%
Bone marrow	5, 6, 7	7.3%
Salivary glands	6, 7	100%
Thyroid	9, 10	100%
Oesophagus	10	10%
Skin	6, 8	2.0%

Effective dose (E) was calculated as the sum of the products of the measured equivalent doses H_T and the ICRP tissue-weighting factors (w_T). It is important to note that these doses include the contribution of the scout images acquired to verify the correct positioning of the patient.

3. RESULTS AND DISCUSSION

Figure 1 shows the results of P_{KA} obtained with the two CBCT equipments and both acquisition protocols. One can see that for both protocols, acquisitions result in lower P_{KA} values for the i-CAT scanner than for the PreXion 3D scanner. Although the scan time to obtain an image with the i-Cat scanner is higher than the time necessary when using the PreXion scanner (Table 1), the X ray exposure time is nevertheless lower than for the PreXion, because the i-CAT scanner operates with a pulsed X ray mode, while the PreXion scanner operates with a continuous exposure mode. The pulse width is 11ms, resulting in a total exposure time during image acquisition of 7.2s and 3.6s for High Resolution and Standard protocols, respectively. The PreXion CBCT scanner uses the continuous mode to allow the acquisition of more images and the reconstruction of small slices, improving the spatial resolution. Similar results were obtained by Vassileva and Stoyannov [7] with the CBCT scanner ILUMA^{TM} ranging from 110 to 185 µGy•m^2 for adult protocols. Torres et al. [8] reported P_{KA} values of 45.3 to 24.4 µGy•m^2, for the i-CAT HR and S protocols, respectively. These values are lower than obtained in our study because the axial image slice FOV is 60×160mm and ours is 80×160mm for i-Cat and 81×76 mm for PreXion.

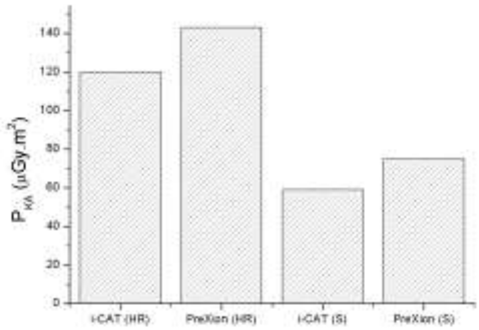

FIG. 1. P_{KA} values obtained with i-Cat and PreXion CBCT equipment with standard (S) and high resolution (HR) protocols for implant dental planning.

Results of mean organ doses measured with TLDs in the anthropomorphic phantom, irradiated with both CBCT scanners using high-resolution and standard protocols are shown in the Figure 2. For both CBCT scanners, the results show that the eye absorbed doses using HR protocol is around two times higher than eye absorbed doses received by the standard protocol. On the other hand, using the HR protocol the eyes received 3 times more absorbed dose from the PreXion scanner than from the i-Cat scanner.

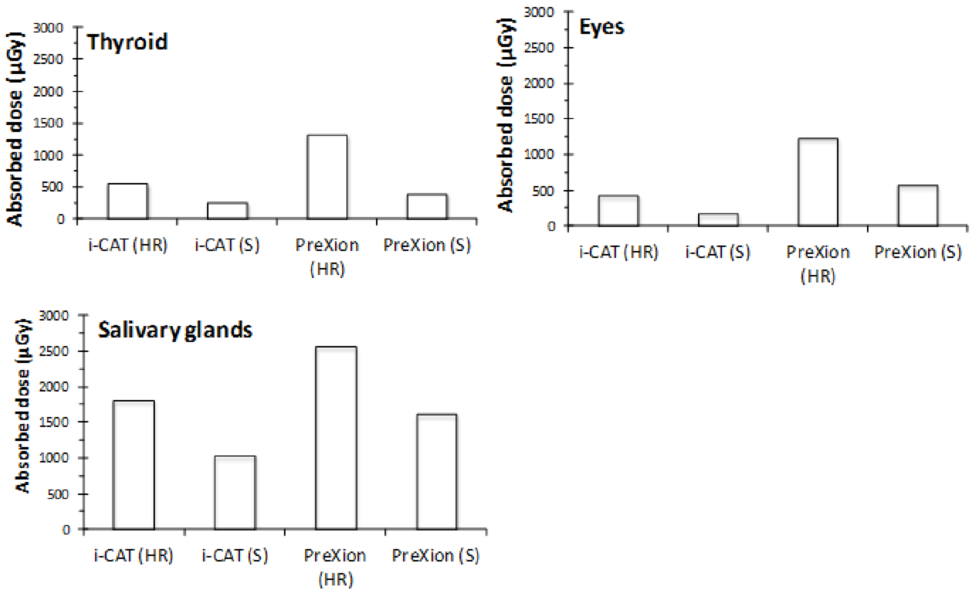

FIG. 2. Mean organ absorbed doses for the eye, salivary glands and thyroid.

Using the measured organ absorbed doses, the irradiated fraction of the organ/tissue and the tissue weighting factor, effective doses for the high-resolution protocols were calculated as 139 µSv (i-CAT) and 127 µSv (PreXion). Although the P_{KA} was higher when using the PreXion scanner compared to the i-Cat scanner, the effective dose for the PreXion acquisition was lower than i-Cat, due to the smaller FOV used. For the standard protocols, the effective doses were: 70 µSv (i-CAT) and 64 µSv (PreXion). These values are similar to those found by Ludlow et al. [9] and Silva [10]: 69 and 61 µSv for the i-CAT standard protocol (with a FOV of 130×160 mm). For the PreXion 3D, Ludlow et al. [9] published values of 388 µSv (HR) and 189 µSv (S), much higher than those found in this work.

4. CONCLUSION

The data showed that the use of HR protocols without any criteria may contribute to elevated patient absorbed doses and asociated radiation risks. Eye and salivary gland absorbed doses from dental CBCT are not negligible and they should be recorded in the patient records for future considerations.

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REFERENCES

[1] SCARFE, W.C., FARMAN, A.G., SUKOVIC, P., Clinical Applications of Cone-Beam Computed Tomography in Dental Practice, J. Can. Dent. Assoc. **72** 1 (2006) 75–80.

[2] LUDLOW, J.B., DAVIES-LUDLOW, L.E., BROOKS, S.L., Dosimetry of two extraoral directi digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit, Dentomaxillofacial Radiology **32** (2003) 229-234.

[3] HEALTH PROTECTION AGENCY. Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment, HPA-CRCE-010, HPA Working Party on Dental Cone Beam CT Equipment, United Kingdom (2010).

[4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication No. 103, Ann. ICRP 37, Elsevier, Amsterdam and New York (2007) 2-4.

[5] LUDLOW, J.B., DAVIES-LUDLOW, L.E., BROOKS, S.L., HOWERTON, W.B., Dosimetry of 3 CBCT devices for oral and maxillofacial radiology, Dentomaxillofacial Radiology **35** (2006) 219-226.

[6] ROBERTS, J.A., DRAGE, N.A., DAVIES, J., THOMAS, D.W., Effective dose from cone beam CT examinations in dentistry, Br. J. Radiol. **82** (2009) 35-40.

[7] VASSILEVA, J., STOYANOV, D., quality control and patient dosimetry in dental come beam CT, Rad. Prot. Dosim. **139** 1-3 (2010) 310-312.

[8] TORRES, M.G.G., CAMPOS, P.S.F., SEGUNDO, N.P.N., et al., Evaluation of referential dosages obtained by Cone-Beam Computed Tomography examinations acquired with different voxel sizes, Dental Press J. Orthod. **15** 5 (2010) 42e1-4.

[9] LUDLOW, J.B., IVANOVIC, M.I., HILL, C., Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology, Oral Surg. Oral Med. Oral Path. Oral Radiol. Endod. **106** 1 (2208) 106-114.

[10] SILVA, M.A.G., WOLF, U., HEINICKE, F., et al., Cone-beam computed tomography for routine orthodontic treatment planning: A radiation dose evaluation, Am. J. Orthod. Dentofacial Orthoped. **133** 5 (2008) 640.e1-5.