

## ONLINE ARTICLE\*

# Evaluation of referential dosages obtained by Cone-Beam Computed Tomography examinations acquired with different voxel sizes

Marianna Guanaes Gomes Torres\*\*, Paulo Sérgio Flores Campos\*\*\*, Nilson Pena Neto Segundo\*\*\*\*, Marlos Ribeiro\*\*\*\*\*, Marcus Navarro\*\*\*\*\*, Iêda Crusóé-Rebello\*\*\*\*\*

## Abstract

**Objectives:** The aim of this study was to evaluate the dose–area product (DAP) and the entrance skin dose (ESD), using protocols with different voxel sizes, obtained with i-CAT Cone-Beam Computed Tomography (CBCT), to determine the best parameters based on radioprotection principles. **Methods:** A pencil-type ionization chamber was used to measure the ESD and a PTW device was used to measure the DAP. Four protocols were tested: (1) 40s, 0.2 mm voxel and 46.72 mAs; (2) 40s, 0.25 mm voxel and 46.72 mAs; (3) 20s, 0.3 mm voxel and 23.87 mAs; (4) 20s, 0.4 mm voxel and 23.87 mAs. The kilovoltage remained constant (120 kVp). **Results:** A significant statistical difference ( $p < 0.001$ ) was found among the four protocols for both methods of radiation dosage evaluation (DAP and ESD). For DAP evaluation, protocols 2 and 3 presented a statistically significant difference, and it was not possible to detect which of the protocols for ESD evaluation promoted this result. **Conclusions:** DAP and ESD are evaluation methods for radiation dose for Cone-Beam Computed Tomography, and more studies are necessary to explain such result. The voxel size alone does not affect the radiation dose in CBCT (i-CAT) examinations. The radiation dose for CBCT (i-CAT) examinations is directly related to the exposure time and milliamperes.

**Keywords:** Cone-Beam Computed Tomography. Radiation. Voxel.

## Editor's summary

The voxel size, the smallest unit of a Cone-Beam Computed Tomography (CBCT) image, is related to the definition of tomographic image.

The question raised by the authors of this study is whether voxel size can affect radiation dose during CT scanning. Measurement of dose-area product (DAP) and entrance skin dose (ESD) when

\* Access [www.dentalpress.com.br/journal](http://www.dentalpress.com.br/journal) to read the full article.

\*\* MSc in Dentistry, Federal University of Bahia (UFBA). Specialist in Dental Radiology and Imaging.

\*\*\* Associate Professor, UFBA.

\*\*\*\* PhD in Dental Radiology, Campinas State University (UNICAMP).

\*\*\*\*\* Undergraduate Research Internship - PET, School of Dentistry, UFBA.

\*\*\*\*\* Adjunct Professor, Federal Institute of Education, Science and Technology of Bahia (IFBA).

\*\*\*\*\* Adjunct Professor, UFBA.

TABLE 1 - Protocols for image acquisition for the i-CAT device.

Protocol	Scanning time (s)	Voxel size (mm)	Peak voltage (kVp)	mAs
1	40	0.2	120	46.72
2	40	0.25	120	46.72
3	20	0.3	120	23.87
4	20	0.4	120	23.87

TABLE 2 - Mean values of radiation doses (ESD and DAP) for the four protocols.

Protocol	Entrance Skin Dose - ESD (mGy)	Dose Area Product-DAP (mGy m <sup>2</sup> )
1	3.77	44.92
2	3.78	45.30
3	2.00	24.43
4	2.00	24.98
	(p = 0.00083)	(p = 0.000145)

obtaining CBCT images with an i-CAT (Imaging Sciences International, Hatfield, PA, USA) was performed according to the protocols specified in Table 1. In all protocols, the field of view (collimation) of the scan was equivalent to 6 cm. The tests were repeated four times for each protocol.

The median DAP and ESD values found for the four protocols are shown in Table 2. A significant difference ( $p < 0.001$ ) was found among the four protocols for the two radiation dose assessment methods. The size of the voxel by itself did not influence the exposed radiation dose. When the exposure factors (TE, kVp and mAs) are maintained, simply changing the voxel size does not influence the radiation dose significantly. However, the protocols correlate the use of smaller voxels with greater milliamperage exposure times, which invariably increases the exposure dose.

## Questions to the authors

### 1) Which of the image acquisition protocols you tested is the most cost-effective? Why?

Not only this but other studies have shown that the protocol using a 0.3 mm voxel offers a combination of good resolution and reduced radiation dose. It is therefore the most cost-effective.

### 2) Does the size of the field of view (FOV) used in Cone-Beam CT examinations influence the radiation dose?

Yes. Especially when it comes to kerma area product (KAP), which increases the probability of stochastic effects. However, in our study, no influence was observed because we used the same FOV in all incidences and measurements. But, for example, in CBCT scans with a reduced FOV or restricted to measurement levels by sextants, the dose received is significantly reduced, implying very specific indications.

### 3) Do studies of radiation dose with Cone-Beam CT pose any difficulties or limitations?

Yes, researchers are still seeking a dosimetric quantity and/or a methodology that allows CBCT exposures to be assessed in order to estimate stochastic effects and compare exposures with other technologies. This is only made possible thanks to the volumetric acquisition and advanced technology of CBCT equipment.

#### Contact address

Marianna Guanaes Gomes Torres  
Rua Araújo Pinho, 62, Canela  
CEP: 40.110-150 - Salvador / BA, Brazil  
E-mail: iedacr@ufba.br

# Evaluation of referential dosages obtained by Cone-Beam Computed Tomography examinations acquired with different voxel sizes

Marianna Guanaes Gomes Torres\*, Paulo Sérgio Flores Campos\*\*, Nilson Pena Neto Segundo\*\*\*, Marlos Ribeiro\*\*\*\*, Marcus Navarro\*\*\*\*\*, Iêda Crusoé-Rebello\*\*\*\*\*

## Abstract

**Objectives:** The aim of this study was to evaluate the dose–area product (DAP) and the entrance skin dose (ESD), using protocols with different voxel sizes, obtained with i-CAT Cone-Beam Computed Tomography (CBCT), to determine the best parameters based on radioprotection principles. **Methods:** A pencil-type ionization chamber was used to measure the ESD and a PTW device was used to measure the DAP. Four protocols were tested: (1) 40s, 0.2 mm voxel and 46.72 mAs; (2) 40s, 0.25 mm voxel and 46.72 mAs; (3) 20s, 0.3 mm voxel and 23.87 mAs; (4) 20s, 0.4 mm voxel and 23.87 mAs. The kilovoltage remained constant (120 kVp). **Results:** A significant statistical difference ( $p < 0.001$ ) was found among the four protocols for both methods of radiation dosage evaluation (DAP and ESD). For DAP evaluation, protocols 2 and 3 presented a statistically significant difference, and it was not possible to detect which of the protocols for ESD evaluation promoted this result. **Conclusions:** DAP and ESD are evaluation methods for radiation dose for Cone-Beam Computed Tomography, and more studies are necessary to explain such result. The voxel size alone does not affect the radiation dose in CBCT (i-CAT) examinations. The radiation dose for CBCT (i-CAT) examinations is directly related to the exposure time and milliamperes.

**Keywords:** Cone-Beam Computed Tomography. Radiation. Voxel.

## INTRODUCTION

Successful dental treatment must be based on full planning and that includes the use of images to help with diagnosis. Computed tomography (CT) provides important three-

dimensional images and its use is increasing. However, the radiation dose accumulated in head and neck structures and its high cost are major disadvantages of this technique.<sup>1-8</sup>

A new CT technology, Cone-Beam Com-

\* MSc in Dentistry, Federal University of Bahia (UFBA). Specialist in Dental Radiology and Imaging.  
\*\* Associate Professor, UFBA.  
\*\*\* PhD in Dental Radiology, Campinas State University (UNICAMP).  
\*\*\*\* Undergraduate Research Internship - PET, School of Dentistry, UFBA.  
\*\*\*\*\* Adjunct Professor, Federal Institute of Education, Science and Technology of Bahia (IFBA).  
\*\*\*\*\* Adjunct Professor, UFBA.

puted Tomography (CBCT), has recently become available. This technology was specifically developed for the head and neck region and provides three-dimensional volumetric images similar to medical tomographic images, at low cost and with reduction of patient exposure to radiation, because its field of vision (FOV) is limited to the axial dimension.<sup>2,5,7,9-12</sup> The voxel size is lower on CBCT compared with conventional CT. On the i-CAT device, for example, the voxel size can vary from 0.12 to 0.4 mm for the acquisition of images from the mandible, whereas on conventional CT the voxel size is normally 0.5–1 mm.<sup>6,13</sup> Generally, the smaller the voxel size and the longer the scanning time, the better the resolution and the details. However, a smaller voxel size is associated with a longer scanning time, which has some disadvantages such as greater possibility of patient movement during the examination, elevated radiation doses and longer reconstruction time.<sup>14,15</sup>

The aim of this study was to evaluate the dosage area product (DAP) and entrance skin dose (ESD), using protocols with different voxel sizes, using the i-CAT CBCT device, to determine better parameters based on radioprotection principles.

## MATERIALS AND METHODS

The DAP and ESD measurements using CBCT images from the i-CAT device (Imaging Sciences International, Hatfield, PA) were performed according to the protocols in Table 1. The scan height (collimation) was 6 cm for all protocols. The examinations were repeated four times for each protocol.

The RADCAL 9095 dose meter (Radcal Corp., Monrovia, CA, USA) and the PTW DAP meter (PTW, Freiburg, Germany) were used. All equipment was calibrated in laboratories within the Brazilian Metrology Network (Rede Brasileira de Metrologia-RBM). A pencil-type ioniza-

TABLE 1 - Protocols for image acquisition for the i-CAT device.

Protocol	Scanning time (s)	Voxel size (mm)	Peak voltage (kVp)	mAs
1	40	0.20	120	46.72
2	40	0.25	120	46.72
3	20	0.30	120	23.87
4	20	0.40	120	23.87

tion chamber (100 mm) was fixed on one end of the tomograph, coupled to an electrometer, so that it was possible to measure the doses given while the images were obtained (ESD). A multiplicative factor calculation was performed based on the distance between the x-ray beam output and the sensor, to compensate for the distance from the center of the device to the position of the ionization chamber. For the DAP measurement, a PTW device was coupled to the other end of the device.

The Kruskal-Wallis and Dunn tests were used to assess the data;  $p < 0.001$  was considered statistically significant.

## RESULTS

The median values for ESD and DAP for the four protocols are shown in Table 2. Statistically significant differences ( $p < 0.001$ ) were found among the four protocols for both radiation dose evaluation methods.

Dunn's test showed that in the DAP evaluation, protocols 2 and 3 showed a statistically significant difference, and it was not possible to detect which of the protocols were significantly different in the ESD evaluation.

## DISCUSSION

CBCT is a new technology and adequate knowledge is necessary to measure the radiation dose. We believe that the proposed method, using the ESD and DAP, can be considered for dose measurements in this type of examination.

TABLE 2 - Mean values of radiation doses (ESD and DAP) for the four protocols.

Protocol	Entrance Skin Dose - ESD (mGy)	Dose Area Product-DAP (mGy m <sup>2</sup> )
1	3.77	44.92
2	3.78	45.30
3	2.00	24.43
4	2.00	24.98
	(p = 0.00083)	(p = 0.000145)

Protocols 1 and 2 showed very similar ESD and DAP values, and even though the voxel sizes were different, the exposure time (ET), the kilovoltage (kVp) and the milliamperage x exposure time (mAs) remained constant. The same applies to protocols 3 and 4 (Tables 1 and 2). This shows that the voxel size does not influence the radiation dose; that is, when the exposure factors (ET, kVp and mAs) are the same, a single alteration of the voxel size does not alter the radiation dose significantly. However, the protocols couple the use of smaller voxels with greater exposure time and milliamperage, which invariably cause an increase in the exposure dose. Completely pre-established protocols are provided by the i-CAT manufacturer.<sup>15</sup>

A greater voxel size, associated with a low

mAs and reduced ET, is able to reduce the dose by as much as 50%.<sup>16</sup> In our study, whereas the ET and mAs practically doubled from protocols 3 and 4 to protocols 1 and 2, the radiation doses (ESD and DAP) behaved similarly for all protocols, being approximately doubled in protocols 1 and 2 compared with protocols 3 and 4 (Tables 1 and 2).

The limitation of the Dunn test in presenting significant difference among the protocols and in evaluating ESD occurred because of the small sample. But, despite the small sample, protocols 2 and 3 showed a significant difference between (p=0.0065) for the DAP; this was only possible because of the extremely relevant difference that exists between these protocols.

In conclusion, DAP and ESD are presented as evaluation methods for radiation doses in CBCT, and more studies are necessary to further elucidate such findings. The voxel size alone does not affect the radiation dose in CBCT (i-CAT) examinations. The radiation dose for CBCT (i-CAT) examinations is directly related to the exposure time and milliamperage.

## ACKNOWLEDGMENTS

The authors express sincere gratitude to CAPES (Coordination of Improvement of Higher Education), IFBA (Federal Institute of Technological of Bahia) and Clinica Odontobioimagem, for supporting our projects.

## REFERENCES

1. Lam EW, Ruprecht A, Yang J. Comparison of two-dimensional orthoradially reformatted computed tomography and panoramic radiography for dental implant treatment planning. *J Prosthet Dent.* 1995 Jul;74(1):42-6.
2. Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2003 Oct;96(4):508-13.
3. Kobayashi K, Shimoda S, Nakagawa Y, Yamamoto A. Accuracy in measurements of distance using limited cone-beam computerized tomography. *Int J Oral Maxillofac Implants.* 2004;19:228-31.
4. Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakos C.J. Dose reduction in maxillofacial imaging using low dose cone beam CT. *Eur J Radiol.* 2005 Dec;56(3):413-7.
5. Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging for preoperative planning of implant placement. *Clin Oral Investig.* 2006 Mar;10(1):1-7.
6. Pinsky HM, Dyda S, Pinsky RW, Misch KA, Sarment DP. Accuracy of three-dimensional measurements using cone beam CT. *Dentomaxillofac Radiol.* 2006;35:410-6.
7. Van Assche N, van Steenberghe D, Guerrero ME, Hirsch E, Schutyser F, Quirynen M et al. Accuracy of implant placement based on pre-surgical planning of three-dimensional cone-beam images: a pilot study. *J Clin Periodontol.* 2007 Sep;34(9):816-21.
8. Hirsch E, Wolf U, Heinicke F, Silva MAG. Dosimetry of the cone beam computed tomography Veraviewepocs 3D compared with the 3D Accutomo in different fields of view. *Dentomaxillofac Radiol.* 2008;37:268-73.
9. Loubele M, Maes F, Schutyser F, Marchal G, Jacobs R, Suetens P. Assessment of bone segmentation quality of cone beam CT versus multislice spiral CT: a pilot study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006 Aug;102(2):225-34.
10. Loubele M, Van Assche N, Carpentier K, Maes F, Jacobs R, van Steenberghe D, et al. Comparative localized linear accuracy of small-field cone-beam CT and multislice CT for alveolar bone measurements. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2008 Apr;105(4):512-8.
11. Suomalainen A, Vehmas T, Kortseniemi M, Robinson S, Peltola J. Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography. *Dentomaxillofac Radiol.* 2008 Jan;37(1):10-7.
12. Lascaia CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). *Dentomaxillofac Radiol.* 2004 Sep;33(5):291-4.
13. Mischkowski RA, Pulsfort R, Ritter L, Neugebauer J, Brochhagen HG, Keeve E, et al. Geometric accuracy of a newly developed cone-beam device for maxillofacial imaging. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2007 Oct;104(4):551-9.
14. Stratemann SA, Huang JC, Maki K, Miller AJ, Hatcher DC. Comparison of cone beam computed tomography imaging with physical measures. *Dentomaxillofac Radiol.* 2008 Feb;37(2):80-93.
15. 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 Jul;35(4):219-26.
16. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *Eur Radiol.* 1998;8(9):1558-64.

Submitted: July 2010  
Revised and accepted: August 2010

---

### Contact address

Marianna Guanaes Gomes Torres  
Rua Araújo Pinho, 62, Canela  
CEP: 40.110-150 - Salvador / BA, Brazil  
E-mail: iedacr@ufba.br