# ASSESSMENT OF PROTOCOLS IN CBCT WITH SYMMETRIC AND ASYMMETRIC BEAM USING EFFECTIVE DOSE AND $P_{KA}$

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**Abstract**

The cone beam CT is an emerging technology in dental radiology with significant differences the point of view of design technology between the various manufacturers on the world market. This study aims to evaluate and compare protocols with similar purposes in a cone beam CT scanner using TLDs and air kerma - area product ($P_{KA}$) as kerma index. Measurements were performed on two protocols used to obtain the image the maxilla-mandible in equipment GENDEX GXCB 500: Protocol [GX1] extended diameter and asymmetric beam (14 cm x 8.5 cm - maxilla / mandible) and protocol [GX2] symmetrical beam (8.5 cm x 8.5 cm - maxillary / mandible). Was used LiF dosimeters (TLD 100) inserted into a female anthropomorphic phantom manufactured by RSD - Radiology Support Devices. For all protocols evaluated the value of $P_{KA}$ using a meter Diamentor E2 and PTW system Radcal Rapidose. The results obtained for Effective Dose / $P_{KA}$ these measurements were separated by protocol image. Protocol [GX1]: 44.5 μSv/478 mGy.cm2; protocol [GX2]: 54.8 μSv/507 mGy.cm2. These values indicate that the relationship between the diameter of the image acquired in the protocol [GX1] and the diameter of the image in the protocol [GX2] is equal to 1.65, the Effective Dose for the first protocol has lower value at 18%. $P_{KA}$ values reveal very similar results between the two protocols, although, common sense leads to the interpretation that imaging protocols with field of view (FOV) of large diameters imply high values of effective dose when compared to small diameters. However, in this particular case, this is not true due to the asymmetrical beam technology. Conclude that for the cases where the scanner uses asymmetric beam to obtain images with large diameters that cover the entire face there are advantages from the point of view of reducing the exposure of patients with respect to the use of symmetrical beam and / or to FOV images with a smaller diameter.

***Keywords***: Cone Beam CT; Effective Dose and Kerma Area Product

# 1.- INTRODUCTION

At the end of the 1990s, a new generation of CT scanners intended for dentistry was developed. Differing from the traditional medical tomograph, which has the radiation beam in a fan-shape, these new scanners have a radiation beam with conical geometry. The first commercial model for the acquisition of volumetric images for applications in dental radiology based on cone beam tomographic technique was presented by (Mozzo, et al. 1998). The model first commercialized was the NewTom-9000, manufactured by Quantitative Radiology, Verona, Italy. The dosimetry and obtaining kerma index in tomography with a fan-shaped beam are well established with standardised phantoms. The indices of air kerma or weighted air kerma in computed tomography, $C_a$ and $C_w$ (International Atomic Energy Agency 2002), are well defined and are very useful in evaluating protocols and estimating effective dose. These indices are obtained by measuring the air kerma free in air or at defined positions within the phantom with a pencil ionisation chamber typically with a length of 100 mm.

The determination of the weighted air kerma index in computed tomography ($C_w$) uses the phantom dosimetric standard: four holes in the periphery and a central hole (International Atomic Energy Agency 2002). This phantom is suitable for use in conventional scanners with a fan-shaped beam whose axis of rotation is fixed independently of the structure being examined.

Currently, the cone beam CT is an emerging and powerful technology in dental radiology that presents significant differences from the point of view of technological design between different manufacturers on the world market (Batista, Navarro e Maia 2013). The vast majority of models available in the market for cone beam CT scanners have the option of changing the rotation axis, which is a user choice according to the examination being performed. Thus, it makes unfeasible the use of the index Cw as the quantity to be used in evaluations of radiation exposure parameter or for comparing techniques. Consequently, the existing dosimetric phantoms do not have the characteristic necessary to allow dosimetric measures at cone beam CT scanners (Batista, Navarro e Maia 2013). Essentially for this reason the estimates / assessments of exposure levels in Cone Beam CT is based on thermoluminescent dosimetry and $P_{KA}$. Additionally another option, with the main objective to reduce costs associated with detectors of large dimensions, is available on some models. Thus, some equipments acquire images with superior physical area of the image receptor diameters. This is only possible with the displacement of the image receptor of the central position in conjunction with the use of asymmetric or off-axis beams.

This study aims to evaluate and compare protocols similar purposes on equipment from the cone beam CT using TLDs inserted into anthropomorphic phantom and the product in the air kerma - area as kerma index ($P_{KA}$).

# 2.- MATERIALS AND METHODS

## 2.1. Equipment and Protocols assessed

Two protocols were evaluated in a cone beam CT scanner GXCB 500 Gendex, KaVo Dental GmbH In Table 1 we present the technical characteristics of the equipment. Measurements were taken at two protocols destined to obtain the image of the two dental arches, maxilla and mandible: protocol [GX1] extended and asymmetric beam diameter (14 cm x 8.5 cm - maxilla / mandible) and Protocol [GX2] symmetrical beam (8.5 cm x 8.5 cm - maxillary / mandibular).

Table 1 - Technical Specifications of CBCT Gendex GXCB

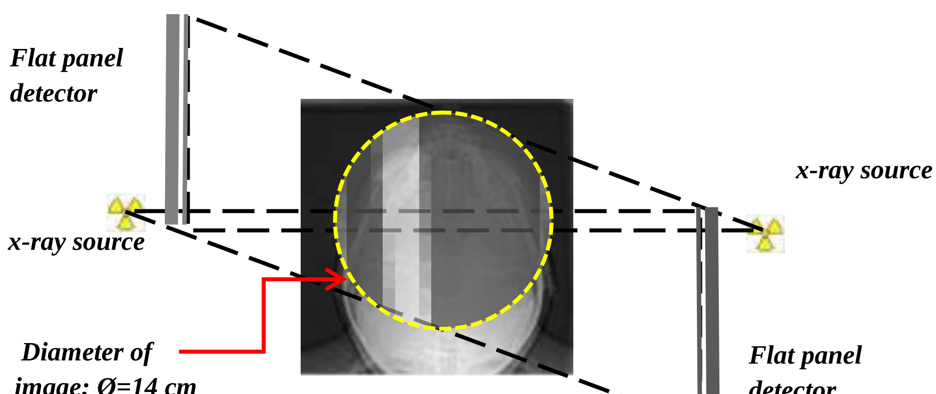
| | |
|---|---|
| kV | 120 |
| Focal Spot | 0,5 |
| Voxel Sizes | 0,4 mm / 0,3 mm / 0,25 mm/ 0,2 mm/ 0,125 mm |
| Image Detector | Amorphous Silicon Flat Panel |
| Sensor Size | 13 cm x 13 cm |

| | |
|---|---|
| Resolution | 14 lp/cm (voxel size 0,2 mm ) |
| Shades of gray | 16384 shades of gray – 14 bit |
| FoV | 8 x 8 cm – Standard 14 x 8 cm – EDS |

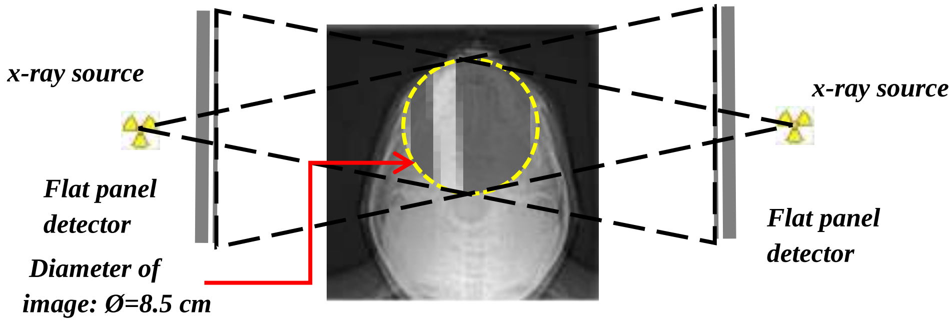

(a) (b)

Figure 1 – (a) The female Phantom RSD; (b) Positioning of Anthropomorphic Phantom to carry out the exposures under the same conditions of clinical location.

The geometry of irradiation, symmetric and asymmetric beam for each protocol are shown in Figures 2. The asymmetric geometry of Figure 2 (a) is obtained by shifting the detector and adjusting the beam collimators for obtaining x-ray asymmetrical beam and so generates an image with a diameter of 14 cm. In the condition of Figure 2 (b) a symmetrical beam is used to generate an image with a diameter of 8.5 cm.




(a)




(b)

Figure 1 – Geometry for image acquisition. (a) asymmetric beam (b) symmetric beam.

We use LiF dosimeters (TLD 100) inserted in a female anthropomorphic phantom manufactured by RSD - Radiology Support Devices. In Figure 1 we present the position of the simulator to perform the exposures. For all protocols evaluated the value of $P_{KA}$ using a $P_{KA}$-meter, PTW Diamentor E2, and a solid state multimeter, Radcal Rapidose.

## 2.2. - Positioning of dosimeters

Twenty-six dosimeters, TLD-100 (LiF: Mg, Ti) were used. The TLDs were inserted in the simulator, in representative positions of the structures of the head and neck as shown in Table 2 (Ludlow, et al. 2006, Koivisto, et al. 2012). The location of the tissues / organs was guided by experts in dental radiology.

Table 2 shows the distribution of thermoluminescent dosimeters in each slice the phantom.

Table 2 - Distribution of dosimeters (TLDs) in the various tissues and organs the phantom.

| nº *TLD* | Organ or tissue(slice) |
|---|---|
| 1 | surface of the left cheek (5)* |
| 2 | posterior neck (5)* |
| 3 | left thyroid (8)* |
| 4 | right lens (3)* |
| 5 | left lens (3)* |
| 6 | posterior calvarium (2) |
| 7 | calvarium right (2) |
| 8 | calvarium left (2) |
| 9 | anterior calvarium (2) |
| 10 | midpoint of the brain (2) |
| 11 | pituitary gland (3) |
| 12 | right orbit (3) |
| 13 | left orbit (3) |
| 14 | center of the spinal spine (5) |
| 15 | right parotid (5) |
| 16 | right ramus (5) |
| 17 | reft parotid (5) |
| 18 | left ramus (5) |
| 19 | center of the sublingual gland (6) |
| 20 | right submandibular (6) |
| 21 | left submandibular (6) |
| 22 | right mandible (6) |
| 23 | left mandible (6) |
| 24 | esophagus (9) |
| 25 | right thyroid (9) |
| 26 | left thyroid (9) |

## 2.3. – Calibration, irradiation and readout of the TLDs

The dosimeters were calibrated by exposing each crystal individually, the values of known dose of 1 and 15 mGy generated by a beam of X-rays with computed tomography qualities RQT RQT 8 and 10 with a distance of 1 meter between the focal point and position the crystal. The equipment generating X-rays used was Pantak / Seifert 160HS ISOVOLT model, installed in the Institute of Nuclear Energy Research Lab - IPEN.

The reading of the TLDs in the calibration process and the process for obtaining the values of dose was performed in a Harshaw TLD reader, model QS 3500 with the support of

WinREMS software, coupled to a data acquisition system. The determining absorbed dose for each TLD is the result of the dose response curve, obtained considering the correction factor related to the calibration and reference light at the time of reading. The coefficient of variation of 8% was TLD (4). For each protocol was carried out three exposures and the final value to be considered is the value of the dosimeter reading divided by three.

## 2.4 - Effective Dose

The effective dose values were obtained using Equation 1:

$$ED = \sum_T H_T . w_T \quad (1)$$

Being equivalent dose HT defined by Equation 2:

$$H_T = w_R \sum_i f_i . D_{Ti} \quad (2)$$

where $w_R$ is the radiation weighting factor ($w_R$ =1 Sv/Gy for x-rays), $f_i$ is the fraction of the slice tissue $T_i$ that has been irradiated, $D_{Ti}$ the absorbed dose in tissue $T_I$ in the slice *i* and $w_T$ is the factor weight of the tissue (Koivisto, et al. 2012). The weighting factor, $w_T$ used for organs and tissues are presented in the recommendation published by the International Commission on Radiological Protection, ICRP 103, (ICRP 2007).

# 3.- RESULTS

The results obtained for Effective Dose / $P_{KA}$ these measurements were separated by protocol image. Protocol [GX1]: 44.5 μSv/478 mGy.cm$^2$; protocol [GX2]: 54.8 μSv/507 mGy.cm$^2$. In Table 3 present the results of equivalent dose to the organs and tissues of the structure of the head and neck for both dosing protocols.

Table 3 - Values of equivalent dose and effective dose (ICRP 103, 2007)

| **Organ/Tissues** | **Equivalent Dose, (μSv)** | |
|---|---|---|
| | Protocol [GX1]: 14 cm x 8.5 cm | Protocol [GX2]: 8.5 cm x 8.5 cm |
| Salivary glands | 11.3 | 16.3 |
| Thyroid | 7.0 | 6.8 |
| Bone marrow | 6.5 | 6.9 |
| Bone surface | 1.8 | 1.9 |
| Esophagus | 0.7 | 0.7 |
| Brain | 0.8 | 1.3 |
| Skin | 0.6 | 0.7 |
| Remainder | 15.9 | 20.4 |
| Lymphatic nodes | 6.9 | 9.4 |
| Extrathoracic airways | 49.4 | 43.8 |
| Muscle | 6.9 | 9.4 |
| Oral mucosa | 143.3 | 202.9 |
| Effective dose | **44.5 μSv** | **54.8 μSv** |

# 4.- DISCUSSION

These values indicate that although the diameter of the image acquired in the protocol [GX1] is greater than the diameter of the image in the protocol [GX2], with a ratio between the diameters is equal to 1.65, the Effective Dose for the first protocol, [GX1], has a lower value of approximately 18%. In contrast the values of $P_{KA}$ show very similar results between the two protocols. Thus, it was demonstrated that although common sense leads to the interpretation of imaging protocols with field of view (FOV) of large diameters imply high values of effective dose compared to small diameters. However, in this particular case, this is not true due to the asymmetric beam technology.

The value of the effective dose associated with the image of 14 cm diameter is less than the value of effective dose for image with diameter equal to 8.5 cm is easily explained: in the asymmetric beam or off-axis geometry, Figure 2(a), organs such as salivary glands and lymph nodes remain exposed to the direct beam only part of the time of acquisition (Morant, et al. 2013). This is verified through the values of equivalent dose, Table 3 in these organs derived from two protocols [GX1]/[GX2]: salivary glands 11.3 μSv/16.3 μSv and lymph nodes 6.9 μSv/9.4 μSv.

# 5.- CONCLUSIONS

Conclude that for the cases where the scanner uses asymmetric beam to obtain images with large diameters that cover the entire face there are advantages from the point of view of reducing the exposure of patients with respect to the use of symmetrical beam and / or to FoV images with a smaller diameter.

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