EFFECTIVE DOSE COMPARISON BETWEEN PROTOCOLS STITCHED AND USUAL PROTOCOLS IN DENTAL CBCT FOR COMPLETE ARCADE

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Abstract

To visualization a complete dental radiology dental lives together with two separate proposals: [1] protocols diameter encompassing the entire arch (single) or [2] protocol with multiple fields of view (FOV) which together encompass the entire arch (stitched FOVs). The objective of this study is to evaluate effective dose values in examination protocols for all dental arcade available in different outfits with these two options. For this, a female anthropomorphic phantom manufactured by Radiology Support Devices twenty six thermoluminescent dosimeters inserted in relevant bodies and positions was used. Irradiate the simulator in the clinical conditions. The protocols were averaged and compared: [a] 14.0 cm x 8.5 cm and [b] 8.5 cm x 8.5 cm (Gendex Tomography GXCB 500), [c] protocol stitched for jaw combination of three volumes of 5.0 cm x 3.7 cm (Kodak 9000 3D scanner) [d] protocol stitched FOVs 5.0 cm x 8.0 cm (Planmeca ProMax 3D) and [e] single technical FOV 14 cm x 8 cm (i-CAT Classical). Our results for the effective dose were: a range between 43.1 and 111.1 microSv for technical single FOV and 44.5 and 236.2 for technical stitched FOVs. The protocol presented the highest estimated effective dose was [d] and showed that lowest index was registered [a]. These results demonstrate that the protocol stitched FOV generated in Kodak 9000 3D machine applied the upper dental arch has practically equal value effective dose obtained by protocol extended diameter of, [a], which evaluates in a single image upper and lower arcade. It also demonstrates that the protocol [d] gives an estimate of five times higher than the protocol [a]. Thus, we conclude that in practical terms the protocol [c] stitched FOVs, not presents dosimetric advantages over other protocols.

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

1. - Introduction

The cone beam computed tomography (CBCT) was introduced into the dentistry in the late 1990s (Mozzo, et al. 1998). Since its inclusion in dental radiology and acceptability of this new imaging technique has embedded new technological developments that cover from the image receptor to its mechanical structure. At the present time these equipments have become compacts dimensions and providing varied field of view (FOV) that allow image acquisition from a single dental unit until the entire face including all the teeth and joints. And currently the cone beam computed tomography in dentistry offers two options for the purchase of full dental arcade images from: (1) use a diameter of FOV encompassing full arcade, single FOV; (2) to combine several images from sectored dental units and add up all the images, stitched FOV.

All technological option adopted for diagnosis in humans must comply with the diagnostic goal with the image quality that allows the maximum possible information about the area being examined. At the same time, from the point of view of radiological protection of the patients one should always seek exposures that meet the ALARA principle, "as low as reasonably achievable" (Endo, et al. 2013, Batista, Navarro e Maia 2013, Batista, Navarro e Maia 2012).

In actuality, there is difficulty in conducting comparative studies of estimates of effective doses from various equipment present in the market and its technological conception. These difficulties mainly lie in differences in exposure parameters, filtration, volumes and geometries used. In the literature, many results of the evaluation the estimate of the effective dose for the various protocols equipment gifts are presented (Roberts, et al. 2009, Rottke, et al. 2013, X. M. Qu, et al. 2010).

In this context, this study aimed of assessing protocols single FOV and Stitched FOVs that have the same clinical purpose by using estimates of effective dose.

2.- Materials and methods

2.1. -Anthropomorphic phantom

In this study was used a female Alderson anthropomorphic phantom manufactured by Radiology Support Devices. The phantom represents a typical adult woman with 1.6 m 55 kg

(Goren, et al. 2013). It is made up of a human skeleton filled with material of atomic mass equivalent to human soft tissue. In this study, 10 slices were used phantom, numbered from 1 to 10, with 2.5 cm thickness each, as shown in Figure 1.. The slices have various cylindrical holes filled with billets. Each billet has appropriate space, 3 mm *x* 3 mm *x* 1 mm, for placement of dosimeters.

2.2. - Equipment used protocols assessment

Were assessments in this study, four CBCT equipment and five different protocols. All the techniques employed make it possible to obtain images of the maxillofacial dental arcade or upper or lower maxillary according to the protocols available on CBCT equipment. list of equipment: i-CAT Classical, Kodak 9000 Extraoral Imaging System, Planmeca ProMax 3D and Gendex GXCB 500. Exposure parameters used within this study are listed in Table 1. For all exposures, was considered a patient with medium-sized and pre-defined protocols in equipment normally used in the routine image facilities.. The CBCT equipment i-CAT Classical and Gendex GXCB 500 performed the technical single FOV (protocols [a], [b] and [e]). The equipment KODAK 9000 Extraoral Imaging System and Planmeca ProMax 3D perform technique stitched FOVs (protocols [c] and [d]). All protocols, [a], [b], [c], [d] and [e] are typical of the equipments and are part of differents protocols, depending on the purpose of diagnosis.

Figure 1 - Head and Neck physical anthropomorphic phantom representing an average adult woman.

Table 1- Parameters used for exposure of the phantom

Protocol	*FOV*[1] (cm)	angle (degree)	kilovoltage (kV)	current (mA)
[a]	Ø14 x 8.5	360	120	5
[b]	Ø 8.5 x 8.5	360	120	5
[c]	Ø 3.7 x 5	360	70	8
[d]	Ø 5 x 8	210	84	12
[e]	Ø 14 x 8	360	120	3 – 7

1 - Values in inches. First corresponds to the diameter of the FOV second value and the height of the FOV.

In all exposures, the TLDs were used in the same positions in the phantom.. The position of the simulator in the CT scanners, for each exposure was performed with the aid of lasers sstema locators CBCT with preview and aided by a professional. The contribution of the radiation emitted in the preview was also counted to obtain the estimated effective dose.

2.3. - Thermoluminescent dosimeters

In this study 26 were utilized dosimeters (TLD-100 consisting of LiF: Mg, Ti). TLDs were calibrated by using known parameters of exposure, ranging from 1-15 mGy in diagnostic radiology qualities, with protocol computed tomography (RQT8, RQT9 and RQT10). For calibration, an industrial X-ray equipment, Pantak / Seifert 160HS ISOVOLT model was used, belonging to the Institute of Nuclear Energy Research Lab - IPEN. All readings (calibration and measurements) were performed on the Harshaw TLD reader, model QS 3500 with the aid of WinREMS software, coupled to a data acquisition system. As a result of calibration, obtained a dose-response curve. The determination of the estimated dose was measured in each TLD result of this dose response curve, correcting the calibration factor and the reference light at the time of reading. The mean coefficient of variation of TLD was approximately 8%.

2.4. - Location of TLDs and irradiation simulator.

The selection of tissues and organs for placing TLDs in this study was based on the methodology presented by Ludlow et al (Ludlow, et al. 2006) and J. A. Roberts et al (Roberts, et al. 2009).

In total 8 organs and tissues were selected for evaluation. The definition of organs and tissues were selected from the International Commission on Radiological Protection document, ICRP 103 (ICRP 2007). For the location of tissues and organs we count on the support radiologists head and neck. In each protocol three exhibitions and the response of the dosimeter was divided by three were conducted. The positions of the dosimeters, in slices of the simulator, Figure 1, are presented in Table 2.

Table 2- location of the TLDs in the levels of the phantom.

Nº TLD	Organ(slice)
1	Surface of the left side (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	Previous calvarium (2)
10	Middle point of the brain (2)
11	Pituitary Gland (3)
12	Right Orbit (3)
13	Left orbit (3)
14	Center of the spinal column (5)
15	Right parotid (5)
16	Right branch (5)
17	Left parotid (5)
18	Branch left (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)

2.5. - Calculation of the effective dose

The effective dose values were obtained using Equation 1:

$$E = \sum_T H_T . w_T \quad (1) ;$$

where HT set equivalent dose using 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 tissue *T* on the level *i* that has been irradiated, D_{Ti} the absorbed dose averaged over tissue T ie on the slice is w_T factor tissue weighting, (Koivisto, et al. 2012, Roberts, et al. 2009, Rottke, et al. 2013). 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), described in Table 3.

Table 3 - ICRP 103 (2007) Weighting Factor tissue (9).

Organ/Tissue	Weighting Factor
Gonads	0.08
Bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.04
Breasts	0.12
Esophagus	0.04
Thyroid	0.04
Skin	0.01
Bone surface	0.01
Brain	0.01
Salivary glands	0.01
Remaining tissues [a]	0.12

[a] Adipose tissue, adrenals, extrathoracic (*ET*) region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate, small intestine, spleen, thymus, uterus/cervix.

3. - Results

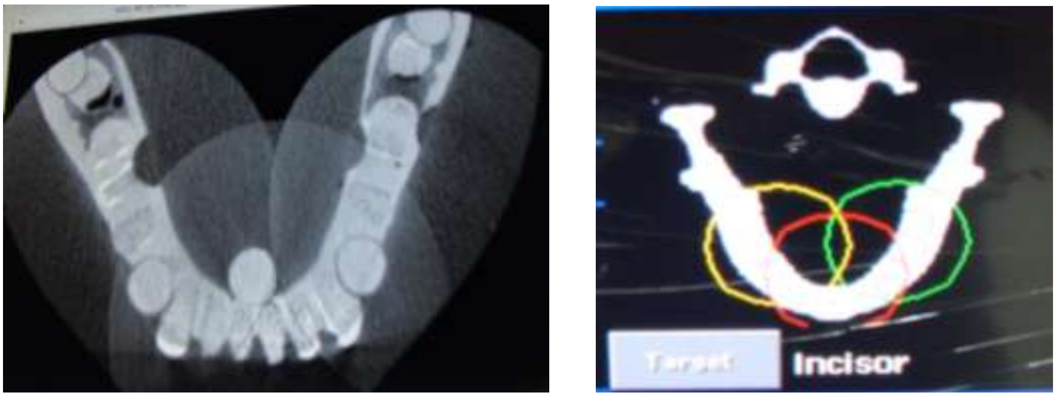
The results obtained in this study to estimate the effective dose ranged between 43.1 and 111.5 microSv for the equipments with CBCT protocols, single FOV ([a], [b] and [e]) and between 44.5 and 236.2 microSv for the equipments CBCT using protocols, stitched FOVs ([c] and [d]). The results of each protocol are presented in Table 4.

Table 4 - Estimation of effective dose using anthropomorphic female phantom.

Exposure technique	Protocol	Effective dose, (microSv)
Single FOV	[a]	43.1
Single FOV	[b]	52.0
stitched FOVs	[c]	44.5
stitched FOVs	[d]	236.2
Single FOV	[e]	111.1

The protocol [c] allows only the realization of the image of the lower or upper jaw. Others protocols allow the visualization of the upper and lower arch in exposure. The highest estimated effective dose is presented by the protocol [d] and smaller, by protocol [a]. Figure

2(a) shows how the disposal performed on the fields of technical FOVs stitched in cross sectional and Figure 2(b) shows the planning presented by the equipment prior to exposure. Figures 2 (a) and 2 (b) clearly show areas interception among the three fields of radiation FOVs. Figure 3 shows the arrangement of the single FOV in the technical field in the cross section.



(a) (b)

Figure 2- (a) Photograph of technical stitched FOVs (b) digital image of planning irradiation to obtain the image in the technical stitched FOVs. (Equipment ProMax 3D).

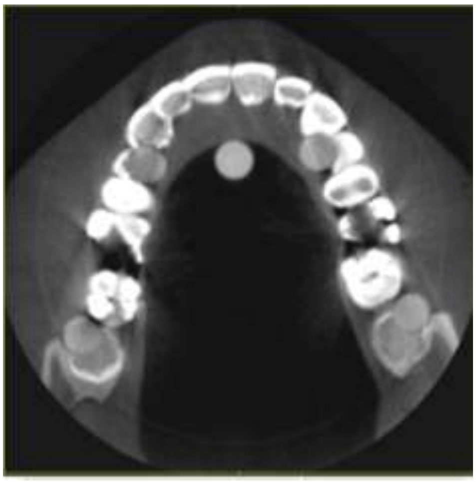


Figure 3- Picture for Single FOV CBCT protocol in field 14 cm x 8.5 cm. (Gendex Tomography GXCB 500).

4. - Discussion

As there is a variety of CBCT equipment available in the market and each device has particularities in exposure parameters (kilovoltage, milliamperes, time, and filtration) and in the size of the FOV becomes necessary to evaluate the differents protocols and estimate the effective dose associated to the radiological procedure (Rottke, et al. 2013, Pauwels, et al. 2012).

Usually, to estimate the effective dose, it is used a phantom anthropomorphic male (Rottke, et al. 2013, Ludlow, et al. 2006, Pauwels, et al. 2012, X. Qu, et al. 2012). However, in this study we used an anthropomorphic simulator female. To compare our results with other studies should consider that male of female phantom differ in the dimensions of the face. Nevertheless, a recent study conducted with Monte Carlo simulation, (Morant, et al. 2013) using male and female mathematical simulation the authors found higher equivalent doses for all organs and tissues in the female simulator, except for the brain. In another study by R. Prins, et all, in male, female and child physical simulators, when measuring the equivalent dose in the eye and brain showed no significant differences (Prins, et al. 2011).

The present evaluation provides experimental data acquired in four different cone beam CT scanners that can be compared with results from computer simulation and used to present data in average effective dose for both sexes as ICRP 103 (ICRP 2007).

In this study, we observed that, if the objective is to obtain all image of dental arch, it is observed that the equipment that carry out the technique stitched FOVs show an estimate of greater effective dose than equipment using the technique Single FOV. The estimation of the effective dose protocol as [d] is 5 times higher than the effective dose estimation protocol as measured by [a] and 2-fold higher than that measured by the effective dose protocol [e].

The results presented by the protocol [d] is in accordance with studies made by Qu Xing-min et al (X. M. Qu, et al. 2010), in their studies received an effective dose of 216 microSv to the same protocol as this study obtained an estimate of dose effective microSv 236. This difference can be related to the dimensions of the phantom - difference between female and male phantom used in the work of Qu et al. (X. M. Qu, et al. 2010) – or dosimetric factors installing the equipment.

With respect to Protocol [a], it is observed that it presents the lowest effective dose estimate, 43.1 microSv. This value corresponds to 15% less than the protocol [b], 58% lower than the protocol [and] with [b] and [e] being the same technique research imaging. Another factor to be taken into consideration is that in the protocol [c], it is only possible to obtain the image of the lower or upper jaw. Thus, when looking at Table 4, it appears that the estimated effective dose of [c] is almost the same as [a] and 12% less than [b]. Of course it should be taken into consideration also the amount of irradiated tissue. In this sense, the protocol [c] is more specific, however, if the goal is obtaining a picture of the upper and lower dental arch, the level of estimated effective dose, in this study the best option is to use CBCT equipment with technical Single FOV.

Upon observing Figure 2, we see that the technical stitched FOVs in some points of the target volume there is an overlap of fields, while in technical Single FOV, this fact does not occur. Was observed a large range of between dose protocols with the same purpose.

5.- CONCLUSIONS

Thus, we conclude that, compared with the estimate of effective dose in practical terms protocols [c] and [d] not have advantages over other protocols. As associated with this protocol there is possibility of compromising image with movement artifacts we evaluated that this does not present significant practical advantages. With respect to Protocol [a], protocol diameter extended-valued lower than the other effective dose, thus causing an advantage in terms of reduced patient exposure.

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