Volume : 4 | Issue : 5 | May 2015 • ISSN No 2277 - 8179

Research Paper

Cone Beam Computed Tomography: Dosimetry for Temporomandibular Joint Exam

MEDICAL SCIENCE

KEYWORDS : cone beam computed tomography; temporomandibular joint; radiation dosimetry

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ABSTRACT

The aim of this study was to evaluate the skin doses of radiation on the head and neck when submitted in Cone Beam Computed Tomography (CBCT) examinations of the Temporomandibular Joint (TMJ). A anthropomorphic phantom (model RS-230, Radiation Support Devices) and three different CBCT units CS 9000 (Carestream Health, New York, USA), I-CAT and Gendex CBX500 were used for this study. Thermoluminescent dosimeters, type TLD-100, were placed on the surface corresponding to the eyes, as well as the parotid, submandibular and thyroid glands. The radiation dose on the surface of the head and neck increased with the increase in kilovoltage and FOV; eyes and parotid glands were the organs most exposed in all equipment and protocols. It is essential to assess the doses in organs and tissues that are located withinor very near the radiation field, especially in examinations that use a small field of view.

INTRODUCTION

Imaging methods for the evaluation and diagnosis of conditions that involve the temporomandibular joint (TMJ) include radiographs and more complex examinations such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI).

CT is considered a valuable tool for the detection of bone changes in the TMJ, providing greater sensitivity and specificity when compared with MR.[1,2] Cone beam computed tomography (CBCT) on the other hand, has been widely used in the fields of endodontics, oral surgery, oral medicine, orthodontics, and other dental specialties. It is an excellent option because of its low cost, relatively smaller size, and in particular, because of its low doses of radiation. [3-5]

Despite the levels of exposure to radiation in CBCT being relatively low when compared with multi detector computed tomography (MDCT), the dose values are still considered high when compared with other image acquisition methods used in dentistry. The effective dose in CBCT, for example, is 3 to 7 times higher than the effective dose in a panoramic radiograph of the face. [6,7]

The factors that influence the dose of radiation in CBCT are lack of uniformity in the configuration of equipment, which present very different voltage ranges; changes in the exposure parameters[8]; FOV - field of view variables6 and in the angle of rotation.[9]

Therefore, the risks involved in CBCT examinations must always be examined, taking into account the irradiation of sensitive organs that do not form part of the diagnostic investigation. The aim of this study then, was to evaluate the doses of radiation on the head and neck in CBCT examinations of the TMJ with different exposure parameters, and to evaluate the quality of the radiation beam that emerges from the appliance.

MATERIAL AND METHODS

A tissue-equivalent phantom of the head and neck (Radiation Support Devices, model RS-230), FIGURE 1, with the same density and atomic number as bone tissue and the soft tissue of in an typical adult male patient was used. For the dosimetric evaluations, a total of 43 pairs of thermoluminescent dosimeters of the TLD-100 type (LiF:Mg,Ti) were used. One pair of dosimeters was used to evaluate the background radiation. Therefore, it was not exposed to the x-ray beam from the CBCT scanner, but was sent to the reader together with other exposed dosimeters. The other 42 pairs were divided into three sets with seven pairs in each set in order to evaluate the dose of three different model of equipment and protocols. The dosimeter sets were placed on radiosensitive organs of the anthropomorphic phantom: (a) eyes, bilaterally, (b) parotid glands, bilaterally, (c) thyroid, and (d) submandibular glands, bilaterally.

The dosimeters were duly calibrated for the standard energy range of the CBCT beam and then exposed twice, for greater reliability of the dose readouts.

The scans were performed with three types of CBCT equipment: CS 9000 3D (Carestream Health, New York, New York); Gendex CBX500 (Gendex Dental Systems, Pennsylvania, USA) and i-CAT classic (Imaging International Sciences, Hatfield, Pennsylvania, USA).

In the CS 9000 specifically, the joint was centralized by means of the position of the laser light projected on the TMJ studied. We placed the leadmarks horizontally at 3.5cm above the external acoustic meatus and vertically at 1.0 cm ahead of the same structure. The image of each TMJ was acquired separately due to the scanner with limited volume (FOV of 5 x 3.7 cm).

The images were acquired with two different exposure protocols for each type of equipment.

After performing the exposures, the TLDs were sent to a dosimetry laboratory for readouts. The air-kerma values of the background radiation were subtracted from the values of doses on the surfaces corresponding to the organs evaluated, and the level of

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background radiation was considered, starting from the time of sending the lot of dosimeters until their return for readout.

To evaluate the characteristics and agreement of the X-ray beam, a multimeter of the semiconductor type, model Rapidose, (Radcal Corporation, Monrovia, CA, USA) was used and placed on the CBCT unit detector. All the dose measurement instruments were duly calibrated.



Figure 1: Anthropomorphic phantom with TLDs in place

RESULTS

Table 1 shows the parameters and characteristics of x-ray beams evaluated on each CBCT used.

The exposures performed and readouts of TLDs are presented in table 2. The dose values presented are for TMJs.

TABLE 1

PARAMETERS OF CBCT X-RAY BEAMS

Nº of pulses	720	620	621
Filtration (mm)	3.3	15.7	14.1
HVL (mmAl)	2.6	9.4	9.3
kV measured	65.4	122	125
mAs	108	30	36.12
kV nominal	80	120	120
CBCT unit	CS 9000	Gendex CBX500	i-CAT

TABLE 2.

SKIN DOSES FOR EACH PROTOCOL AND CBCT EQUIPMENT

Skin Dose (mGy)	Right Eye	2,36	3,63	2,45	2,25	3,48	3,4
	Left eye	2,5	3,74	2,94	2,92	4,47	4,57
	Right Parotid	0,56	1,02	1,48	0,59	0,73	1,54
	Left Parotid	0,34	1,12	1,62	0,68	0,53	1,78
	Right Submand	0,12	0,56	0,15	0,07	0,11	0,25
	Left Submand	0,2	0,5	0,14	0,12	0,15	0,22
	Thyroid	0,01	0,008	0,04	0,02	0,04	0,08
	Protocol	60 kV,108 mAs FOV (50 mm x 37 mm)	80 Kv, 108 mAs FOV (50 mm x 37 mm)	120 kV, 30 mAs, FOV (140 mm x 85 mm)	120 kV, 30 mAs, FOV (140 mm x 60 mm)	120 kV, 36 mAs, FOV (140 mm x 60 mm)	120 kV, 36 mAs, FOV (140 mm x 80 mm)
CBCT UNIT		CS9000		Gendex CGX500		I-CAT Classic	

DISCUSSION

The CBCT of the TMJ provides accurate measurements of the volume and surface of the condyle, which are extremely advantageous in clinical practice with regard to evaluation of patients with joint dysfunctions.[10] The exposure conditions that patients undergo must be strictly monitored however, as optimized parameters reduce the risks of biological effects.

Table 2 shows the skin doses during the TMJ examination. The organ most irradiated was the eye, due to the fact that the eyes are nearer and in the same plane as the joints. There are many studies on CBCT dosimetry, especially in comparison with other imaging methods, however for TMJ tomography there are a limited number of publications.[11]

Using an effective dose in a small CBCT field in paticular can lead to rather imprecise results due to the low volume irradiated and difficulties with positioning the dosimeters on internal organs. Lukat (2013)[11] evaluated the effective dose for examination of the TMJ in two types of equipment: (1) Hitachi CB MercuRay with a large FOV and (2) Kodak 9000 3D with a small FOV. However, Lukat (2013)[11] presented no values for the dose received by the lenses or organ, normally within the field of radiation (FOV) and with elevated radiosensitiv-

ity. Knowing the effective dose value for exposures with a very low irradiated volume does not show the value of the dose in relevant organs completely located within the field. This highlights the limitation of the effective dose method in measuring the dose of cone beam tomographs with a small FOV, and also does not portray the risk involved in tomographic examinations of the TMJ.

In calculating the effective dose, organs distant from the field of radiation with insignificant contributions are also considered. However, when pondered and added for presentation of the effective dose value, they lead to a loss of individual information of doses in organs and tissues. Thus, they may mask significant exposures. In our study, for example, the doses for the thyroid gland ranged between 0.008 mGy and 0.08 mGy, while for the lens, they ranged between 2.43 mGy and 3.98 mGy for CS 9000 3D.

It is worth pointing out that the International Commission on Radiological Protection [12] revised the dose limit for the lens based on new epidemiological evidence, reducing it from 150 mSv/year to 20 mSv/year for occupational exposures. This suggests that the radiosensitivity of the lenses is higher than previously thought, as well as the risk of developing cataracts. It is therefore imperative to have knowledge of, and optimize the conditions that involve exposure to the lenses[13], and it is because of this that the kerma dose in the air on the organ or skin surface is the most appropriate method for measuring the dose and evaluating the risks involved in cone beam tomography exams. Two previous studies showed the use of lead glasses as a way of significantly reducing the doses in the crystalline lens, reducing the risk of cataracts. The lead glasses are useful because they are inexpensive and can be used in both procedures with limited to total face FOV's.[13,14] Considering TMJ image acquisition, the lead glasses become a valuable tool in reducing the radiation doses because the joint lies in the same horizontal plane of the crystalline lens, allowing the structure to be within the primary beam.

A discrepancy in the skin doses for the scanners evaluated were noted. The i-CAT classic presented higher doses for the crystalline lens compared to the other two scanners. Even using higher voltage (120 kV) and FOV (140 mm x 85 mm), the Gendex CBX500 presented smaller doses in lens than the CS 9000. Thus, despite the CS 9000 having limited FOV, it did not result in reduced doses. Also, the increase in the number of repetitions by positioning error becomes more evident due to the fact that the CS 9000 has smaller and limited FOV, making the correct positioning of the centralized structure with the isocenter more difficult. It is worth mentioning the need to constantly train professionals who perform the procedures so that repetitions of examinations caused by positioning error can be avoided.

The technical parameters implemented by CBCT equipment operators or established by manufacturers, as well as the characteristics of each scanner can directly affect the radiation dose the patient will be exposed to. The influence of filtration suggests reducing the radiation dose. Some devices have begun to incorporate 0.5 mm copper as an additional filter to reduce such dosages.[15] In a cone beam CT scanner Mercuray, after insertion of copper in the filter output of the x-ray beam, it was possible to reduce the doses by approximately 14%.[8]

The settings of the i-CAT and Gendex CBX500 used for this study differ from the CS 9000 3D with respect to the high filtration (15.7 mmAl and 14.1 mmAl, respectively), a high half value layer (9.4mmAl and 9.3mmAl respectively) and the high voltage application (120 kV). These characteristics are reflected in the energy, the intensity of the beam reaching the detector, as well as the amount of photons that focus on the surface of the organs.

Like theGendex CBX500, the i-CAT behaved similarly with very close doses in the crystalline evaluations for the two FOVs used, however using the lowest product current time in both machines is recommended whenever possible as a way to reduce the dose in the structure. One could also make use of the change in the voltage (applicable only in the CS 9000 3D scanner), allowing for a dose reduction by using lower voltages as long as in both the Gendex and i-CAT the voltage is fixed and established by the manufacturer. Thus, in both the Gendex CBX500 and i-CAT, when the height of the FOV is changed, the major impact on doses is felt in the parotid because the use of smaller FOVs will lower the contribution of the primary beam on these organs, unlike the crystalline which aren't subject to a significant influence because they are located in the center of the beam and on the same horizontal line positioning.

The results demonstrate that the restriction of the radiation field in the area of interest is an important factor in reducing doses: being farther from the primary beam, we obtain very low values in the three TMJ acquisitions in the three types of equipment.

CONCLUSIONS

In conclusion, based on high dose values measured for the lens, it is essential to assess the doses in organs and tissues that are located within or very near the radiation field, especially in examinations that use a small field of view. ``

ACKNOWLEDGEMENTS

The authors thank the Laboratory of Physical Radiology of the Federal Institute of Bahia (LAFIR/IFBA), the Laboratory of Metrology of Ionizing Radiations of the Federal University of Pernambuco (LMRI-DEN/UFPE), for kindly allowing the use of the instruments used in the dosimetric evaluation by making available the instruments for the dosimetric evaluation, and the Lab TCFC 3D (Laboratory of Cone Beam Computed Tomography) of the Dental Faculty of the Federal University of Bahia, for their support in conducting this study.

Volume : 4 | Issue : 5 | May 2015 • ISSN No 2277 - 8179

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