ORIGINAL ARTICLE

Estimation of Effective Radiation Dose to the Eye Lens in Dental Cone Beam Computed Tomography

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ABSTRACT

Introduction: Recent advancement in technology, has significantly improved the clinical application of Cone Beam Computed Tomography in the field of dentistry. The main objective of this study is to estimate the effective dose to the eye lens in Cone Bean Computed Tomography. **Method:** The effective dose to the lens of the eye was estimated using Dose Area Product (DAP) values from i-CAT 17-19 Platinum CBCT scanner during the CBCT examination of either the maxilla or mandible, with an exposure parameters of 120kVp and mAs 37.07. **Results:** The estimated effective dose for lens of the eye is 8.0±2.49mSv for voxel size 0.2 whereas 6.21±1.55mSv for voxel size 0.25 for CBCT of Mandible and 5.74±1.73mSv for voxel size 0.2 whereas 5.28±1.35mSv for voxel size 0.25 for CBCT of Maxilla. **Conclusion:** The effective dose to the lens of eyes for a standard protocols 0.2voxel with 26.9 sec and 0.25 voxel with 26.9 sec in CBCT for maxilla and mandible respectively are within the threshold limit of 2.0Gy. Therefore for further reduction of the effective dose to the lens of the eyes we recommend for developing a protocol with lower radiation dose and also implement the application of using an effective protective measures such as bismuth eye shield.

Keywords: CBCT, Effective Dose, Eye Lens

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INTRODUCTION

The advancement of medical technology plays a significant role in the field of dental sciences. Prior, advanced imaging like Multi-Slice Computed Tomography (MDCT) were practiced but it is linked with high radiation dose to the radiosensitive organs such as the eyes. In the year 1996 , a dedicated computed tomography for dental sciences was introduced known as Cone Beam Computed Tomography (CBCT) which yields relatively less radiation dose and also low cost with higher diagnosing, treating , planning efficiency(1). The invention of CBCT technology made huge impact in maxillofacial imaging. At present it is frequently used in the evaluation of bone and dental pathologies, as well as fracture, maxillofacial deformity, and prior to surgical evaluation of impacted tooth, imaging of temporomandibular joint and also for analyzing bone availability for placement of implant(2). Orthodontics application provides images that permits overlay-free visualization of structural and anatomic relationships which is required for addressing various radiologic questions. Even though Cone beam computed tomography has significantly lesser radiation dose in comparison with the conventional computed tomography, yet are higher than the traditional dental radiography (3, 4). Since x-rays are used for imaging in CBCT scans there is a chance of certain biological effects of radiation. These effects of radiation can be short term somatic effects (early or acute), long term or late somatic effects, genetic effects (heritable effects) (5).

Cataractogenesis: The lens of the eye is made up of transparent fibers which transmit light. The lens focuses light on the retina for image information and transmission through the optic nerve. Most common causes for cataract are aging, trauma, radiation exposure, congenital or may occur after an eye surgery. The probability that a single exposure of approximately 2Gy may result in formation of cataract which results in partial or complete vision loss. Laboratory experiments with mice have shown that cataract may occur with dose of 0.1Gy. Highly ionizing neutron radiation is extremely efficient in inducing cataract. A low neutron dose of 0.01Gy is known to cause cataract in experimental mice. Evidence of radiation induced cataract in humans is established on the observation of small group of people who were accidentally exposed with substantial doses to eye lens (5).

With recent advancements, clinical application of CBCT in the field of dentistry has been significantly increased. Though it provides lesser radiation dose in comparison with the conventional computed tomography, yet are higher than the traditional dental radiography. With the radiation that is used for imaging in CBCT scans, there is a chance of certain radio biological effects to the patients. To avert the risk of radiation effect it is necessary to identify the dose received and suggest the use of lower dose protocol and also provide radiation protective measures bismuth eye shield should be recommended to be practiced during the scan time. The main objective of this study is to estimate effective radiation dose to the eye lens in dental Cone Beam Computed Tomography of Maxilla and Mandible and compare the effective dose of the eye lens between Maxilla and Mandible scan in CBCT.

MATERIALS AND METHODS

Ethical clearance report was received from the institutional ethics committee. This study was conducted using i-CAT 17-19 Platinum CBCT machine in Dept. of Oral Medicine and Radiology. A total of 120 subjects referred by the dental physicians for the CBCT of either maxilla or mandible for diagnosis and treatment were included. The scans were acquired using two standard protocols practiced at the center (Table I) 0.2voxel and 26.9 sec and 0.25 voxel and 26.9 sec, with an exposure parameters of 120kVp and mAs 37.07. Multi-O meter was affixed to the patient's forehead at the level of glabella using head binder strap during the scan period. The surface entrance dose value was noted from the Multi-o-meter reading was reported as entrance surface dose and the Dose area product (DAP) was obtained from the workstation which was recorded and tabulated for further computation of the effective radiation dose to lens of the eyes.

Effective radiation dose of eye lens was calculated using the formula: $EfD = DAP \times W_T \times k$ (5)

Where:- DAP = Dose Area Product, W_T = Tissue weighting factor, k= correction factor for eye lens. The Tissue weighting factor of eye lens is 0.01(6). The correction factor of the beam energy of eye lens which is 0.94(7) to calculate the effective dose received by eye lens.

Statistical analysis

The data was analyzed using Social Package of Statistical Science Software (SPSS, version 16.0). Descriptive statistics was used to calculate Mean, Standard deviation and since the data was not normally distributed, to report the entrance surface dose frequency statistic was used to calculate the quartiles. Values for the entrance surface dose measurement were reported as median and upper and lower quartiles and the effective dose values are reported as mean ± SD.

Table I: Technical specification of i-CAT 17-19 Platinum CBCT

Specification	Value
Voltage	120 kV
Max. Tube current	7mA
Exposure type	Continuous
Field of view size (cm)	16cm Custom: Maxilla - 23x17, 16x13, 16x11, 16x10, 16x8, 8x8, 16x6 Mandible - 16x6

RESULTS

Entrance Surface Dose (ESD)

In this study entrance surface dose to the eye lens during CBCT of maxilla and mandible were estimated for two standard protocols 0.2voxel and 26.9 sec and 0.25 voxel and 26.9 sec. and is reported as median and upper and lower quartiles as the data violates the normality assumption. The median ESD of mandible for 0.2voxel and 26.9 sec is 23.60μGy [Q1=11.84, Q3=34.66]. The minimum and maximum ESD values recorded were 6.54μGy and 103.50μGy respectively. The median ESD of mandible for 0.25voxel and 26.9 sec is 17.75μGy [Q1=13.56, Q3=21.87]. The minimum and maximum ESD values recorded were 7.54μGy and 85.28μGy respectively (Table II). The median ESD of maxilla for 0.2voxel and 26.9 sec is 12.44μGy [Q1=9.75, Q3=18.77].The minimum and maximum ESD values recorded were 4.29μGy and 82.12μGy respectively. The median ESD of maxilla for 0.25voxel and 26.9 sec is17.92μGy [Q1=12.20, Q3=33.90].The minimum and maximum ESD values recorded were 2.7μGy and 96.48μGy respectively (Table III).

Table II:Surface Entrance dose to the eye lens during CBCT of Mandible

Variable (Voxel size & time)	Median (Q1, Q3) (Surface Entrance Dose μGy)	Minimum (μGy)	Maximum (μGy)
0.2voxel and 26.9 sec	23.60 [11.84, 34.66]	6.54	103.50
0.25voxel and 26.9 sec	17.75 [13.56, 21.87]	7.54	85.28

Table III: Surface Entrance dose to eye lens during CBCT of Maxilla

Variable (Voxel size & time)	Median (Q1, Q3) (Surface Entrance Dose μGy)	Minimum (μGy)	Maximum (μGy)
0.2voxel and 26.9 sec	12.44 [9.75, 18.77].	4.29	82.12
0.25voxel and 26.9 sec	17.92 [12.20, 33.90].	2.7	96.48

Effective Radiation Dose

In this study effective dose to the eye lens during CBCT of maxilla and mandible are estimated for two standard protocols at 26.9 sec for two different voxels of 0.2 and 0.25, and reported as mean and standard deviation. Mean and Standard Deviation of Effective Dose was calculated for two voxels of Mandible and was noted as 8.0±2.49mSv for voxel size 0.2 whereas 6.21±1.55mSv for voxel size 0.25 (Table IV).Mean and Standard Deviation was calculated for two voxels of Maxilla and was noted as 5.74±1.73mSv for voxel size 0.2 whereas 5.28±1.35mSv for voxel size 0.25 (Table V).

Table IV: Effective radiation (E) (mSv) dose to the eye lens during CBCT of Mandible

Variable (Voxel size & time)	Mean (Effective dose mSv)	Standard deviation	Minimum (mSv)	Maximum (mSv)
0.2voxel and 26.9 sec	8.0	2.49	3.14	12.44
0.25voxel and 26.9 sec	6.21	1.55	2.30	9.49

Table V: Effective radiation (E) (mSv) dose to the eye lens during CBCT of Maxilla

Variable (Voxel size & time)	Mean (Effective dose mSv)	Standard deviation	Minimum (mSv)	Maximum (mSv)
0.2voxel and 26.9 sec	5.74	1.73	2.94	8.77
0.25voxel and 26.9 sec	5.28	1.35	0.82	7.89

DISCUSSION

Cone Beam Computed Tomography has made significant impact in maxillofacial imaging which provides better image quality with the advancement in the technology. With the recent advancements, clinical application of CBCT in the field of dentistry has been significantly increased. It provides lesser radiation dose in comparison with the conventional computed tomography, but still a little higher than the traditional dental radiography. Biological radiation hazard has always been a concerned when dealing with imaging technology, therefore even in CBCT scans, there are chance of certain biological effects of radiation to the head and neck area. Hence to prevent and reduce risk of radiation effect it is necessary to identify the dose received and suggest the application of the various dose reduction techniques or radiation protective measures.

In our study, we estimated the effective dose to lens of eyes during the CBCT of maxilla and mandible region using two standard protocols at 26.9 sec for two different voxels of 0.2 and 0.25, for FOV of 16x6cm. Several studies has been performed to estimate the dose received by eye lens during the CBCT examination using different techniques and protocols. In the year 2016 a study was performed by Takao Kanzaki et al(7),in which the investigators have estimated absorbed dose to eye lens during various dental radiographic imaging procedures using a head and neck phantom and evaluated the radiation dose by placing the fluorescence glass dosimeters (FDGs) on the eyes of the phantom. The investigator found that the eye lens dose for all the radiographic examination was ranged between 0.02 to 0.19mGy, except in helical CT were it was found to be 11.87mGy, which is still lower than ICRP Publication 118 recommendation (500mGy)(8). Where as in a study conducted by R Pauwel's et al(9), in the year 2013 to estimate the effective radiation dose to eye lens in relation to effect of field of view and angle of rotation. This study was performed using an Alderson Radiation Therapy (Phantom) which represents an average adult male consisting of 2.5cm thick 11 slices having holes for inserting the dosimeter, total of 148 thermoluminiscent dosimeter (TLD-100) were used to estimate the dose. Phantom was scanned using two standard exposure factor for adults 90 kVp, 87.5mAs for full rotation 360° and 90 kVp, 45mAs for half rotation 180°. Result showed effective dose to eye lens during both jaw with FOV of 8x8 for full rotation was found to be 692μSv and for half rotation was 292 μSv, and with the FOV of 10x10 for full rotation was found to be 5308μSv for both jaws. The present study showed an effective dose which is slightly higher as the exposure parameters were higher 8.0±2.49mSv for voxel size 0.2 whereas 6.21±1.55mSv for voxel size 0.25 for CBCT of mandible and 5.74±1.73mSv for voxel size 0.2 whereas 5.28±1.35mSv for voxel size 0.25 for CBCT of maxilla.

In the year 2011, R Prins et al(10) reported that there was significant decrease in the eye dose during CBCT by using lead glass. It was an experimental study wherein three different phantoms are used. To access the radiation dose to the eyes and brain tissue, thermoluminiscent dosimeters were used and to measure the lens dose, OSL dosimeter was placed over the eyes of the phantom. The scans were done using two technique, full facial scan without collimation and with collimation only to include maxilla-mandibular area. Both the scans were done with same parameters of (120kVp, 3.8mA, and 7.8s). Three sets of scan were acquired with and without lead glasses. The investigator have reported that scans performed with lead glass can decrease the radiation dose to the lens of eyes up to 67%, without affecting image quality. In the present study effective radiation dose to lens of the eyes during CBCT of maxilla and mandibular region is estimated in which the scans were performed for the subjects who were referred for routine CBCT examination of maxilla and mandible. The scans were performed using two standard protocol at 26.9 sec for two different voxels 0.2 and 0.25, for an FOV of 16x6cm with the exposure parameter of 120kVp, 37.07mAs and 26.9s. The dosimetry values obtained from Multi-O-Meter which was placed over the patient's forehead at level of glabella was used for estimating the entrance surface dose which has a significant role in measuring effective dose as the surface entrance dose increases it will result in increase of DAP consequently higher effective dose. The effective dose was estimated using DAP values which was obtained from the workstation. The findings of the present study shows an effective dose which is within the recommended threshold dose.

The study has various implications as it helps us determining the radiation dose to eye lens which is highly radiosensitive organ, meanwhile the study can also be used to determine the radiation dose to the maxilla and, mandible while performing the dental CBCT, which comes with the multiple protocol settings of various FOV and voxel size. The study will help to estimate the variation of radiation doses with different FOV and voxel size. Although the present study is mainly focused on estimating the radiation dose reaching the eye lens which is useful but at the same time there are certain limitations to the study such as the sample size was limited and the effective dose was calculated for only one particular Field of view whereas further studies can be carried out and radiation dose for various FOV and voxels can be determined independently. We also noted that the higher voxel size has lesser effective radiation dose as noted in table IV and V.

In present study effective dose has been calculated for only one standard FOV, but since there are many FOV options (different size of face frame, pediatrics etc.), hence further studies can be performed using different FOVs for more specific dose estimation.

CONCLUSION

The result of this study showed effective dose of 8.0±2.49mSv for voxel size 0.2 whereas 6.21±1.55mSv for voxel size 0.25 for CBCT of Mandible and 5.74±1.73mSv for voxel size 0.2 whereas 5.28±1.35mSv for voxel size 0.25 for CBCT of Maxilla are within the threshold limit of 2.0Gy recommended to induce cataract. Therefore for further reduction of the effective dose to the lens of the eyes we recommend for developing a protocols with lower radiation dose and also implement the application of using effective protective measures such as bismuth eye shield which will help to further reduce the dose much more below the recommended radiation dose to eye lens.

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