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Determination of Scattered Radiation to the Thyroid Gland in Dental Cone Beam Computed Tomography

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ABSTRACT

Background: Cone beam computed tomography (CBCT) is a specialized medical equipment and plays a significant role in the diagnosis of oral and maxillofacial diseases and abnormalities; however, it is attributed to risk of exposure of ionizing radiation. The aim of the study was to estimate and determine the amount of scattered radiation dose to the thyroid gland in dental CBCT during maxilla and mandible scan.

Materials and Methods: The average scattered radiation dose for i-CAT 17–19 Platinum CBCT (Imaging Sciences International) was measured using a Multi-O-Meter (Unfors Instruments), placed at the patient's neck on the skin surface of the thyroid cartilage, with an exposure parameter of 120 kVp and 37.07 mAs. The surface entrance dose was noted using the Multi-O-Meter, which was placed at the time of the scan at the level of the thyroid gland on the anterior surface of the neck.

Results and Discussion: The surface entrance dose to the thyroid from both jaws scans was 191.491±78.486 μGy for 0.25 mm voxel and 26.9 seconds, and 153.670±74.041 μGy from the mandible scan, whereas from the maxilla scan the surface entrance dose was 5.259±10.691 μGy.

Conclusion: The surface entrance doses to the thyroid gland from imaging of both the jaws, and also from imaging of the maxilla and mandible alone were within the threshold limit. The surface entrance dose and effective dose in CBCT were dependent on the exposure parameters (kVp and mAs), scan length, and field of view. To further reduce the radiation dose, care should be taken in selecting an appropriate protocol as well as the provision of providing shielding to the thyroid gland.

Keywords: Cone Beam Computed Tomography, Maxilla, Mandible, Scattered Radiation Dose, Thyroid Gland

Original Research

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Introduction

Diagnostic imaging plays an essential role in clinical diagnosis and assessment. Dental imaging has been simplified with the implementation of cone beam computed tomography (CBCT) and various advanced imaging techniques, resulting in better diagnostic abilities and dental radiographic imaging. CBCT is an advanced and specialized dental imaging modality, which has given us an easy approach from two-dimensional

(2D) to three-dimensional (3D) in dentistry imaging [1]. Although conventional X-ray, orthopantomography, lateral cephalometry and advanced imaging modalities like multi-slice computed tomography (CT) were in clinical practice prior to CBCT, considering the radiation dose and cost to the patient, their use had been limited [1, 2]. CBCT imaging is of great importance in dentistry, endodontics, orthodontics, and maxillofacial surgery for assisting dentists and surgeons with planning optimal treatments for their patients. Radiation exposure is minimized since CBCT acquires images based on pulsed intervals, which prevents exposure during full rotation of the patient [1, 3]. Although the radiation dose from CBCT is significantly lower than that of conventional CT, it is still higher than that of traditional dental radiography [4].

During the maxillofacial or head and neck scans in a dental CT examination, the adjoining surrounding areas are irradiated with scattered rays apart from the area of interest. Thereby exposing one of the most radiosensitive organs, thyroid gland [4, 5], which has a tissue weighting factor of 0.04 [6] since it has both direct and indirect impacts in the metabolism, irradiating the thyroid gland may lead to dysfunction of gland affecting the production of thyroid hormones [7].

Surface entrance dose (SED) is the radiation dose to the surface of the skin and is usually measured using a dosimeter. The effective dose is summation of the multiplications of the equivalent dose with the tissue weighting factor [8]. Radiation safety is becoming an increasingly pressing issue with the growing use of CBCT imaging in dental radiology. As a result of CBCT scans, although only a portion of the head is exposed to primary radiation, adjacent parts of the body are frequently exposed to scattered X-rays [9]. The secondary radiation dose to radiosensitive organs is a matter of great concern [8]; hence, the monitoring of such organs is highly imperative.

Materials and Methods

The study was conducted at the Department of Oral Medicine and Radiology from June 2019 to May 2020 using a CBCT machine i-CAT 17-19 Platinum (Imaging Sciences International, Hatfield, PA, USA). A total of 105 subjects who were referred for CBCT of both jaws and 42 subjects each for maxilla and mandible scans were recruited for this study.

The scans were acquired using standard protocol practiced at the center (Table 1). Measurements of SED were made using a Multi-O-Meter (Unfors Instruments, Billdal, Sweden) whose calibration was conducted biannually. A dosimeter was placed on the anterior surface of the subject's neck at the level of C5–T1, below the thyroid shielding collar (0.5 mm lead equivalent).

Results and Discussion

This study evaluated the SED to the thyroid gland during CBCT of both the jaws, also during the CBCT scan of the maxilla and mandible alone, using a standard protocol of 0.25 mm voxel and a scan time of 26.7 seconds. The results were represented as mean ± standard deviation with the minimum and maximum ranges (Table 2).

With the advancement in technology and innovations in dental radiography, CBCT has proved to be one of the most preferred dental imaging modalities to image the complexes of the maxillofacial structures. A CBCT scan of both jaws, or a CBCT scan of the maxilla or mandible, is a common diagnostic examination for oral and maxillofacial pathology for the dentist and maxillofacial surgeon. But on the other hand, the biological effects of radiation and radiation-induced biological hazards have always been of great concern while dealing with X-ray imaging equipment [10, 11], so it is highly significant to measure the radiation dose received by radiosensitive organs during diagnostic imaging in order to minimize

Table 1. Technical Specification of i-CAT 17–19 Platinum Cone Beam Computed Tomography

Specification	Value
Voltage (kVp)	120
Maximum tube current (mA)	7
Exposure type	Continuous
Acquisition time (s)	26.9
Diameter (cm)	16 (custom)
Height (cm)	6
Voxel (mm)	0.25

Table 2. Surface Entrance Dose (μGy) to the Thyroid during Cone Beam Computed Tomography Scans of Both Jaws (μGy)

Variable	Voxel size & Time	Minimum dose (μGy)	Maximum dose (μGy)	Mean ± SD (μGy)
Both jaws	0.25 mm voxel and 26.9 s	24.630	357.900	191.491 ± 78.486
Mandible		15.170	274.900	153.670 ± 74.041
Maxilla		0.000	36.700	5.259 ± 10.691

SD, standard deviation.

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the probability of biological radiation effects and also to derive an appropriate dose reduction technique and protection measures.

Various studies have reported the radiation dose received by the head and neck organs from various radiographic procedures. In our study, we reported the amount of SED received from scattered dose to the thyroid gland during dental CBCT of the maxilla and mandible scan using a single standard protocol setting of 120 kVp, 37.07 mAs, 7 mA, 16 cm × 6 cm, 0.25 mm voxel, and 26.9 seconds.

In a study conducted by Pauwels et al. [12], SED to the thyroid gland with two different CBCT units were compared: SCANORA 3D (Biotech Innovations Limited, Hong Kong) at 85 kVp, 8 mA, and 30 mAs, and NewTom 9000 (NewTom, Bologna, Italy) with 110 kVp, 15 cm field of view (FOV). With the SCANORA 3D device the dose ranges from 23 to 2,559 μGy where the mean was 284 μGy, on the other hand, with NewTom 9000 in the center 2 (University of Vilnius), SED to the thyroid surface ranged from 6 to 1,027 μGy with a mean of 131 μGy. And at center 1 (University of Athens), SED to the thyroid ranged from 400 to 1,600 μGy, with a mean of 1,007 μGy. The lowest SED was to the thyroid and eye. According to the present study, the SED to the thyroid gland was 191.491 ± 78.486 μGy, from the scan of the mandible 153.670 ± 74.041 μGy where the maxilla recorded the highest SED of 36.70 μGy with the exposure setting of 120 kV, 37.07 mAs, 7 mA, 16 cm × 16 cm, 0.25 mm voxel, and 26.9 seconds, which is lower than the dose reported by Pauwels et al. [12].

Another study conducted by Akyalcin et al. [13] measured the peak skin dose with a phantom using an optically stimulated luminescence dosimeter. The CBCT devices used were Galileos Comfort (Sirona, Charlotte, NC, USA) 85 kVp 42 mA 15 cm × 15 cm FOV with a skin dose to the thyroid region of 4.62 mGy and a thyroid absorbed dose of 0.46 mGy, and thyroid skin dose of 4.14 mGy with Kodak 9500 (Kodak, Rochester, NY, USA), 20 kVp 108 mA and FOV 20 cm × 18 cm. The peak skin dose was observed to be much higher than in the present study. Although the technical parameters were much lower as compared to our study, the FOV used was much larger which may have contributed to the more dose. When the scan length and FOV vary, SED values may also vary. Therefore, more scattered radiation is likely to reach the thyroid gland from the mandible scan than the maxilla scan, or from both jaw scans, than from the scan of only the maxilla or mandible, which is clearly observed in the present study. During the maxilla scan, the scattered dose reaching the thyroid surface was 5.259 ± 10.691 μGy, and during the mandible 153.670 ± 74.041 μGy, but during both jaws scans the scattered dose reaching the thyroid was 191.491 ± 78.486 μGy.

Many authors have reported doses with different CBCT scanner equipment, technical protocol settings, and their role in radiation output. Ghanbarnezhad Farshi et al. [14], reported SED to different organs of the head and neck with a phantom using three CBCT units, NewTom VGi (NewTom) and Planmeca Promax 3D (Planmeca, Helsinki, Finland), in another study Heiden et al. [15], in Brazil reported a study performed on a phantom with i-CAT Next Generation (Imaging Sciences International) and SCANORA 3D, using thermoluminescent dosimeter placed on the thyroid surface. The mean absorbed dose to thyroid surface in i-CAT device ranged between 0.02 and 2.23 mGy, from SCANORA 3D dose ranged from 0.01 to 2.96 mGy. The scans were acquired in four different FOVs: high-resolution small FOV, standard small, standard large, and fast large. Therefore, with advancements in technology and the fast-growing medical imaging industry, there is a high probability that equipment may also be a contributing factor to radiation output and subsequently, induce radiation dose to patients. Although the CBCT exposures are higher than conventional dental equipment, dose output is dependent on exposure settings, the protocol used, and equipment type, so appropriate selection of technical parameters was necessary to minimize the radiation dose. Face frame and chin-thyroid distance, which vary from person to person and between adults and children, are two common factors that contribute to thyroid radiation risks

Although SED measurement is not as applicable or appropriate as the equivalent dose, it could be considered an approximation of the radiation dose imparted to the organs through a specific task. During our study, the indicated reading captured was the scattered radiation dose reaching the thyroid skin surface from the CBCT scan of the maxilla and mandible. From these observations, scattered radiation reaching the thyroid region is much lower than in studies conducted by Pauwels et al. [12], Akyalcin et al. [13], and below the recommended threshold level.

Although this study mainly focused on estimating the scattered radiation dose reaching the thyroid surface, there could be some possibility of primary radiation reaching the thyroid surface, which will also contribute to the radiation dose to the thyroid gland. Since the thyroid is a radiosensitive organ, measures should be taken to reduce the dose in every possible way. Even though the dose received from one scan may not be enough to cause any biological effect, the cumulative dose received by the patient can lead to consequences in the future, which increases the risk of radiation-induced thyroid abnormalities. Thus, the application of proper thyroid shield, FOV, and appropriate technical parameter settings during the scan is a way to provide better protection to the thyroid gland.

Conclusion

Therefore, according to the present study, we conclude that the SED to the thyroid gland from the CBCT imaging of both jaws, maxilla and mandible alone was within the equivalent dose limit of 50 mSv (International Commission on Radiological Protection 103) [6]. The radiation dose in CBCT was dependent on the exposure parameter, scan length, and FOV. For further dose reduction, low dose protocol and radiation protection measures must be considered, and thus by providing proper thyroid shielding and care should be taken during selection of protocol and FOV. Thyroid shielding is recommended for all age groups.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Ethical Statement

The study approval was attained from the Institutional Ethics Committee (IEC No: 69/2019) and Clinical Trials Registry-India (CTRI) registration was done (CTRI/2019/04/018574). Informed consent was obtained from all subjects who participated in this study.

Author Contribution

Conceptualization: Dkhar W, Vineetha R, Chhaparwal Y. Methodology: Hrangkhawl W, Dkhar W. Data curation: Hrangkhawl W, Dkhar W, Madhavan TS. Formal analysis: Madhavan TS, Chhaparwal Y. Visualization: Dkhar W. Investigation: Hrangkhawl W, Sharath S, Vineetha R, Chhaparwal Y. Resources: Vineetha R. Software: Sharath S, Chhaparwal Y. Supervision: Dkhar W, Chhaparwal Y. Validation: Dkhar W. Writing - original draft: Dkhar W, Sharath S. Writing - review & editing: Dkhar W, Madhavan TS. Approval of final manuscript: all authors.

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