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Imaging Dose of Kodak Carestream 9000 Cone-beam Computed Tomography for Endodontic Procedures

Mastroianni NM[1], Mansdorf DF[1], Branets I[2,4], Goren AD[2,4]*, Dauer LT[3], Quinn B[3], Kelly K[3], Manders T[1] and Cymerman JJ[1,5]

[1]Division of Endodontics, Stony Brook School of Dental Medicine

[2]Department of Cariology & Comprehensive Care, NYU College of Dentistry

[3]Medical Physics, Memorial Sloane Kettering Cancer Center

[4]Department of Prosthodontics and Digital Technology, Stony Brook School of Dental Medicine

[5]Department of Oral Biology, Stony Brook School of Dental Medicine

Abstract

Background: The purpose of this study was to determine radiation exposure utilizing the Carestream Kodak 9000 CBCT machine with a small field of view for endodontic procedures. Previous studies have not been done to measure exposures taken with and without leaded glasses and thyroid shielding during such procedures.

Methods: Anthropomorphic phantoms corresponding to a 30 year old female and a 10-year-oldmale were used for all exposures. CBCT scans were taken using the Kodak Carestream 9000 CBCT at the preset endodontic settings and the field of view for maxillary anterior and maxillary molar regions. The images were performed with and without leaded glasses and a thyroid shield for the female. Dosimetry was performed using optically stimulated luminescent (OSL) dosimeters. The effective radiation dose was calculated for the organs of the head and neck. Organ fractions irradiated were determined using ICRP-89 standards. Overall effective doses were calculated in micro-Sieverts and were based on the ICRP-103 tissue weighting factors.

Results: The effective doses measured with the CBCT for the adult female were 12.3 micro-Sieverts for tooth #6, 10.4 micro-Sieverts for #14, and 13.1 micro-Sieverts for #14 with thyroid collar and leaded glasses. The effective doses measured for the 10 year old pediatric patient were 17.8 micro-Sieverts for tooth #6 and 2.9 micro-Sieverts for tooth #14.

Conclusion: The effective dosages measured, are low enough to be considered an alternative or supplement to traditional 2-D imaging. This study confirms that small field of view CBCT imaging is an effective method to obtain additional useful information following ALARA principles.

Keywords: Juvenile patient radiation; Adult radiation; Effective dose; Cone- beam Computed Tomography; Equivalent dose

Corresponding Author: Dr. Goren AD, Department of Cariology and Comprehensive Care, New York University College of Dentistry, New York, USA. E-mail: ag153@nyu.edu

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Background Information

Endodontic diagnosis and treatment planning requires the use of radiographic imaging and interpretation as well as clinical sensibility testing. Radiographic imaging obtained for Endodontic purposes include bitewing radiographs, periapical radiographs, and Cone-Beam Computed Tomography (CBCT), which may be taken pre-operatively, intra-operatively, and/or post-operatively. There is limited radiation dosimetry data in the endodontic literature regarding the use of CBCT for evaluation of endodontic pathology in adult and pediatric patients. Additionally, the literature minimally expresses the amount of radiation exposure to various organ sites during CBCT evaluation [1-3]. The parameters of this study included the use of two CIRS phantoms, one adult female and one ten-year-oldjuvenile, as well as Optically Stimulated Luminescent (OSL) dosimeters to measure radiation exposure.

The International Commission on Radiological Protection (ICRP) developed guidelines for practitioners to limit the amount of radiation exposure to patients in order to reduce the risk of cancer, genetic mutation, and the overall negative effects of radiation [1]. In order to measure the stochastic risks of radiation exposure, which is defined as the probability of cancer induction and genetic damage, the ICRP utilizes two radiation measurements including equivalent dosage and effective dosage measured in microsieverts [4,5]. Specifically, the equivalent dosage factors in the type of radiation producing the evaluated dose. Effective dosage is a measure of the tissue-weighted sum of the equivalent doses in individualized specific tissues and organs [6-8].

It has been recommended that during initial endodontic consultation, two periapical radiographs and should be obtained at different angulations as well as one bitewing in order to appreciate the complex anatomy of the root canal system and periapical tissues [2]. The use of two-dimensional imaging to diagnose endodontic pathosis in areas with complex bony architecture can be challenging. The zygomatic buttress and maxillary sinus are two structures that consistently overlap with roots in the posterior maxilla, limiting the accuracy of periapical radiography [7,3] .

Two dimensional periapical radiography is limited in diagnosing active disease because lesions can only be visualized radiographically once the cortical plate has been perforated. Additionally, periapical pathosis can be identified using periapical radiography if there is sufficient erosion of the inner bone cortex or if there is destruction from the outer surface. Lesions in cancellous bone cannot be detected radiographically [9]; therefore it is possible for active pathology to be left undiagnosed. Through the advent of three-dimensional imaging using Cone-Beam Computed Tomography (CBCT), the limitation of two-dimensional periapical and bitewing radiography can be circumvented.

The ability to achieve diagnostic accuracy with endodontic pathology is further enhanced by the use of CBCT. Through the three dimensional capabilities, CBCT allows the practitioner to assess the size, extent, shape, position and nature of periapical pathology [10]. In addition, the analysis of root anatomy, bony architecture, vital structures such as the maxillary sinus or inferior alveolar nerve, root fractures, and resorptive defects may also be observed [10].

The ICRP guidance regarding optimizing radiation exposure and the As Low as Reasonably Achievable (ALARA) principle must be followed during all dental procedures. Although the amount of radiation per digital periapical, bitewing, or other two-dimension radiograph is minimal, the cumulative effects of radiation exposure throughout the entirety of an endodontic procedure must be taken into account [1]. It is important for clinicians to have justification before radiographic exposure of a patient [11], especially during endodontic treatment of pediatric patients due to their small size and continuous growth and development [12].

It has also been proposed that CBCT radiation effective dosages were substantially lower than medical grade CT scans and on the same order of magnitude as periapical radiographs [13]. It was later reported that these CBCT imaging modalities in dentistry, although diagnostic, were substantially higher than the traditional radiographic techniques employed [14]. Studies were previously conducted analyzing the effective dosages of periapical and CBCT radiography based on background radiation scale. Depending on the CBCT machine utilized and the area being scanned, the approximate ionizing radiation dosages as reported in the study in uSv ranged from 4.7 uSv to 68uSv [15], which was substantially lower than the estimated medical CT results ranging from 2,000 to 10,000uSv [3].

The purpose of this study is to determine the amount of radiation exposure during a small field of view CBCT exam with the Carestream 9000 using a CIRS phantom of an adult female and 10 year old malepediatric patient.

Materials and Methods

Two CIRS phantoms (Computerized Reference Imaging System, (CIRS), Norfolk, Va) were utilized: a juvenile male (CIRS model 704) corresponding to an average 10 year old child and a female adult phantom (CIRS model 702) corresponding to a 30 year old female were used to measure all radiation dosages. OSL standard Nano-dots (Landauer, Glenwood, IL) were placed throughout both the female and pediatric anthropomorphic phantom corresponding to different locations, including: oral mucosa, extrathoracic airway, bone marrow, cortical calvarium, cervical spine, thyroid, esophagus, skin, bone surface, mandible, calvarium, salivary glands, parotid gland, submandibular gland, sublingual gland, brain, lymph nodes, and muscle tissue. The areas exposed included tooth #6 and tooth #14.

Exposure settings on the CBCT were established at 75 KvP, 8 mA, and 10.8 Seconds, 8mA, and a Field of View (FOV) of 4x4cm as recommended by the manufacturer for adult patients. The pediatric settings as recommended by the manufacturer were 65 KvP, 6.3 mA, and 10.8 seconds with a Field of View (FOV) of 5x5cm as recommended by the manufacturer for pediatric patients. Unexposed OSLs were used to determine the baseline exposures. Each phantom was exposed three times for each protocol. The dosimeters were read 3 times and the baseline exposure value was subtracted from the averaged calculations. Data was analyzed using Microsoft excel. Equivalent dosages were calculated using ICRP's 2007 recommendations for tissue weighting factors (4). Additionally, organ fractions as well as organ equivalent doses and overall effective doses were calculated with the use of ICRP-89 and ICRP-103, respectively [16,17].

Results

The effective doses varied depending upon the area evaluated (tooth #6 versus #14), the presence or absence of thyroid collar and leaded glasses. When the adult female phantom was measured without protective equipment, the effective dose was greater on tooth #6 (12.3 uSv) than tooth #14 (10.4 uSv). When evaluating tooth #14, comparing effective doses with and without protective equipment for the eyes, the effective dose was slightly higherwhen wearing protective equipment (13.1 uSv) versus not wearing protective equipment (10.4 uSv) (Table 1). The pediatric phantom results indicated that the effective doses for tooth #6 (17.8 uSv) was greater than the effective dose of tooth #14 (2.9 uSv) (Table2).

Discussion

Radiation exposure and dosimetry can be best interpreted when discussing equivalent dose and total effective dose of a particular region of study. Tissue equivalent dose is defined as the tissue's absorbed dose of radiation adjusted for the radiation-weighting factor. This is calculated by multiplying the absorbed dose with the radiation-weighting factor and the product is expressed in microsieverts. Total effective dose is a calculation the ICRP uses to compare differing exposures. This is calculated by adding the products of the tissue weighting factor and the tissue equivalent dose. The weighting factor describes the individual sensitivity of each tissue and is expressed in microsieverts. Generally, the greater the weighting factor, the more sensitive an organ is to radiation.

Radiation dosage evaluations require the use of specialty equipment to accurately illustrate exposure in patients. Analysis of effective dosages using animal models or other means of human studies would be inaccurate and unethical, respectively. The CIRS phantoms utilized to represent patients are fabricated from materials that allow for accurate simulation of radiation absorption characteristics of human organs and tissues. Additionally, the decision to use OSLDs to measure the absorbed radiation dosages was based on evidence showing their superior effectiveness in the low radiation dose range [18,19]. Through the use of the aforementioned technologies, the radiation emission of the Carestream 9000 CBCT machine was evaluated in reference to specific organs of the head and neck in pediatric and adult phantoms. The results obtained from the CBCT using the settings recommended by the manufacturer for both pediatric and adult patients when evaluating potential endodontic pathosis utilizing a small field of view should be followed up for further evaluation (Figure 1).

Two-dimensional radiography has been the standard of endodontic practice for decades. However, with the advent of three-dimensional technology, clinicians have the capability to accurately perceive all facial regions. The use of CBCT in Endodontics allows for the

Table 1: Effective Dose for tissues irradiated in adult phantom with the without personal protective equipment.

Tissue Irradiated	Equivalent Dosage (uSv) #6	#14 w/o PPE	#14 w/ PPE
Bone Marrow	0.5	0.5	0.5
Thyroid	0.6	0.7	1.1
Skin	0.1	0.1	0.1
Esophagus	0.3	0.3	0.2
Bone Surface	0.2	0.2	0.2
Salivary Glands	7.1	5.4	7.3
Brain	0.4	0.6	0.4
Lymphatic Nodes	0.1	0	0.1
Muscle	0.1	0	0.1
Extrathoracic Airway	0.9	0.7	0.9
Oral Mucosa	2.2	1.7	2.2
Lens of Eye	1060.9	1179.5	494
Effective Dose	12.3	10.4	13.1

Table 2: Effective dose for tissues irradiated in pediatric phantom without personal protective equipment.

Tissues Irradiated	Equivalent Dosage (uSv) #6	Equivalent Dosage (uSv)#14
Bone Marrow	0.81	0.12
Thyroid	0.92	0.16
Skin	0.09	0.02
Esophagus	0.11	0.02
Bone Surface	0.28	0.04
Salivary Glands	10.32	1.11
Brain	0.61	0.81
Lymphatic Nodes	0.09	0.01
Muscle	0.09	0.01
Extrathoracic Airway	1.31	0.26
Oral Mucosa	3.18	0.34
Lens of Eye	108	25
Effective Dose	17.8	2.9

assessment and treatment of a number of complex endodontic conditions including identification of anomalies of within root canal system, diagnosis of periapical pathosis, diagnosis of pathosis of non-endodontic origin, intra or post-operative assessment of treatment complications, diagnosis and management of dentoalveolar trauma, localization and differentiation of root resorption, and presurgical treatment planning [20]. Through three-dimensional radiographic assessment along with a clinical evaluation, endodontists are able to more accurately diagnose and treat endodontic disease thus allowing for improvements in prognostic determination as well as success rates based on case selection.

CBCT radiation dosimetry depends on a number of different factors. Those factors include but are not limited to machine being used, volume, detector type, field of view, voxel size, and number of projections [21]. In the previous literature discussing CBCT usage in Endodontics, it was determined that limited FOV CBCT effective doses ranged from 5-652uSv [22], which the findings in this study further substantiates.

The equivalent doses for each organ measured is related to the amount of biological damage measured in microsieverts caused to

Figure 1: Set up of 30 year old female phantom in proper scanning position in the Carestream Kodak 9000 3D CBCT unit.

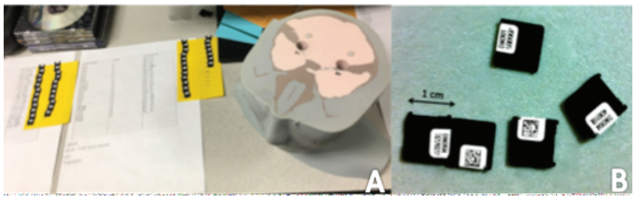

Figure 2: (A) NanoDot optically stimulated luminescent dosimeters (OSLDs) pictured on the left and phantom axial slice with grid holes for OSLD placement on the right. (B) Closer view of NanoDot optically stimulated luminescent dosimeters (OSLDs).

each individual organ system. However, each organ system is not equal regarding the effect of radiation. For instance, bone marrow is much more sensitive than bone cortex. Therefore, bone marrow has a higher tissue-weighting factor. The concept of effective dose was developed by ICRP as a risk-adjusted dosimetric quantity for the management of protection against stochastic effects, principally cancer, enabling comparison of planned or received doses with dose limits, dose constraints, and reference levels expressed in the same quantity (REF ICRP Publication 103) (Figure 2).

When examining the adult phantom, it was observed that the overall effective dose was higher for tooth #6 than #14, which was caused by the specific beam angulation in relation to the position of the more radiation-sensitive salivary glands. Additionally, it was observed that when comparing tooth #14 with and without PPE, that the effective dose was higher when the patient was protected. This was due to increased scatter resulting from the presence of leaded glasses. The leaded glasses protect the eyes, which can be observed in (Table 1), but scattered radiation doses may slightly increase they expose other areas of the head and neck.

Upon examination of the pediatric phantom, it was found that the effective dose for #6 was greater than #14 for similar reasons as the adult phantom. The direction of the beam, the field of view, and the elevation in sensitive tissues result in greater effective dosages for tooth #6 than tooth #14 [23].

Overall the AAE and the AAOMR position statement on CBCT explain that they should be taken when 2D imaging does not provide enough information to manage the patient. Based on the information provided, it seems as though the effective dosages measured are low enough to be considered an alternative or supplement to traditional 2D imaging and that the small FOV CBCT imaging is an effective method to obtain additional useful information follow the ALARA principles.

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