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Estimation of Entrance Surface of X-Ray Dose during Dental Examination

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Abstract

Radiographic examinations play an essential part of dental practice. Because a certain amount of radiation is inevitably delivered to patients, it should be as low as reasonably achievable. The purposes of this study are to measure the dose in dental radiography, and measure the dose into the lens and thyroid during dental radiography exams. Then evaluate the risk for dental radiation examination induced cancer. This work was carried out in four major hospitals in the Sudanese capital Khartoum. Entrance surface dose (ESD) was determined from exposure settings using ESD equation. Totally, 155 patients were included in this study. Mean ESDs obtained was 2.87 mGy. Using a 70 kV to 73 kV voltages for all hospitals, the following results were obtained: the mean radiation dose was 0.33 mGy in the lens which is higher than the other studies, while 0.121 mGy in the thyroid is lower than them. The risks associated with dental examination for patients are negligible. The results of this study provide baseline data to establish reference dose levels for dental examination in very young patients. After analyzing the results, it was concluded that radiation exposure conditions that patients are subjected to dental radiographic procedures should be observed with great accuracy, as the risk of possible biological effect can be reduced if optimum technical parameter are used.

Keywords: X-ray; Entrance surface dose; Dental examination; Radiation risk

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Introduction

The radiographic examination is one of the principal diagnostic methods used in all fields of medical services and contributes to the promotion of the health, both individually and nationally. Accordingly, a certain amount of radiation is inevitably delivered to patients and populations. The risk associated with low-level diagnostic exposures could be expected to be low but greater than zero. For this reason, it is prerequisite to measure the dose to the patients in the diagnostic radiology precisely. In addition, the radiation dose to the patients should be as low as reasonably achievable, a principle known as ALARA [1]. The number of diagnostic examinations should also be taken into consideration because the risk is directly proportional to the frequency of X-ray exposure. Dental radiographic examinations are one of the most frequently performed radiological studies in Sudan. It is useful and necessary tool in the diagnosis and treatment of oral diseases such as caries, periodontal diseases and oral pathologies. Although radiation doses in dental radiography are low, [2,3] exposure to radiation should be minimized where practicable. Dentists should weigh the benefits of dental radiographs against the consequences of increasing a patient's exposure to radiation, the effects of which accumulate from multiple sources over time. The effective dose delivered to patients per radiograph is low but the collective dose is significant because of the large number of radiographs made. Another aspect of protection in medicine is to consider optimization of radiographic procedures. Reduction in exposure dose to patients may be attained by proper management of equipment and the accomplishment of a quality assurance program [4].

The soft tissue can alter the absorption of radiation, increase dispersion, influence the film contrast and density and consequently affect diagnostic precision [5]. Measuring the radiation dose in organ and tissue is essential in estimating the relative risk of cancer associated with radiation induction [6]. There is an increased risk of thyroid cancer from exposure to radiation and also eye affected by ionizing radiation. The international commission on radiological protection (ICRP), published a statement in tissue reactions 2011 suggesting the eye lens, one of the most radiosensitive tissue of the human body, should have a dose absorption threshold below 0.5 Gy instate of 2 Gy. Based on this new threshold to the eye of 20 mSv,

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considerable reduction from the previous 150 mSv dose constrain [7]. The purposes of this article are to estimate radiation doses of thyroid and eyes lens during dental X-ray, and to determined local reference levels dose (RDLs) in Khartoum state.

Methodology

This work was carried out in four major hospitals in the Sudanese capital Khartoum. These hospitals were chosen for the study because they are the largest hospitals in the country in terms of workload.

Information with respect to X-ray radiography unit, including manufacturer, model, year of installation, filtration, maximum Kv, and m As are taken.

To calculate the ESD, the following X-ray tube exposure parameters were recorded for each patient undergoing the specified diagnostic procedure: peak tube voltage (kVp), exposure current–time product (mAs) and focus-to-film distance (FFD). The ESD is defined as the absorbed dose to air on the X-ray beam axis at the point where the X-ray beam enters the patient, including the contribution of the backscatter [8].The ESD was calculated in the present work using the following relation (**Figure 1**).

Figure 1: Formula of ESD.

where is the tube output per m A s measured at a distance of 100 cm from the tube focus along the beam axis at 80 kV p, where kV is the peak tube voltage recorded for any given examination, m As is the tube current–time product, FSD is the focus to patient entrance surface distance and BSF is the backscatter factor [9]. The tube output in mR/m A s was measured using RAD-CHECK PLUS model 06-526 X-ray exposure meter (Nuclear Associates, Victoreen Division, NY, USA). The factor 0.00877 was applied to convert the tube output from mR/m A s to output in mGy/mAs [10]. A value for the BSF of 1.35 [11] was used in this study. The dose rate meter, RADCHECK PLUS used for the measurements has been calibrated at Sudan Atomic Energy Commission (SAEC) Secondary Standard Dosimetry Laboratory. **Table 1** Summarizes the radiographic technical data collected for the four X-ray units, as well as the measured tube output.

Hospital	Radiographic unit model	Installation date	Max .time (sec)	Total filtration (mm AL)	Output (µGy\m As)
A	Vatech	2014	3.2	2.8	17.8
B	Endos_acp	2011	3.2	2	202
C	Vatech	2017	-	2..8	40.9
D	Vatech	2018	0.08	2.8	3.2

Table 1: CDental X- ray technical data and output values for the four X-ray units.

Exposure parameters were registered and dose calculations were performed on a sample of 155 radiographs. All adult patients with age ≥ 16 years were included in this study. Microsoft excel was used for data manipulation and ESD calculations.

Results and Discussion

A total number of 155 radiographs were included in this study. The data were collected in four major hospitals in Khartoum. The patient information and exposure parameters are shown in **Tables 2 and Table 3**.

Centers	Patient age (yrs)	Sample size (N)	BMI (kg/m²)	Weight (kg)	Height (Cm)	No. of film
A	38.48	35	26.07	74.42 ± 19.5618	162.42 ± 10.19598	1 ± 0
B	28.58	60	22.4	62.18 ± 22.46994	163.11 ± 19.87682	1.08 ± 0.278718
C	36.18	55	22.33	61.96 ± 16.09344	166.11 ± 11.21453	1.09 ± 0.292582
D	35.2	5	19.23	52 ± 20.3101	159.2 ± 27.77049	1 ± 0

Table 2: Patient information for selected X-ray examinations, with mean and standard deviation values.

Center	Kv	MAs	SSD(cm)	ESD(mGy)	ED(mSv)
A	72.4 ± 0.49	13.11 ± 16.01	27 ± 0	3.27 ± 0.04	3.18 ± 0. 40
B	70 ± 0	4.06 ± 0.58	33 ± 0	7.207 ± 1.02	6.991 ± 0.99
C	70 ± 0	11.97 ± 2.83	30 ± 0	0.52 ± 0.012	0.46 ± 0.18
D	72.4 ± 0.55	13.5 ± 0	30 ± 0	0.49 ± 0.0013	0.48 ± 0.01

Table 3: Exposure parameters, Entrance surface dose (mGy), and Effective dose (mSv) mean and standard deviation values for Dental exams.

The mean age of the study sample was found to be in the range from 29 to 39 years. The mean patient weight measured for 155 patients was found to be in the range from 52 to 74 kg (**Table 3**).

It can be seen from the table that all hospitals were using fixed kV p, ranging between 70 and 72 kV p, Both high-kV p and low-kV p techniques were reported to be commonly used in dental radiography examinations in Brazil, China, and Europe [12-14]. Cases were observed in SSD as low as 27 cm was used for center A, as a result, higher ESDs were encountered in this hospital with fixed Kv (72.4 kv), and low SSD 30 cm with high mAs (12 mAs) and fixed Kv (70 Kv). The use of optimum FFD and m As is considered very important, since a direct relationship between shorter FFD, higher patient's dose and decreased geometric sharpness is well established [15,16]. When compared to similar studies, the mean ESD values for all hospitals (2.87 mGy) found in the present study were relatively lower than (3.18 mGy) that reported in Malizia [17].

The lowest mean ESDs for dental examination were observed at both hospitals C and D with values of 0.52 and 0.49 mGy, respectively. As it can be seen in **Table 3**, ESDs at these two hospitals are within the DRLs recommended by NRPB, (1.80 mGy) [18,19]. The highest mean ESDs for dental examination were observed at both A and B hospitals with values of 3.27 and 7.21 mGy, respectively. The variations in ESDs among the different radiological departments studied may be attributed to several factors: differences in patient weights, exposure parameters, radiological technique, FFD and total filtration. Several factors could have positively contributed to the results. Equipment performance can be a major factor, as relatively new equipment were reported to be used in **Table 4**.

In relation to the upper incisor, the incidences with 70 kV and 72 kV voltage and different m As and SSD equipment A and B had a higher dose increment of radiation in the eye lens (0.38 msv and 0.84 mSv) compare with equipment C and D (0.05 mSv and 0.6 mSv). In the thyroid dose (0.12 mSv and 0.28 mSv) obtained with equipment C and D, doses were higher than obtained from equipment A and B (0.05 mSv and 0.6 mSv) respectively. Radiology reference levels for periapical X-rays were established by Federal Decree No. 453 of the Health Surveillance Secretariat on June 1st, 1998, and indicated values up to 3.5 m Gy as acceptable for skin entrance doses.

The risk of malignancy of thyroid effects were less than 6.0 per million (**Table 4**). The radiation risk per examination was estimated from the effective dose to be 26 per million. The risk of radiation-induced cancer can be considered as negligible (**Table 5**).

Comparing the average between the values obtained from this work for the radiation dose in the lens and thyroid, with those contained in four studies that reference protocols between 60 kV and 80 kV, and tube current intensities applied to the tube between 4 m As and 14 m As, it appears that in the present study, the average is lower in the thyroid (0.002 m Gy) and is in the highest position in relation to the eye lens (0.84 m Gy), pointed out in **Table 5** and **Figure 2**.

Centers	Organ	Organ equivalent dose (mSv)	Risk factor × 10-4 Sv-1	Cancer probability × 10-6
A	Thyroid	0. 12 ± 0.0016	20	2.4
	Lens	0. 38 ± 0.0047	-	-
B	Thyroid	0.279 ± 0.040	20	5.58
	Lens	0.839 ± 0.1188	-	-
C	Thyroid	0. 02 ± 0.0072	20	0.4
	Lens	0. 05 ± 0.0217	-	-
D	Thyroid	0. 02 ± 0.0003	20	0.4
	Lens	0.06 ± 0.0009	-	-

Table 4: Mean of organ radiation dose (mSv) and radiation risk.

Author	Lens	Thyroid
Endo et al. [6].	0.028	0.354
Ludlow et al. [19]	0.020	0.050
Gavala [12]	0.055	0.088
López [7]	0.010	0.47
A	0. 38	0.012
B	0.839	0.279
C	0. 05	0.002
D	0. 06	0.002

Table 5: Radiation dose in head and neck organs: comparison between results of different studies.

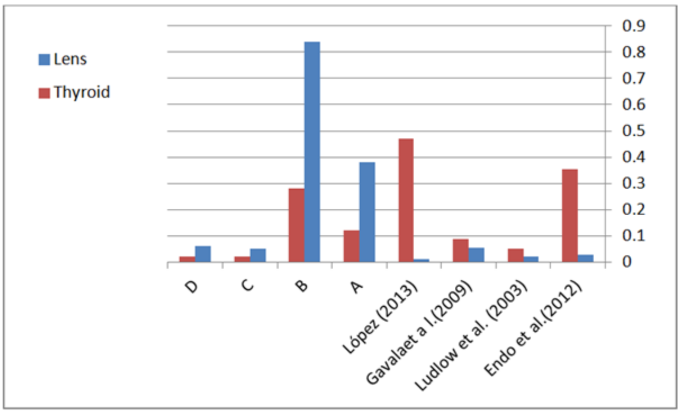

Figure 2: Radiation dose in head and neck organs: comparison between results of different studies.

Conclusion

From the result and analyzed, we highlight the importance of using low radiation doses and properly positioning the equipment to generate radiographic views for dental examinations region because if the beam is not in the exact position indicated, there may be a radiation dose increase in organs near the examined region. As a result, an optimum radiological examination can be obtained, resulting in an image of diagnostic quality and low radiation doses that minimize biological effects on radiosensitive structures in the head and neck region. The radiation exposure conditions to which patients are subjected to in dental radiographic procedures should be observed with great accuracy, since the risk of possible biological effects can be reduced if optimal technical parameters are used.

Recommendation

Measuring radiation doses in organs and tissues is essential in estimating the relative risk of cancer associated with radiation induction.

Reducing tube current time product (m As), using tube current modulation, reducing peak-voltage (kV p), using relatively higher pitches, and limiting both scan regions and multiphase examinations are among the methods that are used to reduce the radiation dose. Although it is possible to reduce the m A and kV p parameters in OPG devices.

The National Council on Radiation Protection and Measurements (NCRP) recommends the use of thyroid shielding for children and indicates that thyroid shielding should be used for adults as long as it will not interfere with the examination.

Recently, the American Thyroid Association (ATA) issued new guidelines on how to minimize any unnecessary exposure to radiation during the execution of medical and dental imaging procedures, such as the use of thyroid collars for dental X-rays.

The dentists and trainers must have high knowledge about X-ray machine to avoid the significant dose during diagnosis. The dentists and trainers should know the most radiosensitive organs such as lens, thyroid and salivary glands. The exposure should be following the international rules of exposure and acceptable exposure factors in order to achieve ALARA principle. Patients should be well instructed about the procedure to avoid repetition of the radiograph. Also should be protected with lead aprons and the inverse square law should be considered.

If the patient is pregnant, the possibility of obtaining information from a no radiological investigation should be considered. If the radiological examination is considered essential it should be performed and due consideration should be given to optimization.

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