AN ASSESSMENT ON THE RADIATION DOSE RECEIVED BY THE EYES & THYROID USING PANORAMIC VIEW (OPG): PHANTOM STUDY

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ABSTRACT

Introduction: The purpose of this paper is to assess on the radiation dose received by the eyes and thyroid on the panoramic view (OPG), using the phantom with the selected exposure setting based on the patient's body habitus/size. **Methods:** Optically Stimulated Luminescence (OSL) dosimeters were placed on the three critical organs; right eye, left eye and thyroid and were exposed to the OPG machine at the Kulliyyah of Dentistry (KOD), International Islamic University, Malaysia (IIUM), Kuantan Campus. The Entrance Surface Doses (ESD) for each critical organ was measured at the Diagnostic Imaging Laboratory, Kulliyyah of Allied Health Sciences (KAHS), IIUM using the OSL reader. The means for each organ were recorded and the statistical analysis was done using the Kruskal-Wallis test to get the significant value for comparing these three organs/groups with selected exposure factor. **Results:** The overall means ± standard deviation (SD) for right eyes, left eyes and thyroid using the selected tube potentials of 62, 64, 66, 68 and 70 kVp were -3.62 ± 0.0058 μGy, -2.10 ± 0.0043 μGy and -3.09 ± 0.0042 μGy. The results were compared to other studies and the reference value or exposure limits from radiation protection organizations/boards. **Conclusions:** This study showed no statistical differences between the ESD for the critical organs when using different tube potentials (kVp) with *p*-value > 0.05. This indicates that the OPG exposure value was relatively lower in dose and produced almost negligible results in this experiment. When comparing this study from the results of other researches, the dose measurement in this study using the OPG equipment was the lowest and below the exposure limits in the radiation protection guidelines. However, further studies should be done using different OPG devices so that various significant and relevant results can be obtained and compared to the other studies. Therefore, this study might be a steppingstone for other studies to further for large scale extension study on radiation dose assessment of the critical organs in dental radiography. It is hoped that through this attempt, Malaysia might be able to produce and establish its own Diagnostic Reference Level (DRL) in dental radiography in the future.

KEYWORDS: Panoramic view (OPG), Entrance Surface Dose (ESD), critical organs, OSL dosimeter, exposure limits

INTRODUCTION

Dental radiography is considered to be one of the radiological examinations which are performed in various countries (Toossi, Akbari, Bayani, Jafari and Malakzadeh, 2009). Orthopantomography (OPG) is a dental radiographic field which is associated with exposure of ionizing radiation to patients. OPG is commonly applied for the assessment of dental treatment, planning for orthodontic and mandibular studies (RadiologyInfo, 2018). According to Batista (2012), dental radiology is widely used since the introduction of dental implant technique. The increasing dental problem in the world has caused dental imaging to become the preferable choice requested by the physicians to cater for dental diagnosis.

Moghadam, Mardani, Hasanzadeh, and Rafati (2015) emphasized that even though dental radiology uses less radiation exposure as compared to other diagnostic radiology examinations, an optimization and radiation protection should be considered to prevent the radiation risks to the patients. Based on the radiation protection principles, the maximum benefit can be achieved and the risk can be minimized if the appropriate using of ionising radiation is practiced. Due to this condition, "As Low as Reasonably Achievable" (ALARA) concept proposed that the technician or the radiographers must take a better-quality radiograph with proper radiation dosage exposed to the patient (Sur and Okano, 2010). In OPG procedure, critical organs such as the eyes, thyroids, brain are being exposed to radiation. Based on a research by the American Cancer Society (2014), an increasing prevalence of cancer (thyroid cancer) in the US due to the increase detection using the sensitive diagnostic procedures has caused an estimated 1890 deaths in 2014. Therefore, it is very important to conduct studies on the radiation dose assessment of the critical organs using the panoramic view and to compare the dose with the reference values and the dose limits from other researches and radiation protection organizations.

Several guidelines have been proposed by national radiation protection organizations such as the Internal Commission on Radiation Protection (ICRP) regarding Diagnostic Reference Level (DRL) and radiation exposure limits to the organs for occupational and public exposures. In conjunction to that purpose, the introduction of dosimeter has played an important role in the radiation dose measurement for medical radiation assessment. The most frequent dose assessments used in the diagnostic radiology are the entrance surface dose (ESD) and dose-area product (Mortazavi et al., 2004). According to the ICRP, personnel occupational exposure should not exceed the limits by which the average annual effective dose should be 20 mSv for 5 consecutive years for the eye lens and 500 mSv per year for the skin's equivalent dose (ICRPaedia, 2018). In intraoral radiography, the DRL value of 7 mGy was proposed by the International Atomic Energy Agency (IAEA), while no DRL was proposed for panoramic radiograph (Mortazavi et al., 2004).

This study aimed to determine the ESD to some critical regions such as the eyes and thyroid in OPG imaging by using selected tube potential, thus to compare and present the findings of the radiation dose obtained in the experiment with the reference values from other studies and radiation protection regulatory body/organizations.

METHODS

Ethical Application and Approval

The study was an experimental mode and the protocol of the study was approved at the Kulliyyah Postgraduate and Research Committee (KPGRC) Meeting No. 06/2017 with the ID number: KAHS 207.

Dosimetry application and calibration

In this study, 45 nanoDot Optically Stimulated Luminescence dosimeter (OSLD) produced by Landauer, Inc. with 10mm x 10mm x 2mm size dimension (Landauer, 2015) were used. Before exposing the OSLDs to radiation, all dosimeters had undergone the annealing process about 12-24 hours. The pre-reading was taken after the annealing process by using the Microstar system and was recorded in the data sheet of Microsoft Excel 2010. The OSLDs were then sealed in a black folded paper to lessen other influence factors that can affect and introduce bias to the reading. These OSLDs were labeled according to the code for each specific region of interest by using the alphabets; A (right eye), B (left eye) and C (thyroid region). Each folded paper or package consisted of three OSLDs; with every region to be exposed will have three values and the values will then be averaged for dose measurement. This precautionary step was practiced in order to reduce any errors and bias. Other precautionary step included securing the OSLDs in the lead carrier while transporting for the data collection at the respective venue located at the Imaging Department, KOD. The measurement of dose for OSLD reading is corrected by using the system autocorrect function as shown by the following measurement information.

$$\frac{\boldsymbol{PMT\ Counts}}{\boldsymbol{Callibration\ factor} \times \boldsymbol{Sensitivity}} = \boldsymbol{Dose}\ (\boldsymbol{mGy}) \qquad \textbf{Equation 1}$$

Calibration name used was 20170712-LowDose setting (diagnostic range**),** with *PMT count* and the *sensitivity* indicated by each of OSLD. The exposed nanoDot OSLDs were read by using the OSL reader (Laundauer Inc.), Microstar system at the Diagnostic Imaging Laboratory located at the Department of Diagnostic Imaging and Radiotherapy (DDIR), KAHS IIUM. The dose values were recorded and average measurement was taken for each region.

Figure 1. OSLD Microstar Reader (left) and nanoDot OSLD (right)

Dental phantom and Orthophantomography (OPG) device

The available phantom used for OPG exposure in dental imaging of KOD, IIUM was a dental quality assurance (QA) phantom: an X-ray Adult Manikin Complete produced by Buyamag, Inc (Figure 2). This phantom is normally used as a simulator phantom and for the OPG assessment in dental QA radiography. The sealed nanoDot OSLDs were mounted on the phantom critical organs; right eye, left eye and the thyroid. The critical organs were exposed using the OPG, Digital Planmeca ProMax 3D (Figure 3) with the selected tube potential (kVp), that followed the panoramic exposure program based on the patient size/body habitus. The standard tube voltage, kVp employed in this equipment with the respective tube current, mA based of patient size criteria were represented in Table 1.

Figure 2. X-Ray Adult Simulator - Manikin Portable Complete with rubber mask (left), without rubber mask (right) and tripod stand

Figure 3. Dental OPG Planmeca Promax 3D machine in Imaging Department, KOD, IIUM (left) and phantom placement in OPG device (right)

Table 1 The details of technical specifications for Dental OPG Planmeca Promax 3D

Tube Housing Assembly	
Types	Promax 3D
Manufactured by	Planmeca Oy, 00880 Helsinki, Finland
Version/manufacture	2010-09
kVmax/total filtration	84 kV/2.5 mm.Al equivalent
Generator	Constant potential, resonance mode high frequency (80-150 kHz)
Focal spot size	0.5 x 0.5 mm
Anode voltage	50-84 kV
SID	500 mm

Table 2 Panoramic exposure values based on patient's size/ body habitus

Panoramic Exposure Values		
Patient Size	**kVp**	**mA**
Child up to 6 years old	62	5
Child 7-12 years	64	7
Adult female or small male	66	9
Adult male	68	13
Large adult male	70	14

Statistical analysis

A non-parametric test, Kruskal-Wallis test was performed using SPSS 12.0.1 for Windows in order to analyze the relationship between the ESD measurement for the region of interests with the exposure factor criteria based on body habitus/size using OPG exposure settings. The Kruskal–Wallis test is equivalent to the parametric test of the one-way analysis of variance (ANOVA), which is used to compare two or more different sample sizes or two or more of the equal independent samples and also to test whether samples originate from the same distribution or not (Coakes, 2005).

RESULTS

The findings on the overall means and the standard deviation for ESD in the three critical organs using the different kVp were as follow: -3.62 ± 0.0058 for the right eye, -2.10 ± 0.0043 for the left eye and -3.09 ± 0.0042 for the thyroid (Table 3). The left eye showed the highest value in ESD reading as compared to other regions. There was no significant difference in ESD measurements for all the assessed critical organs with the application of different kVp values based on body habitus/size criteria OPG exposure settings when analyzed by the Kruskal-Wallis test. The ESD of critical organs for different tube potential (kVp) setting was shown in Figure 4, 5 and 6.

Table 3 Mean and the standard deviation (SD) of entrance skin dose (ESD) for each critical organ.

Organs	Entrance Skin Dose (ESD) in µGy
Right Eye	-3.62 ± 0.0058
Left Eye	-2.10 ± 0.0043
Thyroid	-3.09 ± 0.0042

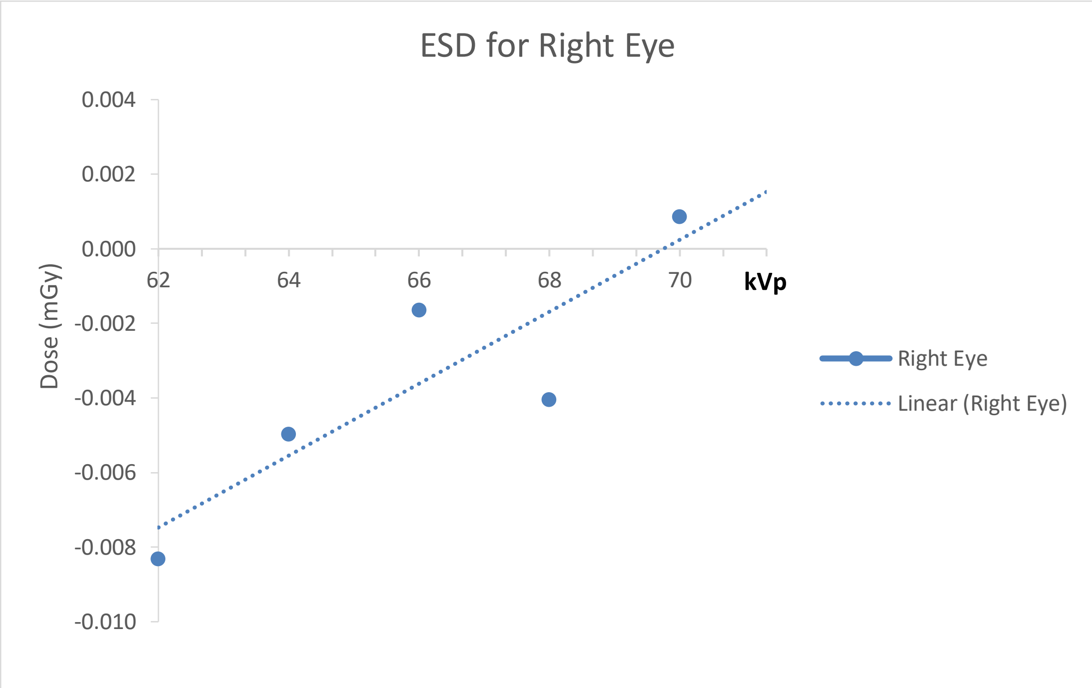

Figure 4. The mean ESD of the right eye using the different tube potentials (kVp)

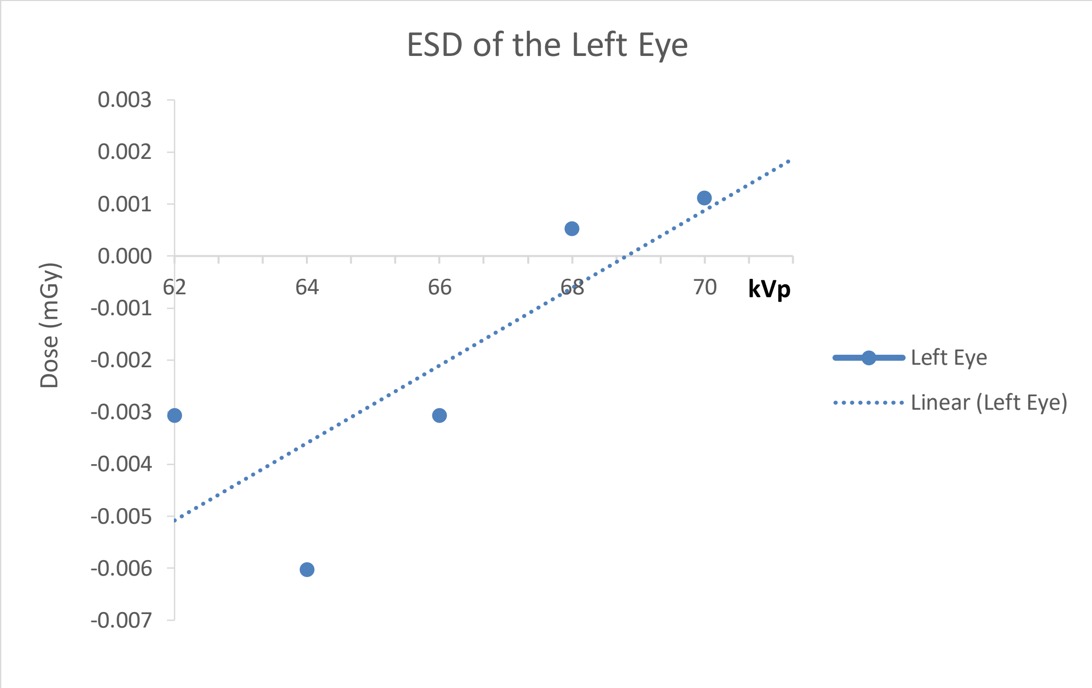

Figure 5. The mean ESD of the left eye using the different tube potentials (kVp)

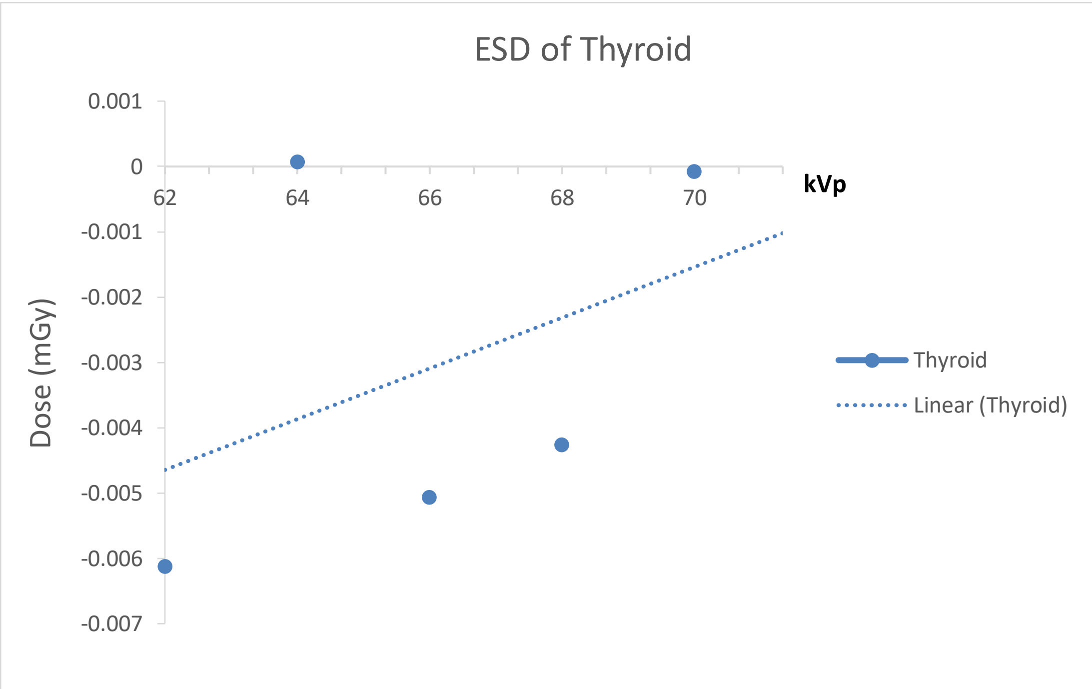

Figure 6. The mean ESD of the thyroid using the different tube potentials (kVp)

The comparison of ESD measurement for different critical organs (right eye, left eye and thyroid) with the selected exposure factor setting based on patient's body habitus/size criteria is shown in Figure 7.

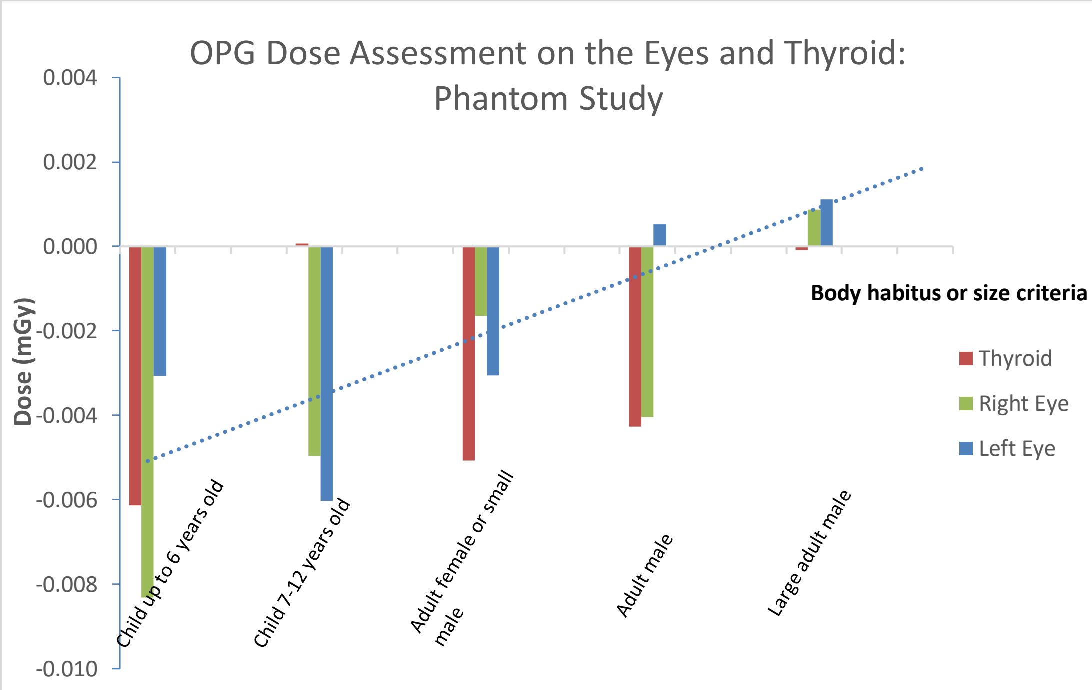

Figure 7. Comparison between ESD of critical organs with exposure setting according to body habitus/size criteria

Table 4 Summarization results for average entrance skin dose (ESD) with standard deviation (SD) in critical organs due to exposure parameters (µGy)

Organs	**5 mA 62 kVp**	**7 mA 64 kVp**	**9 mA 66 kVp**	**13 mA 68 kVp**	**14 mA 70 kVp**
Right Eye	-8.31 ± 0.0111	-4.96 ± 0.0012	-1.64 ± 0.0045	-4.03 ± 0.0007	0.87 ± 0.0040
Left Eye	-3.07 ± 0.0045	-6.02 ± 0.0031	-3.06 ± 0.0029	0.52 ± 0.0021	1.11 ± 0.0061
Thyroid	-6.13 ± 0.0047	0.07 ± 0.0016	-5.07 ± 0.0027	-4.26 ± 0.0056	-0.08 ± 0.0032

DISCUSSION

In this study, it was expected that varying the kVp might resulted in the increment or reduction of the ESD measurement. However, the overall statistical result showed that there was no significant difference between the ESD of the eyes and thyroid with the application of various kVp according to the pre-set values determined by the OPG system. Most of the average ESD values yielded negative results for the critical organs. As expected from the descriptive data, the line graph showed the increasing patterns when varying the tube potential from the lowest pre-set kVp; 62 kVp up to the highest kVp; 70 kVp. There was only slight fluctuation on the values presented in the constructed line graph for each of the critical organs exposure as shown in Figure 4, 5 and 6.

According to studies conducted by Moudi et al. (2013) and Tossi et al (2010), the slight differences between the values yielded during the OPG measurements in the exposed organs were due to several influencing factors; 1) the use of different parameters due to the different standards of exposure setting in dental department, 2) the tube rotation of the OPG device, 3) the OPG beam collimation as relative to the anatomical position of critical organs, and 4) scattered radiation from OPG devices and phantom.

Based on Table 3, the left eye represented the highest recorded ESD as compared to the right eye and thyroid region with the mean ESD and standard deviation of -2.10 ± 0.0043 µGy. This study contradicted the findings by Moghadam et al. (2015), in which the right sided organs received the highest dose measurement as compared to the left sided organs when exposed to the digital OPG device due to the direction of the digital panoramic x-ray tube rotation, which was directed from left to right.

However, another study stated that different devices, especially OPG unit has their own pre-set of exposure setting based on each facility's standard. The exposure parameter in digital devices is believed to be much lower as compared to the analogue system due to the higher sensitivity of digital detectors in the system as compared to the film screen system in analogue devices (Signorelli et al., 2016 and Moudi et al., 2013). Therefore, the statement from both studies has supported the results produced in this study, as most of the average ESD values were relatively lower in the eyes and thyroid when exposed to the digital OPG Planmeca Promax 3D.

The slight fluctuation on the values presented in the constructed line graph for certain point in each of the critical organs' exposure (decreasing in ESD values on the right eye at 68 kVp and sudden ESD increment on the left eye at 62 kVp and thyroid at 64 kVp) was shown in Figure 4, 5, 6. It was assumed that this fluctuation in the ESD reading was observed due to the improper OSLD placement during the experiment. The nanoDot OSLD was positioned too far away from the thyroid region. As a result, this has caused the flaws while taking the dose measurement as there was not an actual dose counted during the measurement.

Figure 7 highlighted the comparison of ESD measurement for different critical organs (the right eye, left eye and thyroid) with the selected exposure factor setting based on the patient's body habitus/size criteria. From the overall result, the graph showed an increasing pattern in ESD measurements. The most highlighted positive values in ESD were recorded on the left eye using the exposure setting for body habitus/size criteria of the adult male and the large adult male with the standard preset values of 68 kVp and 70 kVp. The kVp was increased simultaneously with the tube current, mA as determine by the pre-set exposure value by dental department (refer Table 1). In diagnostic radiography, the ESD is proportional to factors such as the tube current, which control the quantity of number in x-ray production (Mortazavi et al., 2004). As ESD is a measurement of dose by the skin at the entrance point of the x-ray beam, both the tissue's backscattered radiation and the incident air kerma and also from the OPG device are included in the measurement. In this study, the phantom used is made up of various components with different material characteristics which resulted in the different scattered radiation energy production. Due to the increase in the tube potential (kVp) and mA, the scattered radiation produced during the OPG exposure was also higher. In brief, the scattered radiation was responsible for the dose measurement in the critical organs.

In this study, it can be observed that most of the values produced by the eyes and thyroid were relatively small (negative value) when applying the exposure factors on these criteria; children up to 6 years old, 7-12 years old and an adult female or small male. Despite the lower exposure setting were used on these criteria, the other reason of the lowest ESD measurement on critical organs was mainly due to the geometrical position of the beam vertical collimation in OPG device. This statement was supported by Tossi et al. (2010) where they stated that the eyes and thyroid locations were outside of the primary exposure as compared to the mandible, jaw and parotid glands. This resulted in the higher dose measurement on the parotid glands as compared to the dose measured by the eyes and thyroid. The recorded ESD for the eyes and thyroid were noted due to the scattered radiation from the materials and OPG equipment which yielded to these dose measurements on the critical organs.

The comparative result with other studies showed that the radiation doses in this research were not exceeding the doses measured by the other studies with the lowest doses measurement recorded in this research. The absorbed dose for both right and left eyes were the same; 0.11 ± 0.075 mGy while the recorded dose for the thyroid was 0.13 ± 0.079 mGy in the study conducted by Moudi et al. (2013). A study by Tossi et al. (2010) showed the negligible value on the absorbed dose for both eyes while the thyroid received higher dose as compared to this study and another study conducted by Moudi et al. (2013). However, as there is no establishment of the standard reference values or DRL for OPG in Malaysia, the results yielded on this study was still uncertain to provide the acceptable radiation dose to the critical organs.

Since this study was only based on the ESD measurement for the eyes and thyroid region, it does not have more informative value of the effective dose and the absorbed dose as compared to other studies. Therefore, not much relevant data or informative results can be obtained. However, as the ionizing effect of the radiation remains unclear, the dose optimization and ALARA concept are still relevant. Hence, there is the need to further investigate on the radiation dose received by the critical regions in the OPG.

Table 5 Organ doses results for critical organs in comparison with other studies

Organ doses	Entrance surface dose (μGy)	Absorbed Dose (mGy)	
		Moudi et al. (2013)	Tossi et al. (2010)
Right Eye	**-3.62 ± 0.0058 (Negligible)**	**0.11 ± 0.075**	**Negligible**
Left Eye	**-2.10 ± 0.0043 (Negligible)**	**0.11 ± 0.075**	**Negligible**
Thyroid	**-3.09 ± 0.0042 (Negligible)**	**0.13 ± 0.079**	**38**

CONCLUSION(S)

In conclusion, the recent digital OPG yielded lesser doses as shown by this study. Almost all the dose measurements on these critical organs showed the negative result, which was negligible. The recorded dose reading in this study was the lowest as compared to other previous study. The ESD values recorded were not exceeding the guidelines proposed by the National Radiological Protection Board's (NRPB) which was not more than the reference of 65 mGy mm for the standard adult panoramic radiograph using dose width product (DWP) and also below the dose limits recommended by the ICRP for equivalent dose of eye lens and the skin. There was also no significant difference marked on the doses received by the critical organs when varying the kVp.

In brief, despite the different parameter selections (tube potentials), other factors such as the scattered radiation, the types of OPG devices used and the tube rotation, the phantom and the nanoDot OSLD placement has resulted in major difference between the ESD measurements of the critical organs in this study as compared to other studies. In addition, the flaws were also observed in this study. Therefore, few recommendations need to be reconstructed for the future study. There should be a standard measurement for the placement of the OSLDs on the critical organs at the phantom as the precautionary step in order to reduce any errors and bias during practice. It is suggested that comparative studies should be conducted on various OPG devices using real subjects instead of phantom. Furthermore, as this study was primarily conducted in the dental department which utilized the use of OPG, it is hoped the findings could be used to create awareness to the dental practitioners and the radiographers regarding the radiation protection in adopting the ALARA and optimization concept for their future practice.

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