ORIGINAL ARTICLE

Skin Entrance Dose Assessment in Panoramic Radiography: A Local Diagnostic Reference Level

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Abstract

Purpose: The present study aimed to assess the Entrance Skin Doses (ESD) at the thyroid gland region and evaluate the local Diagnostic Reference Level (DRL) in panoramic radiography in a city (Yasuj, Iran).

Materials and Methods: In the current study, 31 patients (17 women and 14 men) with a mean age of 33.90±16.49 years were included. To assess the ESD values, 3 thermoluminescence dosimeters (TLD-100) were attached to the thyroid gland region for each patient. The DRLs were estimated as the third quartile of the ESD values. The ESD variations among the different genders (men and women), devices, and age groups (children [5-10 years], adolescents [11-19 years], and adults [>19 years]) were calculated. T-test, one-way ANOVA, and Bonferroni's post hoc test were used for parametric tests; Kruskal-Wallis and Spearman's correlation coefficient were used for the non-parametric tests.

Results: Mean ESD and DRL values were obtained at 72±21 µGy and 0.091±0.02 mGy, respectively. For ESDs, there was no significant difference between different genders (men: 76±20 µGy and women: 69±23 µGy) as well as among the three investigated devices (P-value> 0.05). The ESD values of children were significantly lower than adolescent and adult patients (P-value<0.001); however, there was no statistically significant difference between the adolescent and adult patients (P-value =0.057).

Conclusion: Compared to national/international, the DRL value in our study was relatively low; patient doses can be decreased in the panoramic examinations by increasing the knowledge of health workers of the radiation parameters, specifically operators.

Keywords: Diagnostic Reference Level; Entrance Skin Doses; Panoramic Radiography; Thyroid Gland; Yasuj City.

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1. Introduction

In modern dentistry, X-ray imaging has become an essential part of dental procedures. Panoramic radiography is a common diagnostic X-ray imaging technique in dental practice [1-3], which has lower ionizing radiation than other dental imaging modalities such as Cone-Beam Computed Tomography (CBCT) and fan-beam CT. However, the increasing use of panoramic images has raised concerns about the potential risk of radiation exposure to sensitive organs near the teeth, such as the thyroid [4]. The thyroid is a sensitive organ to ionizing radiation and should be protected in diagnostic and therapeutic procedures as much as possible. To manage this risk, the International Committee on Radiation Protection (ICRP) recommends measuring the dose of radiation delivered to different organs (especially radiosensitive organs) to estimate the potential biological effects and evaluate the risks of adverse effects such as radiation-induced cancers [5, 6]. Many studies, as well as national and international reports, expressed that there is a relationship between organ-absorbed doses and cancer incidence risk in radiological procedures [5, 7-11].

It is important to optimize the radiation dose during imaging to minimize radiation exposure while maintaining image quality [12]. Measuring the Entrance Skin Dose (ESD) in diagnostic radiology can help to obtain and establish dosimetric levels in various cities or countries [13]. These levels can be used as Diagnostic Reference Levels (DRLs) to be compared with the obtained values in other imaging centers, reassuring clinicians about the acceptable delivered dose to patients. ESD reflects the amount of radiation absorbed dose in the skin at the point of the X-ray beam entrance and can be measured directly by different dosimeters or indirectly by computer simulation or analytical calculations [14]. Factors such as tube current (mA), exposure time, tube peak voltage (kVp), filtration, collimation, and patient size influence ESD in diagnostic radiography [15]. These parameters can be used for indirect obtaining of ESD values through calculations. The ESD can be measured directly using Thermoluminescence Dosimeters (TLDs) or ionization chambers placed on the skin.

Evaluating and establishing valid DRL values in radiography procedures as guidelines can achieving an acceptable dose for every specific diagnosis procedure. Furthermore, knowing the amount of radiation dose delivered to organs can be used for better managing patient doses and raising awareness of radiation protection. There are several studies reporting the local DRL of thyroid ESD values in Iran [4, 16-19]; however, there are no nationwide established DRL values for X-ray diagnostic methods due to the lack of appropriate local data or large-scale studies. Since panoramic radiography is widely used in medical centers, it is necessary to evaluate the radiation dose delivered to radiosensitive organs. Therefore, the aim of the present work was to measure the ESD values of the thyroid gland region as well as obtain and establish the local DRL values in panoramic radiographic images executed in Yasuj city, Iran.

2. Materials and Methods

This cross-sectional study was conducted in 2020-2021 in three specialized busy dental imaging clinics in Yasuj city and approved by the National Ethics Committee (registration no: IR.YUMS.REC.1401.45). Thirty-one patients, including 17 women (54.8%) and 14 men (45.2%) with a mean age of 33.90±16.49 years, were assessed. The procedures were fully explained to the participants, and informed consent was obtained.

2.1. Panoramic Radiography

Three digital panoramic X-ray machines in three dental imaging centers with the following characteristics were assessed. The type of devices and radiation parameter ranges are depicted in Table 1. Total filtration for all devices was 2.8 mm, and the scan time was in the range of 15-18 seconds. Furthermore, the details of the exposure parameters for different age groups are presented in Table 2. The diagnostic value of all acquired images was assessed and approved by the experienced radiologists working in the centers.

Table 1. Type of devices and details of kVp and mAs (mean, SD, minimum, maximum, and third quartile) in each imaging center

Center		Mean±SD	Minimum-maximum	Third quartile		Mean±SD	Minimum-maximum	Third quartile
A (Vatech-A9, Hwaseong, South Korea)		70.1±0.9	67-73	71.6		117.6±7.2	92-135	120.4
B (Planmeca, Promax 3D max, Helsinki, Finland)	**kVp**	67.2±0.7	66-68	67.4	**mAs**	138.7±6.1	126.4-158	144.0
C (Vatech-A9, Hwaseong, South Korea)		70.5±1.1	67-73	71.8		115.3±6.6	95-130	118.6

Table 2. Details of kVp and mAs (mean, SD, minimum, maximum, and third quartile) in each patient age group

Patients' age (years)		Mean±SD	Minimum-maximum	Third quartile		Mean±SD	Minimum-maximum	Third quartile
5-10		68.1±0.8	66-69	69.1		98.5±5.8	92-110	103.3
11-19	**kVp**	70.2±0.8	68-72	71.0	**mAs**	122.7±5.9	95-135	127.1
> 19		71.2±1.0	68-73	71.9		135.5±6.7	110-158	141.8
All		70.2±0.9	67.5-71.8	71.0		123.0±6.2	101.1-139.7	128.4

2.2. TLD Calibration

Standard TLD-100 loose chips (3×3×0.9 mm^3) produced by Harshaw Company (Solon, OH, USA) were used to measure the ESD at the thyroid gland region. All the TLDs were heated at 400°C for 10 min and then cooled to 35°C for annealing. The TLDs were irradiated with an equal dose exposed from a radiology device with the kVp =70 kVp and mAs=100; and the responses of these TLDs were read out using the Harshaw-4500 TLD reader device. The ECC (element correction coefficient) values were obtained for each TLD using Equation 1. Readouts were performed at 240°C for 10 seconds and pre-heating at 135°C for 5-10 seconds in the TLD reader [20].

$$ECC\ i\ =\ TLD\ i\ /\ TLD\ (average) \quad (1)$$

For the TLD calibration and obtaining the TLD calibration curve, a calibrated Barracuda dosimeter (RTI Electronics, Sweden) was used as the reference dosimeter for measuring the delivered dose. In this regard, nine TLD chips in three plastic packs were exposed to doses of 550, 1554, and 4471 µGy by an X-ray machine, in which the radiation parameters were in the range of the panoramic radiography systems. Three TLD chips were also used for background radiation measurements. All of the exposed TLDs' corrected readings (based on the ECC values) were used to calculate the calibration curve [19].

2.3. ESD and DRL Values

Three TLDs, embedded in numbered plastic covers, were used to obtain the ESD values. In this regard, the TLD packs were attached to the skin of the thyroid gland region before the panoramic examination for each patient. After the panoramic imaging procedure, the TLDs were kept for 24 hours and then read with the TLD reader. The readouts were divided by the ECC and multiplied by the conversion factor obtained from the calibration curve to convert the reading to dose [21]. At last, the measured background dose was subtracted from the TLD doses, and the final value was considered as the ESD. The DRL values were calculated as the third quartile of the ESDs based on the ICRP 135 recommendation [6]. Figure 1a and Figure 1b show the TLD positions at the thyroid gland region and panoramic position for a patient, respectively.

2.4. Analysis

Descriptive statistics were expressed in the form of the frequency distribution table as mean, standard deviation, first quartile, third quartile, and percentages. The patients were divided based on their age (three groups), gender (men and women), as well

as various devices. ESD values in each group were compared with other groups to find the effect of gender, age, and type of devices on the ESD values.

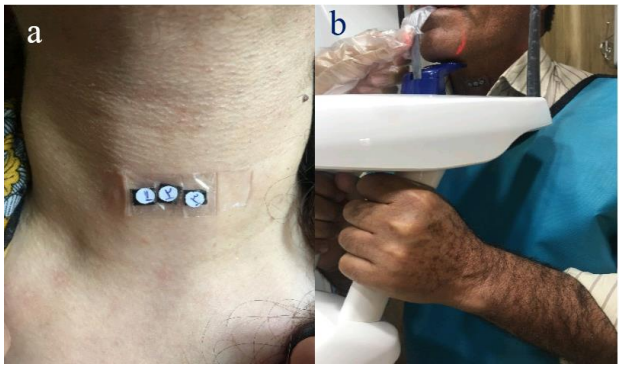

Figure 1. (a) TLD positions at the thyroid gland region and (b) panoramic position for a patient

First, the normality of the groups' data distributions was assessed using the Kruskal–Wallis statistical test. The sample T-test was used as the parametric test for comparing the ESD values of the two groups. The analysis of variance (ANOVA) statistical test, and Bonferroni's post hoc test, as well as the non-parametric analyses were conducted to find the significant differences in the ESD values among the groups. Furthermore, Spearman's correlation was used to find the correlation of ESDs with age. The statistical software package used in this study was SPSS (v. 25, IBM, USA), and the significance level was considered 0.05 for all the tests.

3. Results

The average of ESD values at the thyroid region was 72±21 μGy (ranging from 31-103 μGy). The independent t-test shows that there was no statistically significant difference between the ESD values obtained from men (76±20 μGy) and women (69±23 μGy).

The average and first quartile of measured ESD values and the calculated DRLs (third quartile of ESD) in the evaluated centers are presented in Table 3. The average ESD values measured at three dental imaging centers (A, B, and C) had no statistically significant differences (P-value>0.05).

The patients were divided into three groups based on their age, including children (5-10 years), adolescents (11-19 years), and adults (>19 years). The average and first quartile of measured ESD values, as well as calculated DRLs of the mentioned age groups, are depicted in Table 4. Bonferroni's post hoc test was used to determine significant differences in ESD values among various age groups. The ESD values of children were significantly lower than adolescent and adult patients (P-value<0.001). However, there was no statistically significant difference between the adolescent and adult patients (P-value =0.057), in which the average and first quartile of ESD values were lower in adolescents.

Table 5 illustrates Spearman's correlation coefficients (along with the significance levels) between the ESD values with kVp and mAs, in the

Table 3. Average, first quartile, and third quartile (DRL) of ESD values in the evaluated dental imaging centers

Dental imaging center	Average thyroid surface dose (mGy)	First quarter (mGy)	DRL (mGy)	SD	P-value*
A	0.075	0.059	0.83	0.019	0.65
B	0.075	0.059	0.087	0.019	
C	0.090	0.046	0.095	0.028	
All	0.072	0.057	0.091	0.022	

* The P-value shows the significant differences between the DRL values obtained from different imaging center groups

Table 4. Average, first quartile, and third quartile (DRL) of ESD values in patients divided into various age groups

Patients' Age (years)	Number	Average thyroid surface dose (mGy)	First quarter (mGy)	DRL (mGy)	SD	P-value*
5-10	7	0.038	0.032	0.044	0.007	<0.001
11-19	10	0.074	0.060	0.095	0.02	
> 19	14	0.083	0.076	0.092	0.011	
All	31	0.072	0.057	0.091	0.022	

* The P-value shows the significant differences between the DRL values obtained from different age groups

evaluated imaging centers. Spearman's correlation showed that in A and C imaging centers, there was a moderate relationship between ESD with kVp and mAs (R^2 ranged: 0.672-0.798). However, in center B, the related correlation between the values of ESD with kVp and mAs was very weak (R^2<0.1). In general, Spearman's correlation coefficient between the ESD values with kVp and mAs was 0.38 and 0.53, respectively, indicating a weak correlation between the surface dose and kVp/mAs values.

Table 5. The Spearman's correlation coefficient values between the ESDs with kVp and mAs in the evaluated imaging centers

Center	Spearman correlation coefficient (R^2)	Significance level (P-value)
	kVp	
A	0.693	0.018
B	0.087	0.810
C	0.672	0.033
All	0.376	0.037
	mAs	
A	0.672	0.023
B	0.087	0.810
C	0.798	0.006
All	0.531	0.002

4. Discussion

In the present study, thyroid surface dose was evaluated in panoramic examinations at different devices and genders with various age groups. The TLDs were used for estimating the ESD values due to several advantages such as small size, less sensitivity to changes in radiation energy, tissue-equivalent properties, reproducibility, and lower cost [22].

Due to the small difference in filtration thickness, there was no significant difference in ESD values among various devices. In a study, Ekpo *et al.* [23] concluded that additional radiation filtration (0.3 mm copper filter) reduced the patient's dose by about 37% without reducing image quality. Brosi *et al.* [24] assessed the effect of copper filters with thicknesses of 0.1, 0.2, and 0.3 mm on the surface dose, and the corresponding effective doses were measured at tube voltages of 60, 66, and 73 kV. It was observed that copper filters reduced the surface level dose by 25-32%, 32-39%, and 40-44%, respectively, and this range depends on the voltage of the corresponding tube. They also reported that copper filtration reduces the ESD and protects radiation-sensitive organs, but generally does not reduce the effective dose.

Due to the different anatomical structures in the children's group, there is a need to reduce radiation parameters for this group, so the surface dose to the thyroid was lower than in other age groups. In addition, the larger organ size in the adult group causes the lower distance from the X-ray source to the entrance point; as a result, the entrance dose would increase in this group [18]. In Zamani *et al.*'s study [18], thyroid and parotid gland surface absorption doses in the adult group were 60.6±7.3 µGy and 290±4.12 µGy, respectively. These values were 40.7±2 µGy and 189.3±11.5 µGy in the children group. They concluded that the higher ESD values in the adult group can be related to the use of higher radiation parameters. In Poppe's study [25], of dental panoramic devices were selected for four different standard programs: "adult", "adult male", "adult female", and "child". The recommended DRLs of Dose Area Product (DAP) were 101, 87, 84, and 75 mGy.cm², respectively, which was lower in children and higher in adult groups. Moudi *et al.* [16] concluded that the difference in the ESD was significant in the age group of 4-10 years and 10-40 years, as well as between the age group of 1-40 years and over 40 years. In line with our results, the average absorbed dose increased with increasing age.

Despite the low level of average ESD in women compared to men, there was no statistically significant difference. Women and men are different in terms of anatomical structure, bone thickness, and tissue volume in the face, which do not have obvious differences from each other. For this reason, the radiation parameters (kV and mAs) in the devices are almost the same for both sexes.

There was a statistically significant relationship between kVp and mAs with ESD values. These findings are consistent with the results of Gavala *et al.* [26] reporting that reducing the effective dose in digital panoramic radiography is possible if the lowest possible radiographic settings are used. However, Mortazavi *et al.* [17] expressed that there was no significant difference between the average ESD for radiographs performed at 66 kVp (0.072±0.019 mGy) and 68 kVp (0.070±0.016 mGy). Since the intensity of X-rays is directly proportional to mAs and the amount

of kVp, the higher the voltage, the more energy and penetration power of X-rays. In addition, based on the 15% low (by halving mAs per kV, only 15% should be added to the initial kV to obtain the same density), it can be concluded that by reducing the settings of digital panoramic radiography (reducing kVp and mAs), the average thyroid surface dose can be reduced.

The patients using the two devices (A and B) had lead aprons, and the patients using the C device did not use lead aprons and the results of the average thyroid ESD in three panoramic machines were not statistically significant, which was consistent with Rottke *et al.* [27] results. Hafizi *et al.* [4] showed that frontal lead shields and equivalent lead shields can reduce the thyroid dose by about 50% and 19%, respectively. It can be concluded that the shielding area is an important parameter in reducing thyroid gland dose. Lead frontal shields with large effective shielding areas are suitable for thyroid gland dose reduction during panoramic dental imaging. All current lead protective shields that are practically used for protecting the thyroid are ineffective against primary and scatter radiations because scatter radiation is from inside the body and cannot be prevented in any way [4]. The slight variation in the ESD values among the three panoramic devices can be related to the clinical settings, X-ray unit, and patient age.

The third quartile value of thyroid ESD was assessed as the local DRLs in the current study; however, most of the previous studies estimated the DRL values based on the third quartile of DAP median ($mGy.cm^2$) values [18, 28-31]. Based on the current result, the average value of local DRL was obtained at 0.091 mGy (91 µGy) for panoramic dental radiography. We compared our DRL values with other national/international values (assessed based on the ESD values), depicted in Table 6. Manousaridis *et al.* [32] assessed the DRL values for panoramic dental examinations in Greece. They have measured the DRLs for several panoramic systems using various patient types, including children, small adults (corresponding to females), and average adults (corresponding to males). Bahreyni and Akbari [33] obtained the DRL values based on the parotid ESD values using two TLDs from panoramic radiography. Naserpour *et al.* [34] estimated the ESDs and related DRL values for the lens of the eyes, thyroid, and parotid glands during dental panoramic radiography in Khorramabad, Iran, using TLD dosimeters. In general, the discrepancies between the DRLs with the other related studies can be due to various dosimeters, types of imaging systems, and radiation parameters (kVp and mAs).

In the current study, we tried to compare the ESD/DRL values for three high-load panoramic machines; however, wider-scale evaluations can be carried out for other machines/vendors and compared with CBCT examinations. Additionally, for future research, it is recommended to measure/establish the ESD/DRL values with larger sample sizes and use other dosimeters like DAP and film.

5. Conclusion

Our results demonstrated that there is a statistically significant relationship between kVp and mAs with ESD values. Due to the higher values of kVp and mAs, the ESDs of adolescent and adult patients were significantly higher than children's groups. Although our obtained DRL was relatively lower compared to the national/international values, patient dose (while maintaining acceptable image quality) can be

Table 6. The DRL values (mGy) based on ESD measurements for the current study and other national/international values

This study, Yasuj city, 2023		**Manousaridis *et al.*, 2015, Greece [31]**		**Bahreyni and Akbari, 2012, Khorasan province [32]**		**Naserpour *et al.*, 2019, Khorramabad, [33]**	
Age (years)	DRL (mGy)	Groups	DRL (mGy)	Patient characteristics	DRL (mGy)	Patient characteristics	DRL (mGy)
5-10	0.044	Children	2.2	150 adults, average 35 years and 69 kg	0.4	180 patients with an age range of 7-60 years	0.4
11-19	0.095	Small adults	3.3				
> 19	0.092	Average adults	4.1				
All	0.091	-	-				

decreased by increasing the knowledge of health workers of the radiation parameters, specifically operators.

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