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Entrance Surface Dose Measurement on the Thyroid Gland in Orthopantomography: The Need for Optimization

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ABSTRACT

Background: The anatomic position and proven radiosensitivity of the thyroid make it an organ of concern in dental X-ray examinations. A National Radiation Protection Department (NRPD)-sponsored pilot study carried out in the Dental Radiology Department of RUMS. To assess if the radiation dose in panoramic radiographies could be reduced without significant impairment of the subjective image quality, It is well-known that critical organs such as thyroid gland are exposed to X-rays in panoramic radiography and these exposures should be kept as little as reasonably achievable. To perform quality assurance and optimize the relationship between radiation dose and image quality, accurate dose measurements in diagnostic radiology procedures are necessary.

Materials and Methods: Thermoluminescent dosimetry (TLD) is widely acknowledged to be the recommended method for measuring entrance surface doses (ESD). In this study, ESD was measured using LiF thermoluminescent dosimeters (TLD-100) on the thyroid of 40 patients who had referred to the School of Dentistry, Rafsanjan University of Medical Sciences. Patients were not exposed to any additional radiation and the radiographs were used for diagnostic purposes. TLDs were calibrated with radiation energies similar to those commonly used in orthopantomography. The panoramic radiographies were performed using the PM 2002 CC unit. The patients' mean age was 29.53 years. Three TLD chips were placed on the thyroid of each patient. The doses were averaged for each radiography and mean ESD of all patients calculated.

Results: Two different tube voltages were applied (66 and 68 kVp). The overall mean ESD (both kVps, 6 mA, and 2.5 mm Al filtration) on the thyroid in orthopantomography was 0.071 ± 0.012 mGy (ranged from 0.01 to 0.40 mGy). The mean ESD for radiographies performed with 66 kVp (20 patients) and 68 kVp (20 patients) were 0.072 ± 0.019, and 0.070 ± 0.016 respectively. No statistically significant difference was found between these means.

Conclusions: Despite there is no published national report on the thyroid ESD in orthopantomography, the measured surface doses in our study are inconsistent with the only one already reported about the same experiment. However, due to lack of national diagnostic reference levels for orthopantomography, it is not clear whether in case of the PM 2002 CC unit used in this experiment, reducing the radiation dose to a level that still keeps a diagnostically acceptable image quality is necessary. We hope that similar nationwide studies are performed and the national reference levels for orthopantomography are set.

***Keywords:** Orthopantomography, OPG, panoramic radiography, entrance surface dose, thyroid.*

INTRODUCTION

Medical exposures are the most important source of public exposure to man-made radiation. In spite of the fact that several major dose surveys in diagnostic radiology have been performed in developed countries, in developing countries such basic

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information is still lacking. In level I countries there is a physician for less than 1000 persons. Although only 25% of the world population are living in level I countries, where about 70% of the diagnostic X-ray examinations are performed (Ng *et al.* 1998).

Patient dose measurement is widely considered as an important quality control tool in medical radiology. Quality Assurance (QA) in diagnostic radiology provides a satisfactory image quality with a reduction of patient dose (lowest achievable level). Entrance surface dose (ESD) and dose-area product (DAP) are the most important parameters measured in diagnostic radiology (Williams and Montgomery 2000). In dental radiographies, the thyroid gland is an organ of concern. This importance is due to the anatomic position and proven radiosensitivity of the thyroid (Bristow *et al.* 89). It has been reported that each one million full-mouth surveys (D-speed film with round collimation) may produce about 100 excess fatal cancers. It should be noted that for risk estimation, an excess case of cancer is considered as an extra death. The proportional frequencies for these 100 excess fatal cancers are thyroid cancers (40%), salivary gland cancers (39%), leukemias (13%), brain tumors (6%), and esophageal cancers (2%) (Bristow *et al.*1989). Leukaemias are usually observed as a wave from 5 to 30 years following exposure, while other cancers typically start to appear about 10 years following exposure and remain presumably for the lifetime. In dental radiography, the gonadal dose is so small and the risk of heritable defects is negligible (White 1992).

Since the introduction of the term "Diagnostic Reference Level (DRL)" by ICRP in 1996 (ICRP, 1996), there have been continuing worldwide efforts to develop and implement DRLs in diagnostic radiology as well as nuclear medicine. DRLs help avoid radiation dose to the patient that does not contribute in medical diagnosis. ICRP in its 1996 publication recommends that to set DRLs and identify unusually high exposure levels, the radiation quantity assessed should be easily measurable, such as absorbed dose in air or tissue equivalent material at the surface of a phantom or representative patient. A diagnostic reference level value of 7 mGy is proposed for intraoral radiographies by the International Atomic Energy Agency (IAEA), while no DRLs are proposed for panoramic radiographies (Gonzalez *et al.* 2001).

ESD is a measure of the absorbed dose by the skin at the entrance point of the X-ray beam. ESD measurement can be performed directly or indirectly. ESD in diagnostic radiography is proportional to factors such as the tube current, exposure time and the square of tube voltage (Parry *et al.* 2002). Thermoluminescent dosimeters (TLD) can be used for measuring ESD directly. Using ionization chambers and computing the dose indirectly is an alternative method. In diagnostic radiology, ESD depends on irradiation factors such as beam energy, tube current, exposure time, filtration, collimation, and patient size. It should be noted that the selection of a DRL using a percentile point on the observed distribution of dose for patients, should be specific to a country or region (ICRP 2002). However, in IR Iran, due to lack of large scale studies, no diagnostic reference levels have been set for X-ray diagnostic procedures.

Orthopantomography (OPG) is a favorite radiographic method for overall assessment of caries, periodontal disease, malocclusion and some of the other common dental disorders. The standard panoramic film in OPG depicts all bone detail well. According to the guidelines of the American Academy of Pediatric Dentistry, panoramic examination is an alternative to periapical radiography and is especially useful for the assessment of growth and development (Hayakawa *et al.* 2001). The absorbed dose from a full mouth survey (20 E-speed films with round collimation) has been reported to be 17 times greater than a panoramic radiograph (Miles *et al.* 1992).

It is well-known that dosimetry is an imp ortant part of quality assurance (QA) in diagnostic radiology. Thermoluminescent dosimetry, for its simplicity in clinical use, speed and being unobtrusive, is the recommended method for entrance dose measurements (Burke and Sutton 1997). TLD-100 (LiF:Mg, Ti) is the most commonly used thermoluminescent material for patient dosimetry (Burke and Sutton 1997). The minimum detectable dose (MDD) for TLD-100 is believed to be 50-100 µGy (reviewed in Burke and Sutton 1997). In the countries with advanced medical systems such as some European countries and the United States, guidelines for medical exposures have been set since many years ago and are clinically applied now (Hiramatsu and Koga 2001). In Iran, as many other developing countries, there is no guideline for medical exposures. The main purpose of this study was to assess the regional distribution of entrance surface doses (ESD) on the thyroid in panoramic radiographies and to assess if the radiation dose in panoramic radiographies could be reduced without significant impairment of the subjective image quality. We hope that similar nationwide studies are performed and the radiation exposure of the patients set under the levels proposed by the international authorities.

MATERIALS AND METHODES

Dosimetry

Measurement of dose on the skin on the thyroid gland was made using thermoluminescent dosimeters (TLD-100, Harshaw, USA) encapsulated individually in sealed plastic foils. The lithium-fluoride chips (LiF:Mg, Ti) were 0.85 mm thick, 3 mm diameter chips. Three chips were mounted on a tape and placed in the center of the X-ray beam on the skin of the patients. Therefore, backscatter radiation was included in the recorded surface dose. The recorded doses by these three chips were averaged for each radiography and the mean absorbed dose for each radiography calculated. The dosimeters were calibrated in SSDL laboratory, National Radiation Protection Department. In each experiment, two TLD chips were used to determine the background radiation. The thermoluminescent signal was read out with a Harshaw 4500 (Harshaw, Bicron, USA) reader.

Exposure factors

The patients were examined in the same department. All exposures made with a PM 2002 CC unit (Planmeca Oy, Helsinky, Finland). Two different tube voltages were used for panoramic radiography (66 and 68 kVp). The tube current, exposure time and total filtration were 6 mA, 18 s and 2.5 mm Al respectively. All patient imaging was performed as routine examinations and patients were no subjected to extra examinations or any increase in radiation dose.

RESULTS

A total of 40 patients were included in this study. Patient information and exposure parameters are summarized in Table 1. The overall mean (±SD) age of the patients was 29.52±13.19 years (34.77±5.22 years for males and 34.77±5.22 years for females). The difference between the mean age for males and females was not statistically significant. The purpose of OPG examinations was diagnostic (30%), surgical (30%), orthodontic (25%), and other purposes (15%). The overall mean (±SE) entrance surface dose of the

Table 1. Basic data on the age of the study participants, purpose of radiographic examination and tube voltage.

Basic Info.	Females (N=27)	Females (N=13)	Total (N=40)
Age (Mean±SD)	27±11.56	34.77±5.22	29.52±13.19
Purpose of Radiography			
▸ Diagnostic	29.6%	30.8%	30%
▸ Surgical	33.3%	23.1%	30%
▸ Orthodontic	25.9%	23.1%	25%
▸ Others	11.2%	23%	15%
Tube Voltage Used (Frequency)			
▸ 66 kVp	48.1%	76.9%	50%
▸ 68 kVp	51.9%	23.1%	50%

patients was 0.071±0.012. The distribution of ESDs measured on the thyroid glands of the study participants in OPG examinations is shown in Figure 1. No correlation was found between

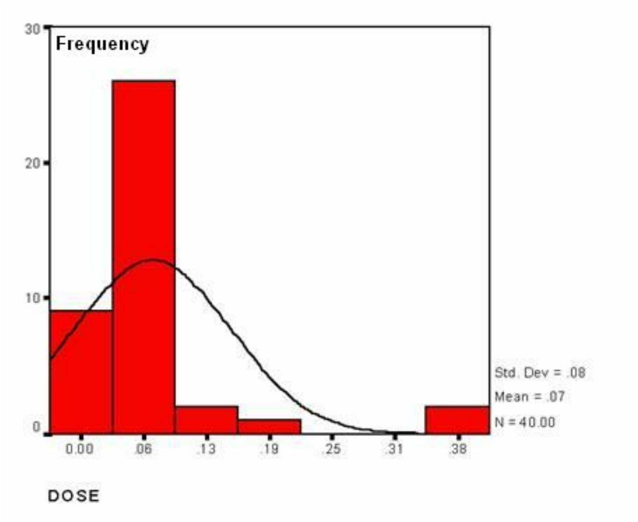

Figure 1. The distribution of ESDs measured on the thyroid glands of the study participants in OPG

the patients' age and ESD on the thyroid gland (Figure 2).

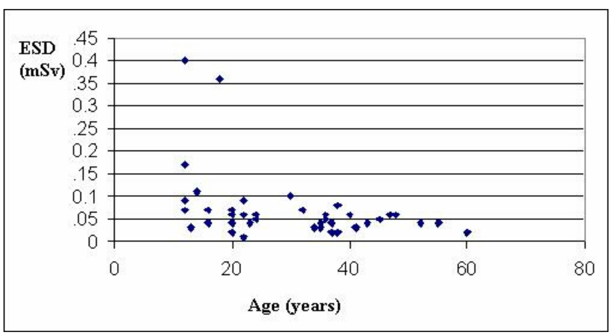

Figure 2. The correlation between patients' age and ESD on the thyroid in OPG.

As shown in Table 2, the mean ESD for panoramic radiographies performed with 66 kVp (50% of the patients) and 68 kVp (50% of the patients) were 0.072 ± 0.019 mGy, and 0.070 ± 0.016 mGy respectively. No statistically significant difference observed between the mean ESDs for radiographies performed with 66 and 68 kVp.

Table 2. Mean entrance surface doses (ESDs) measured on the thyroid gland in OPGs performed with 66 and 68 kVp.

Tube Voltage	No. of Patients (Percent)	Entrance Surface Dose on the Thyroid* (mGy)
66 kVp	20 (50%)	0.072±0.019
68 kVp	20 (50%)	0.070±0.016
Overall (Both kVps)	40 (100%)	0.071±0.012

* Mean±SE

DISCUSSION

X-rays are widely believed to cause malignancies, skin damage and other detrimental effects. The process of reaching a balance between radiation dose and image quality is called optimization (Geijer, 2001). Once installed, each OPG unit is adjusted so that the exposure factors (tube voltage and tube current) and film density are optimized (Williams and Montgomery 2000). Further optimization can be achieved by changing the X-ray beam quality or changing the sensitivity of the screen-film combination (Geijer, 2001).

The results obtained in this study indicate that optimization, as a main radiation protection principle, is not guaranteed in the OPG facility at the Dental Radiology Department of Rafsanjan University of Medical Sciences. Justification of actions, optimization of protection and dose limits for individuals are the main principles of the general radiation protection system (Ishiguchi, 2001). Justification simply means that in medical exposures, the benefits should exceed any possible harmful effect. Optimization means that medical exposures should be kept as low as can be rationally achieved. Therefore, standardization and optimization have been introduced both to reduce the patient exposure and to increase image quality (Almen *et al.* 2000).

When an OPG unit is installed, exposure parameters are adjusted so that the resultant film is optimized (Williams *et al.* 2000). However, dose measurement in routine radiographies, as a periodical or standard procedure, had been adopted in hospital practice (Yakoumakis *et al.* 2001). In studies on optimization, investigations involving real patient images (instead of using simple test objects or anthropomorphic phantoms) produced under clinical conditions are rare and also associated with numerous problems (Almen *et al.* 2000).

The overall results of this study indicate that exposure of the patients in the OPG facility at the Dental Radiology Department of Rafsanjan University of Medical Sciences exceeds the levels reported by the only other investigator who has conducted the same measurements (Diederichs *et al.* 1996). It may be concluded that the health physicists and radiologists at Rafsanjan University of Medical Sciences should conduct extended investigations for reducing the doses to lower levels.

Using the ICRP data, the highest estimated risks following intra-oral and panoramic radiography are for leukaemia (bone marrow), thyroid and bone surface cancer (White 1992). As far as we know, there is only one report on the ESD measurement on the thyroid gland at panoramic radiography. Diederichs *et al.* (1996) measured the skin entrance doses on the thyroid gland on the panoramic radiograph as well as on the combined mandibular and maxillary CT scan. The settings of their conventional panoramic radiograph were 75 kV, 8 mA and 15 seconds exposure time. The skin entrance doses at conventional panoramic radiography and CT for thyroid gland was less than 0.01 mGy. The higher skin entrance doses on the thyroid gland in our study is possibly due to lower tube voltage used in our study. As it was indicated before, in our study two different tube voltages were used for panoramic radiography (66 and 68 kVp). It has been widely reported that dose reduction in panoramic radiography can be achieved by increasing the tube voltage and lowering the tube current (Dannewitz *et al.* 2002). Dannewitz and his colleagues reported that the radiographs taken at reduced tube currents had a lower score for anatomical details. However, they stated that no difference in the scores for pathological findings was detected. It should be noted that increasing the kVp decreases the image contrast and decreasing the mA results in a decreased signal to noise ratio (Dannewitz *et al.* 2002).

Although we are unaware of any other published report on the thyroid ESD in panoramic radiography, there are at least two reports on thyroid dose in phantoms after performing a panoramic examination. Buch and Fensham (2003) recently measured the thyroid dose in orthopantomography. Using an Orthophos panoramic machine, a Toledo 654 TLD reader and a Rando female phantom, they placed the TLD chips in the region of the thyroid and a pantomogram was taken. The dose to the thyroid gland was found to be 0.0896 mSv that is higher than the Thyroid ESD measured in our study. Two years before this study, Hayakawa and his colleagues (2001) used the PM 2002 CC panoramic machine and a Rando phantom for thyroid dose measurement. They used the "adult" or "child" setting on the PM 2002 CC panoramic unit. According to their results, the thyroid dose for regular adult and paediatric exposure programs were 0.037-0.049 and 0.035-0.054 mGy respectively. As our study was only based on the measurement of entrance surface doses on the thyroid gland and the thyroid dose was not measured directly, comparing these data with our results would not be informative. However, the need for optimization of patient doses in pantomography seems to be inevitable.

CONCLUSION

The measured surface doses in our study exceed the doses reported by Diederichs *et al.* (1996). However, as in Iran there is no national DRLs for orthopantomography, it is not clear whether in case of the OPG system used in this experiment, reducing the radiation dose to a level that still provides a diagnostically acceptable image quality is necessary. It can be concluded that an extended study should be conducted to assess if the radiation dose with the panoramic PM 2002 CC system could be reduced without significant impairment of the subjective image quality.

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