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The need for national diagnostic reference levels: Entrance surface dose measurement in intraoral radiography

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ABSTRACT

Background: Intraoral radiographies are the most frequent X-ray examinations in humans. According to International Commission on Radiation Protection (ICRP) recommendations, the selection of a diagnostic reference level (DRL) should be specific to a country or region. Critical organs such as thyroid gland are exposed to X-rays in intraoral radiography and these exposures should be kept as low as reasonably achievable. To assist the development of DRLs for intraoral radiography, a National Radiation Protection Department-sponsored pilot study was carried out.
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 skin (either mandibular or maxillary arcs) of 40 patients. Three TLD chips were placed on the skin of each patient. The doses were averaged for each radiography and mean ESD of all patients calculated.
Results: The mean ± SD entrance surface dose at the center of the beam on the patients' skin in intraoral radiography was 1.173 ± 0.606 mGy (ranged from 0.01 to 0.40 mGy). The mean ESD for male and female patients were 1.380 ± 0.823, and 1.004 ± 0.258 respectively. No statistically significant difference was found between these means. Despite its necessity, in national level, there is no published data on the diagnostic reference levels for intraoral radiography. However, the results obtained in this study are lower than those reported by investigators in other countries.
Conclusion: In IR Iran, due to lack of large scale studies, no diagnostic reference levels have been set for X-ray diagnostic procedures. Due to lack of national diagnostic reference levels, it is not possible to clarify whether in intraoral radiographies any dose reduction techniques are needed. We intend to perform similar nationwide studies to set the diagnostic reference level for intraoral radiography. *Iran. J. Radiat. Res., 2004; 2 (3): 127-133*

Keywords: *Intraoral radiography, entrance surface dose, TLD.*

INTRODUCTION

Medical exposures are the most important source of public exposure to man-made radiation. It has been reported that dental radiology represents the most frequent diagnostic radiological examination in the industrialized world (Horner 1994) and intraoral radiographies are the most frequent X-ray examinations in humans (Kalinowski *et al.* 2001). In spite of the fact that several major dose surveys in diagnostic radiology have been performed in developed countries, in developing countries such basic information is still lacking. In level I countries, where there is one physician

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for less than 1000 persons (only 25% of the world population are living in level I countries), about 70% of the diagnostic X-ray examinations are performed (Ng *et al.* 1998).

Yakoumakis *et al.* (2001) recently reported that intraoral imaging techniques and film processing must be standardized to improve image quality and further reduce patient radiation doses. 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).

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 to 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 International Atomic Energy Agency (IAEA) (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, the square of tube voltage, filtration, collimation and patient size (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. 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 yet.

It is well-known that dosimetry is an important 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). The main purposes of this study were to measure the entrance surface doses (ESD) and to assist the development of regional DRLs for intraoral radiography. We hope that similar nationwide studies are performed and the implementation of the national DRLs be required by the National Radiation Protection Department, Iranian Nuclear Regulatory Authority.

MATERIALS AND METHODS

Dosimetry

Measurement of dose at the center of the beam on the patients' skin was made using thermoluminescent dosimeters (TLD-100, Harshaw, USA) encapsulated individually in sealed plastic foils (Mortazavi *et al.* 2004). 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 at the center of the X-ray beam on the patients' skin (figure 1). 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

Figure 1. Measurement of dose at the center of the beam on the patients' skin was made using 3 TLD-100 chips mounted on a tape and placed at the center of the X-ray beam on the patients' skin.

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 were made with a Heliodent 70 unit (Siemens, Germany). The tube voltage and tube current were fixed on 70 kVp and 7 mA by the manufacturer respectively. The exposure time ranged from 0.16 to 0.41 seconds for lower right first premolars, and upper left first molars, respectively. The total filtration was 2 mm Al. All patient imaging were performed as routine examinations and the patients were not subjected to extra examinations or any increase in radiation dose.

RESULTS

A total of 40 adult patients (22 females and 18 males) were included in this study. Patients' information and exposure parameters are summarized in table 1. The overall mean age of the patients was 30.62 years (30.72 years for females and 30.50 years for males). The difference between the mean age for males and females was not statistically significant. The purpose of intraoral radiographic examinations was diagnostic (37.1%), root treatment (32%), surgical (15%) and other purposes (15.9%). The overall mean (±SE) exposure time was 0.275±0.113 seconds (0.242±0.062 seconds for females, and 0.316±0.146 seconds for males). The difference between the mean exposure time for males and females was not statistically significant.

The distribution of ESDs measured at the center of the beam in intraoral examinations is shown in figure 2. As shown in table 2, the overall mean ESD (±SE) for intraoral radiographies was 1.173 mGy (1.004±0.055 mGy for females and 1.380±0.194 mGy for males).

Table 1. Basic data on the age of the study participants, purpose of radiographic examination (70 kVp and 7mA).

Basic Info.	Females (N=22)	Males (N=18)	Total (N=40)
Age (Mean±SD)	30.72±10.28	30.50±10.73	30.62±10.35
Purpose of Radiography			
• Diagnostic			37.1%
• Root Treatment			32%
• Surgical			15%
• Others			15.9%
Exposure Time	0.275±0.113	0.275±0.113	0.275±0.113

Table 2. Mean entrance surface doses (ESDs) measured at the center of the beam on the patients' skin in intraoral radiography.

Dose (mGy)	Females (N=22)	Males (N=18)	Total	P-Value
Overall Mean Entrance Surface Dose (Mean±SD)	1.004±0.055	1.380±0.194	1.173	0.077*
Areas • Molars of the Mandible • Molars of the Maxilla • Premolars of the Mandible • Premolars of the Maxilla • Incisors and canines of the Mandible • Incisors and canines of the Maxilla				0.032**
Purpose of Radiography • Diagnostic (37.1%) • Root treatment (32%) • Surgical (15%) • Other purposes (15.9%)			1.52 (Max) 0.78 (Min)	0.05***

* Using student's t-test mean ESD in males are compared to that of males.

** Using ANOVA mean ESD in different radiographic areas are compared.

*** Using ANOVA mean ESD in different radiographic purposes are compared.

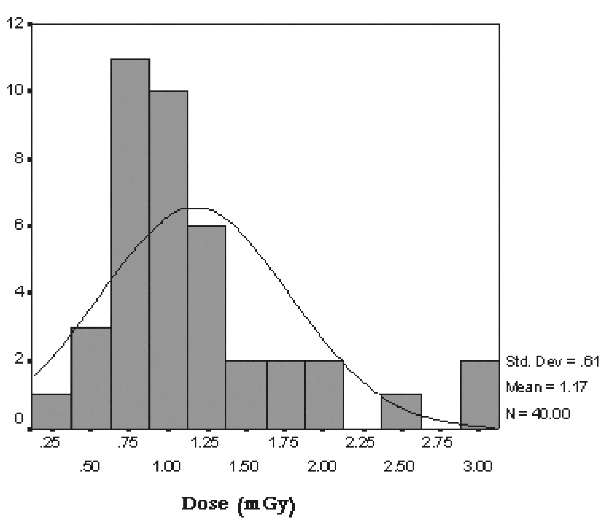

Figure 2. The distribution of ESDs (mGy) measured at the center of the beam on the patients' skin in intraoral radiography.

Again, the difference between the mean ESD for males and females was not statistically significant.

The mean ESD (±SE) for molar teeth was 1.028±0.142 mGy. The highest and the lowest ESDs were 1.52 mGy and 0.78 mGy for radiographies performed for diagnostic purposes and restorative purposes respectively.

The highest ESDs were measured on the upper right (1.53 mGy) and left (1.89 mGy) first molars. On the other hand, the lowest ESDs were measured on the upper right first premolars (0.01 mGy). The Pearson correlation test showed a statistically significant positive correlation between the exposure time and ESD (r=0.823). Radiographic areas were divided into 6 areas as follows:

1. Molars of the Mandible
2. Molars of the Maxilla
3. Premolars of the Mandible
4. Premolars of the Maxilla
5. Incisors and canines of the Mandible
6. Incisors and canines of the Maxilla

Using ANOVA test, a statistically significant difference among the ESDs in these 6 areas were found ($P<0.05$).

DISCUSSION

Gonzalez *et al.* (2001) using thermoluminescent dosimeters, collected data from over 300 intraoral X-ray facilities. They proposed a provisional local reference level of 3.5 mGy entrance surface dose for intraoral radiology. Later, Yakoumakis *et al.* (2001) gathered radiographic images of a dental image quality test tool which were obtained in 108 dental practices. Their results for intraoral radiography showed that the mean entrance surface dose for imaging the phantom was 3.8 mGy. They concluded that intraoral imaging techniques and film processing must be standardized to improve image quality and further reduce patient radiation doses. As shown in figure 2, the distribution of ESDs (mGy) measured at the center of the beam on the patients' skin in intraoral radiography ranged from 0.01 to 0.40 mGy.

The overall results of this study indicate that exposure of the patients at the Dental Radiology Department of Rafsanjan University of Medical Sciences does not exceed the levels either reported by Gonzalez or Yakoumakis. As it was indicated before, IAEA has proposed a diagnostic reference level value of 7 mGy for intraoral radiographies (Gonzalez *et al.* 2001). It may be concluded that the health physicists at Rafsanjan University of Medical Sciences do not need to conduct any urgent intervention for reducing the doses to lower levels.

X-rays are widely believed to cause malignancies, skin damage and other detrimental effects. Radiation induced cancer is widely believed to be a dose dependent phenomenon. The process of reaching a balance between radiation dose and image quality is called optimization (Geijer 2001). When installed, dental radiography units are adjusted so that the exposure factors (tube voltage and tube current) and film density are optimized. Further, optimization can be achieved by changing the X-ray beam quality or changing the sensitivity of the screen-film combination (Geijer 2001).

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). The results obtained in this study indicate that optimization, as a main radiation protection principle is well guaranteed in the intraoral facilities 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 a dental radiography unit is installed, exposure parameters are adjusted so that the resultant film is optimized. However, dose measurement in routine radiographies, as a periodical or standard procedure, has 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 are associated with numerous problems (Almen *et al.* 2000).

CONCLUSION

As a general rule, radiation dose should be reduced whenever it can be performed without significant impairment of the subjective image quality. In spite of the fact that there are still no national diagnostic reference levels for intraoral radiographies, when our results are compared to the levels proposed by IAEA or other investigators, there is no need for urgent interventions for dose reduction in intraoral radiography. However, due to necessity of using national reference levels for radiation protection purposes, making any decision regarding the need for optimization seems to be questionable.

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