Radiation Exposure to Critical Organs in Panoramic Dental Examination

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Abstract- Nowadays, radiography is a necessary procedure in diagnosis and treatment of patients with dental problems. According to the ALARA (as low as reasonably achievable) principle, dentists must take radiographs of sufficient quality at the lowest possible radiation dose to the patients. The assessment of patient dose on panoramic radiography is difficult because of dynamic nature of the imaging process and the narrow width of the x-ray beam. The present work describes an experiment undertaken using thermoluminescence dosimeters (TLD-100) to obtain the absorbed dose in organs and sensitive tissues in head and neck region during panoramic radiography, based on patient measurement. The overall mean entrance surface dose on thyroid, right and left lens of eyes, parotid glands (right and left) and occipital region in panoramic were 38, negligible, negligible, 367, 319 and 262 μGy, respectively. The results show that there are differences between patient doses examined by different panoramic systems. There is a tendency for lower organ doses for digital compared with analogue panoramic units.

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Introduction

Since the discovery of x-rays in 1895, x-rays have been widely used as the most important and reliable scientific tool for effective proper diagnosis of diseases as well as assessing the results of a given treatment to patients. More than a third or half of all crucial medical decisions are dependent on x-ray diagnosis and early diagnosis of some disease depends completely upon x-ray examination. The fact that diagnostic procedures are responsible for maximum population dose arising from man-made sources cannot be ignored. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports that the contribution of the radiation dose due to all diagnostic procedures is 80-90% of the total dose due to man-made radiation sources (1). According to UNSCEAR 2000 Report, dental radiography is one of the most frequent types of radiological procedures performed (2).

Panoramic dental tomography is a successful technique, used by several professionals, such as radiologist, orthodontist and maxillofacial surgeons, for the diagnosis of dental diseases. The equipments used for these procedures are characterized by the fact that the tube and the cassette holder are mobile, so they rotate from one side of the patient's head around his back to the other side. During this motion the film cassette moves in a synchronic way producing a two-dimensional image of the entire curved jaw with orthogonal projections of the teeth. The x-ray beam is very narrow horizontally and it reaches the collimator passing through the vertical slit of the cassette holder. One of the many advantages reported for panoramic radiography is reduction of the radiation dose as a result of the use of a fluorescent intensifying screen or film combinations and machine technology (3).

Although the radiation risk is generally low, we know about of the delayed somatic effects of low doses of x radiation. Dental radiographs mean an increased risk for induction of parotid tumors or thyroid cancer (4). Several methods have been proposed for assessing patient dose in panoramic dental radiography. In previous studies doses measured in phantoms or following hybrid procedures using patients and phantoms (3-6). In particular, measurements performed on patients are scarce.

Generally, the entrance skin doses in different projections are measured, and the best way to measure

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them is by using a thermoluminescence dosimeter (TLD). TLD-100 (LiF:Mg,Ti) is the most commonly used thermoluminescent material for patient dosimetry (7).

The concept of diagnostic reference levels (DRL) has assumed an important place in recent years in the management of radiation doses delivered to a patient in diagnostic radiology. International Commission on Radiological Protection (ICRP) in publication 73 has adopted the concept of "diagnostic reference level" and recommends that it should be selected by professional medical bodies, reviewed at intervals representing a compromise between the necessary stability and the long-term changes in observed dose distributions, and be specific to a country (NDRL) or a region (LDRL) (8). In Iran, as many other developing countries, there is no guideline for medical exposures. The main purpose of this study is an attempt for the first time to evaluate DRL for panoramic examination in Mashhad.

Materials and Methods

To measure the absorbed dose, LiF:Mg,Ti thermoluminescence dosimeter (TLD-100) with dimensions of 3 × 3 × 1 mm were used. The TLDs were annealed at 400 °C for 1 hour followed by a treatment at 75°C for 18 hour in an air oven. Afterwards, the TLDs were cooled down to room temperature. Each single TLD has to be calibrated individually in order to indicate the absorbed dose in microgray (μGy). Calibration was performed by exposing TLDs to diagnostic x-ray energy (70 kVp), used in dental panoramic radiography, that is TLDs were calibrated against a known exposure measured by a 6 cm ion chamber and Radcal monitor (model 9015). All TLD-100 belonged to one batch and they were characterized individually. TLD chips were placed inside plastic sachets and were used in pairs to reduce uncertainties in measurements. The sachets were placed on thyroid gland, left and right parotid glands, occipital region and eye lids. Two additional TLD chips were used to determine the background radiation. After 24h irradiated TLDs were read in a manual TLD Reader (Harshaw TLD reader model 3500). The reading out was performed with WinREMS software. The more energy a TLD is absorbing during the procedure, the more photons would emit during heating. Prior to every measurement, the TLDs were annealed.

In this study six panoramic systems in six radiology centers were studied. Two units of them were equipped with computer radiography. Computer radiography in our study operated with PSP method of panoramic digital imaging.

A sample of at least 15 patients per x-ray unit was chosen. In each examination, information about patient and panoramic parameters were collected such as: age, weight, peak voltage (kVp) and exposure setting (mAs). The patients mean age and weight were 35 years and 69 kg. A total of 800 TLD were read in this study. Mean value of absorbed dose by two TLDs placed on the skin surface of patients at the point of interest was obtained. Quality control tests were performed on individual panoramic machines: accuracy of kilovoltage, accuracy of timer controls, exposure consistency according to radiation guideline reference (9). For Quality control tests an UNFORS Mult-O-Meter (model 512-L, Sweden) was used. This detector was attached to the front side of the secondary collimator parallel to the slit.

Results

Measurement of parameters

Accuracy of kilovoltage: The kVp of each panoramic unit was within ±5 kVp of the indicated value measured. The coefficients of variation of at least five consecutive measurements at the same kVp setting did not exceed 0.02.

Accuracy of timer controls: For each panoramic system, measured exposure time was within ± 10% of indicated time. The coefficient of variation of at least five consecutive measurements at the same timer setting did not exceed 0.05.

Exposure consistency: All apparatus produced a consistent radiation output so that the coefficient of variation at least five consecutive measurements at the same control setting were less than 0.05.

Measurement of organ doses

Table 1 and 2 summarize results obtained for panoramic units in use in this study. Table 1 shows technical parameters of panoramic systems used in this work. Mean ESDs, the highest and the lowest dose values are given in Table 2.

Table 1. Technical parameters of the panoramic equipment.

Center	kV rang	mA range	Time (s)
A	66-70	6-8	18
B*	64-66	4-5	18
C*	64-68	12-14	16
D	64-66	5-6	18
E	60-68	4-8	18
F	68-72	6-9	16

* B and C are equipped by CR systems

Table 2. Mean skin dose measurements (μGy).

Organ	Mean ESD	Highest dose	Highest dose
Left eye	Negligible	-	-
Right eye	Negligible	-	-
Thyroid	38	47	21
Left parotid	319	358	296
Right parotid	367	432	330
Occipital	262	300	208

Discussion

Radiation doses to sensitive head and neck organs have been investigated in many studies. Different panoramic machines and different radiographic techniques are practiced. The reason for such studies is the existence of sensitive organs such as bone marrow, thyroid gland, salivary glands, brain and eye lenses close to radiation field.

Nearly 85% of the cumulative parotid dose from diagnostic radiography is caused by dental x-ray examination (4). According to the national research council's BEIR V committee, thyroid cancer is well established as a late consequence of exposure to ionizing radiation from both external and internal sources (10). Exposure to ionizing radiation will increase the risk of thyroid cancer, and 10% of people with thyroid cancer will die. A significant reduction (15-30%) of absorbed dose to the thyroid gland was obtained using smaller field size in panoramic radiography (11).

A significant external cause of spontaneous posterior subcapsular cataract (PSC) is ionizing radiation by x-ray and by neutron radiation. Chronic exposure to low x-ray dosage has also been implicated (12).

According to Table 2, there are differences in absorbed doses of the same organ arising from different units. It might be due to different parameters used by the individual dentists or due to differences in the units themselves, tube film distance, beam directions, or scanning motion. Kaeppler *et al.* investigated influence of the rotation center in panoramic radiography with two different types of panoramic systems (4). They found that the higher organ doses for Scanora and the high dose at the start and end of taking the radiograph resulted from the curve of the rotation center and the beam geometry with a higher density and higher exposure of the parotid gland, temporomandibular joint, mouth floor and pituitary gland. In the literature the Scanora layer is wider than the Orthophos layer. A greater layer thickness certainly meant a larger zone of sharpness but also resulted in higher organ doses, according to the Kaeppler *et al.* study. These parameters could be investigated in future studies.

In the present work the lowest doses belonged to center B. In this center, conventional film processing had been replaced by computed radiography. Digital radiographs can be obtained using phosphor storage plate (PSP) (semi-direct digital systems) or charged couple device-CCD sensors (direct digital systems). Particularly semi-direct digital systems use PSP to capture the radiographic information, while direct digital systems use a CCD sensor (13). This method is very similar to conventional film. The film and intensifying screen are replaced by a storage phosphor plate. The plate is scanned after exposure, which can take up to 3 minutes or longer depending on the product used. Digital imaging has several advantages such as speed, image manipulation, quality, archiving, access to patient records and the absence of chemicals. Due to these advantages lower mAs is used and a reduction in radiation is expected (13).

An interesting point which can be seen when comparing different centers is that center C was equipped by CR system but no reduction in dose was observed, even in some cases the highest received dose belonged to this center. This may be due to incorrect use of CR and the implementation of high mAs.

Our analysis of comparison of absorbed dose induced by different units show the fact that different dentists have their own preferred contrast for film to be diagnostically acceptable. However, lower voltage must be accompanied by longer exposure time to get enough radiation onto the image receptor that in turn increases the patient exposure.

Beside mAs and kVp, various factors are dealt with panoramic dose. The exposure increases with collimator width, and decreases with respect to three geometric factors related to the equipment and the anatomy of patient: point of measurement, center of rotation distance, tube angular velocity and radius of curvature.

Figure 1 shows a diagram of beam vertical collimation. Light-shaded area covered by primary beam. Note that eye and thyroid are outside the area of primary exposure.

According to this study, absorbed dose was highest in the region of the parotid glands, which were always along two lateral axes of rotation. Dose received by thyroid gland, mainly due to scattered radiation, is comparably less than the dose received by the parotid glands.

Table 3. Sensitive organ doses (µGy) as obtained in this study and similar results reported by other researchers.

Organs	This work	Kaeppler *et al.* (4)	Gonzalez *et al.* (15)	Melgar *et al.* (5)	Bartolota e*t al.* (14)
Eye	N*	18	-	7	1-14
Thyroid	38	62	-	63	13-37
Parotid	343	1181	-	-	90-314
Occipital region	267	-	530	348	-

N *: negligible

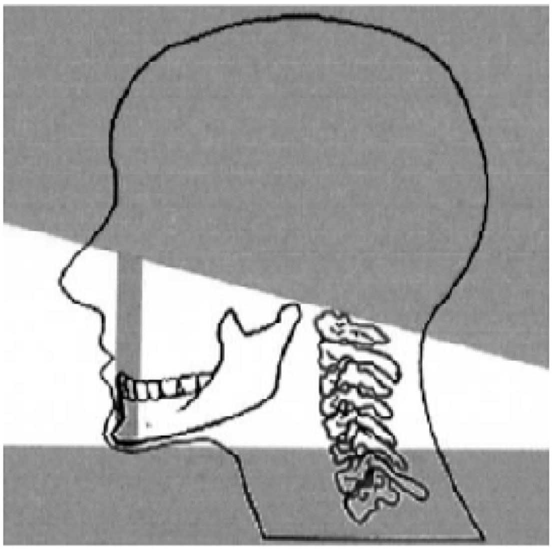

Figure 1. Diagram of beam vertical collimation.

On the other hands, the thyroid gland is one of the most radiosensitive organs and dose imparted in the thyroid gland should be minimized whenever possible. Dosimeters placed on the eyes received no measurable dose. The mean dose measured in the occipital region is one of the highest entrance surface doses to be measured along the x-ray beam trajectory because of reduced scanning speed to avoid a shadow produced by the cervical spine. Several studies have been performed to estimate organ doses, arising from different location of dosimeters and different kinds of panoramic machines yielded different results. In Table 3 some of these results are presented.

Our results show that in some cases dose values are lower than those proposed in other papers. Multiple causes can produce these variations: irradiation geometry, imaging equipments and type of techniques applied, positioning and accuracy of TLD measurements, positioning of patients, etc. unfortunately there are not details in literatures (Table 4). Therefore we are not led to a particular conclusion. Future works includes influence of these factors on patient's dose.

In only similar work on establishment of DRL on basis of patient dosimetry, Gonzalez *et al*. reported that maximum dose in panoramic is received by occipital and measured DRL in Madrid for that region (15). But in the present study, highest dose was yielded for parotid and therefore the establishment of DRL for panoramic in parotid glands is recommended.

As in Iran so far NDRL (National Diagnostic Reference Level) for panoramic has not yet been established, we are not able to make any judgment weather the induced doses to patients in this study are how close or far from an acceptable value (NDRL). We hope results of this work when completed will be useful locally.

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Table 4. Comparison of technical parameters of the panoramic equipment with other studies.

	This work	Kaeppler *et al.* (4)	Gonzalez *et al.* (15)	Melgar *et al.* (5)	Bartalota *et al.* (14)
kVp	63.3	66	Not available	74	75.6
mAs	123.5	*	Not available	120	188

* : mA=16

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