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Original Article

Diagnostic Reference Level Arising from Dental Panoramic Radiography

Mohammad Taghi Bahreyni Toossi[1]*, Fateme Akbari[1]

Abstract

Introduction
The present work describes a study in which, based on patient dose measurements, thermoluminescent dosimeters were used to obtain the diagnostic reference level arising from panoramic radiography.
Materials and Methods
Ten panoramic units and a sample of 15 patients per X-ray unit were studied. Two thermoluminescent dosimeter chips were placed on the skin surface of selected organs. Mean value of two ESDs was taken as the measured representation dose at the point of interest.
Results
Mean ESD on parotid glands derived from panoramic radiography was equal to 369.2 µGy. Individual patients' dose value varied from 180.1 to 470.3 µGy.
Conclusion
Third quartile of mean absorbed dose distribution arising from a particular examination has been adopted as diagnostic reference level. Based on this definition, local diagnostic reference level arising from panoramic radiography of the greater Khorasan province is equal to 400 µG.

Keywords: Diagnostic Reference Level, Iran, Panoramic Radiography, Thermoluminescent Dosimetry

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1- Medical Physics Department, Medical Physics Research Center, Mashhad University of Medical Sciences, Mashhad, Iran.
*Corresponding author: Tel: +98 511 8828576; Fax: +98 511 8002320; Email: bahreynimt@mums.ac.ir

1. Introduction

In 1990, in a joint document by the Royal College of Radiologists (RCR) and the National Radiological Protection Board (NRPB) entitled: "Patient Dose Reduction in Diagnostic Radiology", authors recommended using third quartile of the mean Entrance Surface Dose (ESD) distribution observed for a particular examination on a representative sample of patients at each center as “reference doses” [1].

The purpose of the reference dose is to initiate the first step of a series of actions which if performed step by step. Would lead to optimization of patient dose. It will also help to identify those practices which urgently need investigation and remedial actions. However, it has been emphasized that to be just below the "reference dose" is not necessarily an indication of optimum performance, but for further improvement of local practice, it may help to establish local dose audit standards lower than national reference doses, based on local dose distributions [2, 3].

ICRP in publication 73 has also adopted the concept of "Diagnostic Reference Level (DRL)" 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 country-specific as a National Diagnostic Reference Level (NDRL) or a region as Local Diagnostic Reference Level (LDRL) [4].

According to the UNSCEAR 2000 report [5], dental radiography is one of the most frequent types of radiological procedures performed. Panoramic radiology is a well-established imaging technique used in dental diagnosis.

Evaluating a dose for a panoramic dental X-ray unit is difficult, as it is necessary to integrate the dose from the exposure over the period in which a well-collimated X-ray beam moves around the head. This is measured in terms of the dose of the X-ray beam multiplied by the beam width or “Dose-Width Product (DWP)”. The DWP can be determined from the beam characteristics at the receiving slit measured over one rotation, either by a small detector that can be placed at the centre of the X-ray beam, multiplied by the beam width, measured by film, Thermoluminescent Dosimeter (TLD) array, or using an ionization chamber attached perpendicular to the slit [6, 14].

Previously, ESD has been measured by phantoms [7-12] or by hybrid procedures, i.e., patients and phantoms [13]. Very few measurements have been reported solely by patients [13].

In the UK, rather than measuring the actual patients’ dose at a given skin locations, it is an accepted practice to measure the DWP of the film for the whole panoramic exposure time and for an average adult machine setting, by a dosimeter and film. This method has been adopted by several authors [14-17]. It can also be multiplied by the height of the X-ray beam at the receiving slit to derive the Dose Area Product (DAP) [3]. This method provides information that is independent of geometry, but it is difficult to be correlated with skin dose owing to the beam movement.

In Iran [18], reference levels for conventional radiological examinations have been reported in 2008, but dental radiological facilities have not yet been investigated.

The present study is the first attempt to establish panoramic DRL in Iran (limited to Khorasan province). It will provide guidance on where efforts on dose reduction need to be directed to fulfill the requirements of the optimization process and will serve as a reference for future works. It also provides information for comparing patients of the same category in other countries.

2. Materials and Methods

2.1. Description of the equipment

In this study, TLD-100 (LiF: Mg, Ti) with dimensions of 3×3×1 mm, programmable electrical oven for thermal treatment to TLDs, Harshaw 3500 TLD reader with associated software, conventional diagnostic X-ray system for calibration of TLDs, quality control equipment machines (UNFORS Mult-O-Meter model 303 and model 512-L), and RADCAL monitor (model 9015) with a 6 cm^3 ionization chamber (RADCAL Model 10X5-6) were employed for patient dosimetry.

2.2. Description of the method

2.2.1. Selection of systems and patients

In greater Khorasan province, there are 31 panoramic systems stationed in 29 dental radiology centers from which 9 centers were selected according to the statistical procedure. One of them was equipped with 2 panoramic units. PASS statistical software was employed for sample size determination [19]. Measurements were performed on all adult patients who were referred to these centers. The mean age and weight of 150 adult patients were 35 years and 69 kg, respectively.

2.2.2. Dosimetric systems

Patient doses were measured with TLDs. They were calibrated individually in order to provide the absorbed dose in miligray. 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.

The calibration method recommended by the NRPB was used in this work [20]. They were later read by a Harshaw 3500 TLD Reader.

2.2.3. Patient dosimetry

A plastic sachet holding two TLD chips was placed on the parotid glands and occipital region parallel to the posterior cerebral fossa on the occlusal plane. TLD chips were used in pairs to reduce uncertainties in dose measurements. Mean value of the two ESDs was taken as the measured representative dose at the point of interest. Accuracy of TLD measurements was 7%.

3. Results

The results of dose measurements on four different locations of the head and neck region of 108 patients who were radiographed in 9 different centers (10 machines) are summarized and presented in Table 1. Table 2 shows technical parameters of the panoramic equipment investigated in this study.

A mean surface dose value of 369.2 µGy was obtained for parotid glands and individual values varied between 180.1 and 470.3 µGy. Median dose was equal to 350 µGy and the third quartile was equal to 400 µGy. Although occipital dose was relatively high, in most cases it was smaller than the parotid dose. Dosimeters placed on the thyroid received no measurable dose. Dose received by the thyroid gland, mainly due to scattered radiation, was comparably less than those received by the parotid glands and occipital region. For a better presentation, these values are plotted and shown in Figure 1.

Mean values of kVp and mAs used in this study are presented in Figures 2 and 3.

Table 1. Mean absorbed doses of parotid, occipital and thyroid (µGy)

Machine No.	Parotid Glands	Occipital Region	Thyroid
1	470.3±36.4	381.3±16.2	N*
2	180.1±17.5	319.5±10.6	N*
3	317.6±29.7	267.5±11.7	N*
4	294.9±13.4	237.5±9.9	N*
5	309.1±25.0	321.7±23.7	N*
6	350.2±15.8	300.7±32.7	N*
7	398.8±19.0	344.2±18.5	N*
8	360.0±18.3	251.2±11.0	N*
9	354.8±17.7	263.3±10.8	N*
10	405.0±11.2	415.8±17.4	N*

N*: Negligible

Table 2. Technical parameters of the panoramic equipment investigated.

No.	Panoramic Machine	Manufacturer	Year of Installation	Total Filtration	Analog/Digital
1	Orthophos	Siemens - Germany	2000	2.5 mmAl	Analog
2	PM2002CC proline	Planmeca - Finland	2002	2.5 mmAl	Digital*
3	Promax	Planmeca - Finland	2008	2.5 mmAl	Analog
4	Promax	Planmeca - Finland	2008	2.5 mmAl	Analog
5	Promax	Planmeca - Finland	2006	2.5 mmAl	Analog
6	Proline XC	Planmeca - Finland	2008	2.5 mmAl	Digital*
7	Proline XC	Planmeca - Finland	2005	2.5 mmAl	Analog
8	Proline XC	Planmeca - Finland	2002	2.5 mmAl	Analog
9	Promax	Planmeca - Finland	2006	2.5 mmAl	Analog
10	Promax	Planmeca - Finland	2005	2.5 mmAl	Analog

*: indirect digital radiography

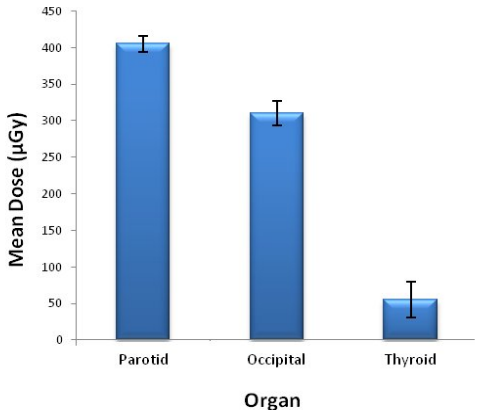

Figure 1. Mean doses of critical organs of patients.

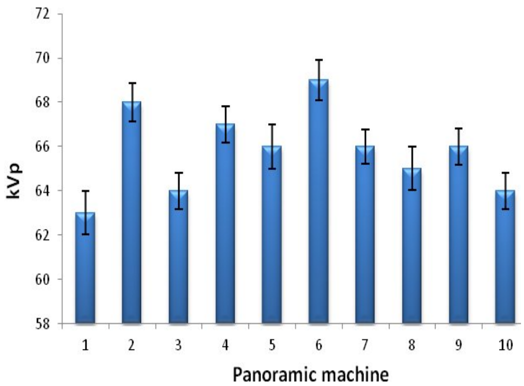

Figure 2. Mean values of kVp used in this study.

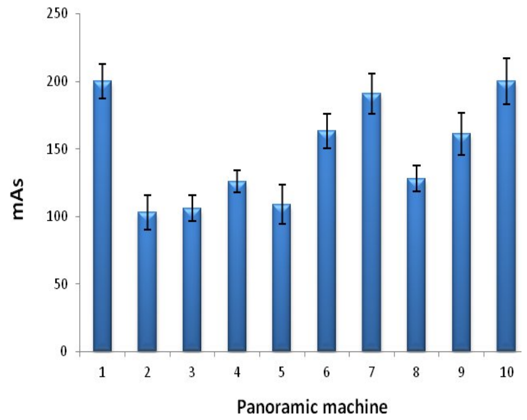

Figure 3. Mean values of mAs used in this study.

4. Discussion

The mean dose measured in the occipital region is one of the highest ESDs along the X-ray beam trajectory, since when scanning this area, the scanning speed will be reduced to avoid a shadow produced by the cervical spine. Dose received by thyroid is comparably less than the doses received at the occipital region and parotid glands because they are out of the primary beam.

Absorbed dose is highest in the region of the parotid glands, which are always along the two lateral axes of rotation. This is in agreement with Looe report [21]. Looe et al. showed that the salivary gland is exposed to a high dose in most cases which is due to its anatomical position scince the parotid gland is located directly above the maxilla and the mandibular gland below the mandible [21]. Because the statistical uncertainties of TLD processing is decreased when higher dose values are measured and because parotid glands are among the organs at risk in dental radiology, the parotid glands have been considered to be the most suitable organ/region in which DRL is established.

According to Table 1, mean absorbed dose of parotid glands in center No. 1 (470.3 μGy) exceeded the suggested reference (400 μGy). It may be concluded that center No. 1 should conduct further investigations to reduce the patient's dose to a lower level perhaps by increasing the tube voltage and lowering the tube current (see Figures 2 and 3).

Besides mAs and kVp, various factors are dealt with panoramic dose. The exposure increases with collimator width, and decreases with in respect to three geometric factors related to the equipment and the anatomy of the patient: point of measurement to center of rotation distance, tube angular velocity, and radius of curvature [7, 22]. G. Kaeppler et al. investigated influence of the rotation center in panoramic radiography with two different types of panoramic systems. They found that the higher organ doses for Scanora and the high dose at the start and the end of taking the radiographs were resulted from the curve of the rotation center and the beam geometry with a higher density and higher exposure of the parotid gland [23]. These parameters could be investigated in future studies.

According to Tables 1 and 2, an interesting point which can be seen when comparing different centers is that centers 2 and 6 were equipped with digital systems but no reduction in dose was observed. This was due to incorrect use of digital systems. Since higher doses may decrease the image noise for digital receptors in a certain range of dose [24], manufacturers should provide accurate and sufficient technical information to the dentists and their staff to help in the optimization of image quality and dose reduction.

Furthermore, it is reported that the use of direct current technology provides a 25% dose reduction when compared with panoramic machines that still use alternating current. In the panoramic examination mode, a 90% reduction in patient exposure is claimed, as compared with Complete Mouth Series (CMS) radiography. This approximates to the dose of a single periapical film [25].

Lee et al. [17] reported DWP reference level of 60.1 mGy.mm in Gwangju which is lower than DWP values presented in Table 3.

In a similar work, Kim et al. measured 106.7 mGy.mm for DRL in Anyang city which is quite different from those reported from other countries, and is higher than that recommended by the NRPB. Excessive exposure of patients is expressed due to incorrect use of automatic film process [16].

Tierris et al. measured DAP values in panoramic radiology with the use of a DAP meter to determine corresponding reference levels in 62 panoramic X-ray units. Measured DAP was 117 $mGycm^2$ for exposure of a male patient [26].

Considering the third quartile value of slit length 137 mm, DAP values reported in this study were in agreement with equivalent results reported by Gonzalez and Napier [26]. Therefore, DLR value in our study can be considered lower than NRPB, Napier, Tierris, Kim, and Gonzales.

The overall results of this study indicate that exposure of the patients in a panoramic facility in the greater Khorasan province, Iran, does not exceed the levels reported by other investigator (as far as we know) who have conducted similar research (Table 3). Gonzalez et al. have reported local DRLs in orthopantomography with the use of TLDs, based on patient measurements in 11 dentistry installations. The proposed DRL was 530 μGy at the occipital region. As that study didn't report detailed information of exposure parameters and panoramic machine models, comparison between the two sets of data may not be informative.

5. Conclusion

In panoramic radiography, the X-ray scanning movement generates a complex dose distribution, thus ESD does not precisely correlate with radiation risk. However, one must use this reference dose as a tool only to improve practices and according to this approach, the dose value obtained at the parotid glands may offer a suitable value for optimizing purposes.

Table 3. Reference levels for panoramic imaging.

NRPB[20] 1999	Napier[14] 1999	Tierris[26] 2004	Kim[16] 2009	Lee[17] 2010	Gonzales[13] 2001	Bahreyni 2011
DWP: 65 mGy.mm	DWP: 66.7 mGy.mm	DWP:85.4 mGy.mm	DWP:106.7 mGy.mm	DWP:60.1 mGy.mm	ESD: *530 µGy	ESD:400 µGy

*: LDRL in Madrid

Therefore, 400 µGy is suggested as LDRL arising from panoramic examinations of the greater Khorasan province, Iran, hoping that this is the first step towards the patient dose optimization in this field of radiography with the aim of triggering a more comprehensive quality assurance and clinical audit program in the province and across the country.

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