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Measuring the dose–width product and proposing the local diagnostic reference level in panoramic dental radiography: a multi-center study from Iran

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Abstract

Objective Although radiation exposure associated with dental radiography is relatively low, patient exposure must be kept practically low. Therefore, it is necessary for each country to establish its own diagnostic reference levels (DRLs) suitable for its equipment and practice. In the present study, dose-width product (DWP) values for panoramic dental radiography were measured and a local DRL was established.

Methods Five panoramic devices from five radiology clinics of Kashan, Iran were selected to measure the DWP values of panoramic dental radiography. To investigate the DWP values, the parameters of each patient's exposure (e.g., tube voltage, tube current, and exposure time) at these five radiology clinics were extracted. Then, the dose value received by each patient was measured based on a CT pencil chamber. Finally, the overall median DWP values for the patients with small, medium, and large sizes were obtained, and these values were considered as the local DRLs for panoramic dental radiography.

Results A total of 99 adult patients were included in the present study. The findings demonstrated that the median and third-quartile DWP values for these five radiology clinics ranged from 42.3 to 94.3 and 49.7 to 142.8 mGy mm, respectively. The local DRL values, which were established as the overall median DWP values, were 43.4, 52.0, and 80.3 mGy mm for the adults with small, medium, and large sizes, respectively.

Conclusion The local DRL proposed in this study for the adult with standard/medium size was lower than those proposed by other reports and seemed acceptable for panoramic radiography in Kashan, Iran.

Keywords Panoramic radiography · Dose–width product (DWP) · Diagnostic reference level (DRL) · Iran

Introduction

Dental radiography is one of the most commonly performed radiological procedures [1]. Panoramic dental radiography, as an imaging procedure, allows fine visualization from all dental elements and their anatomical construction of the maxillo-mandibular complex [2, 3]. Although radiation exposure associated with dental radiography is relatively low [4, 5], patient exposure to ionization radiations must be kept practically low by appropriate equipment and facilities and a quality assurance program in place [6]. In other words, patient exposure to radiation can cause an increased long-term risk of cancer in these patients as well as a potential risk for critical hereditary diseases in their descendants. It is notable that the probability of these radiation-induced side effects is directly proportional to the dose values received by the patients without a dose threshold [5, 7].

Accordingly, there is a clear requirement to measure/estimate and monitor these exposures. Furthermore, based on the recommendation of the International Commission on Radiological Protection (ICRP) No. 103, the dose values received by the patients should be regularly measured and compared with diagnostic reference levels (DRLs) [8].

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The DRLs are commonly applied to control the radiation exposure to a level proportionate to the clinical goal of a medical imaging task [9]. Also, the DRL quantity represents the third-quartile/median value from the distribution of radiation exposure delivered to groups of patients within an agreed weight range for a particular imaging procedure [10, 11]. The national DRL value is usually specified as the third quartile of the distribution of the median values of the proper DRL quantity obtained from each healthcare facility. A local DRL value can be achieved in two ways: (1) For a reasonable number of X-ray rooms (e.g., 10–20), it can be set at the third quartile of the distribution, and (2) for smaller numbers of X-ray rooms or a single facility, it may be defined as the median of the distribution [12]. There are several methods for the assessment of patient dose values in dental radiography [13–16]. Dose–width product (DWP) proposed by Napier [13] is a useful quantity for determining the DRL at panoramic dental radiography and can be obtained from the beam characteristics at the receiving slit. Indeed, the DWP quantity can be measured, either by a small detector located at the X-ray beam center and then multiplied by the beam width, using a thermoluminescent dosimeter array, film, or ionization chamber jointed perpendicularly to the slit [13, 17, 18]. It is noteworthy that the DWP can be well correlated to the dose–area product and can then be converted to the effective dose value by conversion factors [19]. In addition, the DWP is applied for its ease of measurement and does not need the patient to be present during dose measurement [9].

There are several studies investigating the radiation dose in panoramic dental radiography [5, 17, 19–21]. For instance, Lubis et al. [20] assessed the radiation dose resulting from panoramic dental radiography in Indonesia. They reported that the third quartile of kerma–area product values for high- and low-dose modes of the evaluated panoramic devices were 192.4 and 85.2 mGy cm^2, respectively [20]. In another study by Lee et al. [5], reference dose levels for dental panoramic radiography were measured in Gwangju city, South Korea. Their results showed that the 75th percentile DWP for panoramic radiography procedures was 60.1 mGy mm [5]. Doyle et al. [17] measured the DWP and dose-area product values in panoramic dental radiography. They stated that mean and third-quartile DWP values for the studied devices equaled 65 and 67 mGy mm, respectively, and mean and third-quartile dose–area product values equaled 89 and 90 mGy cm^2, respectively. In addition, they reported that the DWP for 30% of the tested devices exceeded the DRL proposed by the National Radiological Protection Board (65 mGy mm) [17].

In the present study, the DWP values of panoramic dental radiography were measured in five radiology centers (Kashan, Iran) and compared with the DRL values proposed by the National Radiological Protection Board (NRPB) [22] and with published data from other researchers [5, 9, 13, 17, 19, 21, 23–25]. Moreover, it was attempted to establish a panoramic local DRL in Kashan, Iran.

Materials and methods

Five panoramic devices from five radiology clinics of Kashan, Iran (A, B, C, D, and E) were selected to measure the DWP values of panoramic dental radiography. All panoramic dental radiology devices used in this study equipped a digital-based imaging system (direct digital receptor). They also equipped options to select the patient size (small, medium, and large) and the mandible/maxilla size (small and large). The characteristics of these units are listed in Table 1.

To investigate the DWP values of panoramic dental radiography, the exposure parameters of each patient (e.g., tube voltage, tube current, and exposure time) at these five radiology clinics during a 1-month period were extracted. Then, the dose measurement was performed based on the technique proposed by the previous studies [9, 19]. For this purpose, first, a piece of film was attached on the digital sensor and exposure was performed to determine the center of the sensor as well as the real horizontal beam width. Then, a CT pencil chamber (type 30,009, PTW, Freiburg, Germany) calibrated in a Secondary Standard Dosimetry Laboratory (Karaj-Iran) was located perpendicularly to the digital sensor, as the center of the chamber was co-incident with the center of the sensor. After positioning the dosimeter, the exposure parameters related to each patient were

Table 1 Characteristics of the panoramic devices used in this study

Radiology clinic	Technical parameters of panoramic units				
	Manufacturer	Nation/country	Panoramic machine	Year of installation	Total filtration
A	KODAK	USA	CS8000C	2014	2.5 mm Al
B	VATECH	South Korea	PCH-2500	2015	2.8 mm Al
C	ORTHOPANTO-MOGRAPH	Finland	FI-04300 TUUSULA	2014	2.5 mm Al
D	PLANMECA	Finland	SCARA2	2013	2.5 mm Al
E	PLANMECA	Finland	PROMAX	2016	2.5 mm Al

simulated and the incident air kerma value was measured in mGy. The dose per exposure cycle was then multiplied by the horizontal beam width on the digital sensor to calculate the DWP value. It is noteworthy that the dose measurements were repeated three times and the obtained average dose value was recorded as the DWP value for that set of exposure parameters.

Results

The recorded exposure parameters for five panoramic devices showed that the mean, minimum, and maximum values of tube potential settings were 69.0 ± 4.0, 62, and 79 kV, respectively, and were 7.9 ± 3.1, 6, and 16 mA, respectively, for tube current settings.

A total of 99 adult patients (41 males and 58 females) were included in the present study. Therefore, 99 experimental exposures were performed at five dental clinics and the findings are listed in Table 2. Based on Table 2, the overall median and third-quartile DWP values were 54.2 and 83.0 mGy mm, respectively.

Moreover, Tables 3 and 4 present the mean, median, and third-quartile DWP values obtained from the radiology clinics in accordance with different patient sizes (small, medium, and large) and their mandible/maxilla sizes (small and large), respectively. The local DRLs, which were established as the overall median DWP values, were 43.4, 52.0, and 80.3 mGy mm for the adults with small, medium, and large sizes, respectively. Also, the overall third-quartile DWP values for the patients with small, medium, and large sizes were 85.9, 110.6, and 128.7 mGy mm, respectively. It is notable that the overall third-quartile DWPs were not 75 percentiles but 80 percentile values.

Table 2 DWP values of 99 patients from panoramic radiography at five radiology clinics

Radiology clinic	Number of patients	Mean ± SD (mGy mm)	Minimum (mGy mm)	Maximum (mGy mm)	Median (mGy mm)	Third quartile (mGy mm)
A	19	79.3 ± 23.4	48.3	129.1	79.6	83.0
B	20	56.4 ± 13.1	43.4	93.5	54.2	58.9
C	20	48.9 ± 15.9	33.2	85.1	42.3	64.5
D	16	95.2 ± 58.4	48.0	211.6	94.3	142.8
E	24	47.0 ± 8.6	35.4	68.7	44.7	49.7
Total	99	65.4 ± 21.0	33.2	211.6	54.2	83.0

Table 3 DWP values (mGy mm) of 99 patients from panoramic radiography in accordance with patient size

Radiology clinic	Small			Medium			Large		
	Mean ± SD	Median	Third quartile	Mean ± SD	Median	Third quartile	Mean ± SD	Median	Third quartile
A	71.6 ± 17.6	80.2	85.9	79.4 ± 31.4	70.8	110.6	102.6 ± 23.0	93.5	128.7
B	41.8 ± 5.1	43.4	46.0	50.1 ± 8.6	48.1	56.3	77.4 ± 1.0	77.4	78.1
C	37.4 ± 2.8	36.6	39.5	54.3 ± 10.7	52.0	66.2	76.7 ± 10.6	80.3	85.1
D	72.9 ± 22.3	79.6	91.1	90.8 ± 38.7	79.1	138.8	145.3 ± 62.7	152.1	211.6
E	40.9 ± 4.6	41.1	44.6	49.9 ± 5.7	49.4	54.4	68.7 ± 00	68.7	68.7
Total	52.9 ± 17.7	43.4	85.9	64.9 ± 19.0	52.0	110.6	94.1 ± 31.3	80.3	128.7

Table 4 DWP values (mGy mm) of 99 patients from panoramic radiography in accordance with the patients' mandible/maxilla size

Radiology clinic	Small			Large		
	Mean ± SD	Median	Third quartile	Mean ± SD	Median	Third quartile
A	53.7 ± 2.7	53.2	56.5	88.3 ± 27.0	85.6	110.6
B	45.5 ± 6.4	44.5	48.1	54.2 ± 14.0	48.2	68.6
C	38.6 ± 4.0	38.8	41.5	60.3 ± 17.0	64.8	73.5
D	55.0 ± 9.8	50.7	66.2	120.1 ± 52.7	109.4	152.1
E	47.2 ± 6.5	47.9	52.0	51.1 ± 9.0	50.1	57.0
Total	48.0 ± 6.6	47.9	56.5	74.8 ± 29.3	64.8	110.6

Discussion

In this report, the mean, minimum, maximum, third quartile, and median DWP values of panoramic dental radiography were obtained from five radiology centers in Kashan, Iran. Furthermore, the findings were analyzed based on the patient size and mandible/maxilla size.

The radiation-induced adverse effects to humans, such as cancer, can be considered in accordance with a linear no-threshold (LNT) model. On this model, the risk associated with low dental radiography exposures can be expected to be low but higher than zero [26]. Consequently, it is essential to precisely measure the dose to these patients. The DWP quantity can be utilized as a dose metric stating the radiation delivered to the patients during standard adult panoramic procedures. This quantity is commonly applied to establish the DRL in panoramic dental radiography [13].

There are several important factors affecting the DWP values, including tube voltage, tube current, exposure time, filtration, patient size, and collimation [4, 27, 28]. Furthermore, many studies have reported large variations in the magnitude of the dose received by the patients with the same procedure type performed at various facilities or even within the same facility [29–32]. According to the data presented in Table 2, it was found that the DWP values obtained from different radiology clinics differed from one another, probably because of the above-mentioned factors and different panoramic devices employed in the present study. For example, the results demonstrated that the median and third-quartile DWP values for these five radiology clinics ranged from 42.3 to 94.3 and 49.7 to 142.8 mGy mm, respectively.

The results (Table 3) also revealed that the DWP values for the patients with a large size were much higher than those of the other two groups (small and medium sizes). Based on the data enlisted in this table, the mean DWP values for small, medium, and large groups were 52.9 ± 17.7, 64.9 ± 19.0, and 94.1 ± 31.3 mGy mm, respectively. In this regard, it was understood that, although the selection of exposure parameters (tube voltage, tube current, and exposure time) was appropriate for the patients with medium and small sizes, these parameters were chosen much more for the patients with large size. Moreover, it was observed (Table 4) that the DWP values for the patients with large mandible/maxilla sizes were higher than those of small size, probably due to the large number of exposure parameters in the patients with large mandible/maxilla size. It is notable that digital techniques do not automatically decrease the patient dose value. In other words, in digital systems, overexposure can occur without any adverse effect on the image quality, and this overexposure may not be identified by the radiologist or radiographer. However, in conventional radiography systems, excessive exposure generates a 'black' film and insufficient exposure generates a 'white' film, both with decreased contrast. Moreover, higher dose values may reduce the image noise for digital receptors. As a result, it is necessary that the DRLs be used for the acquisition of digital images, because high-quality images can also be generated by excessive exposure levels.

In 1996, the International Atomic Energy Agency (IAEA) recommended a guidance dose value (entrance surface air kerma) of 7 mGy for dental periapical radiography [33]. In 1999, Napier proposed the DWP reference level of 67 mGy mm in panoramic radiology [13] and the NRPB suggested the DWP value of 65 mGy mm as the DRL for a standard adult patient [22]. In addition, different values of the DRLs have been recommended for panoramic dental radiography as listed in Table 5.

In the present study, the DRL values were established separately for small, medium, and large sizes of patients, because the DRL quantity is defined for groups of patients

Table 5 DWP values for standard/medium-sized adult panoramic dental radiography

Author and year	Country	Mean (mGy mm)	Median (mGy mm)	Third quartile (mGy mm)
Napier (1999) [13]	UK	57.4	–	66.7
Williams and Montgoery (2000) [19]	UK	65.2	–	75.8
Isoardi and Ropolo (2003) [9]	Italy	75.35	70.9	74.65
Doyle et al. (2006) [17]	UK	65	59.5	67
Kim et al. (2009) [23]	Korea	72.1	–	106.7
Lee et al. (2010) [5]	Korea	47.7	–	60.1
Walker and Putten (2012) [24]	Ireland	–	–	59.89
Niemann et al. (2015) [21]	South Africa	91.3	92.3	127.5
Merce et al. (2018) [25]	–	–	–	80
The present study	Iran	64.9	52.0	110.6

within an agreed weight range. These values were considered as the local DRLs for panoramic dental radiography. The 80 percentile value of DWP distribution for an adult with standard/medium size (110.6 mGy mm) was higher than the local DRLs proposed by Napier (67 mGy mm) [13] and NRPB (65 mGy mm) [22], which were established as the 75 percentile values. However, the local DRL established in this study as the median value (52.0 Gy mm) was lower than the local DRLs proposed by Napier and NRPB. There are several studies measuring the DWP values in panoramic dental radiography [5, 9, 17, 19, 21, 23–25]. For example, Isoardi and Ropolo [9] measured the DWP values of panoramic dental radiology in Italy. The measurements were obtained on five panoramic dental machines. In addition, exposure parameters were set for medium adult patient sizes. Their findings revealed that the median DWP is 70.9 mGy mm, which was higher than the DRL value presented in our study (52.0 mGy mm). In another study by Doyle et al. [17], the DWP values for the panoramic dental radiology procedure in the UK was obtained. The results of 20 panoramic machines indicated that the median DWP for standard adult panoramic scans equaled 59.5 mGy mm, which was higher than that reported by in our study (52.0 mGy mm). Niemann et al. [21] measured the DWP values resulting from five dental panoramic units in South Africa. The median DWP for an adult with standard size was 92.3 mGy mm, which was much higher than that obtained in our study (52.0 mGy mm). Finally, as observed from Table 5, a wide DRL range for panoramic dental radiography has been reported for different countries. These differences may be attributed to the lifetime of devices, the quality control of devices, and different techniques applied for the measurement of the DWP value.

Conclusion

It is essential for each country to establish its own DRLs suitable for its equipment and practice. In the present study, the DWP values were measured for panoramic dental radiography and the local DRLs were established as the median values of DWP distributions. The overall median DWP values for the patients with small, medium, and large sizes were 43.4, 52.0, and 80.3 mGy mm, respectively. The local DRL established for an adult with standard/medium size was lower than those proposed by other reports and seemed acceptable for panoramic dental radiography in Kashan, Iran.

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Compliance with ethical standards

Conflict of interest There is no conflict of interest.

Ethical approval This study does not involve any evaluation of human or animal samples performed by the authors.

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