Assessment of Adult Diagnostic Reference Levels for Panoramic Radiography in Tamil Nadu Region

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Abstract

Aim: The aim of this study was to calculate dose area product (DAP) and to determine diagnostic reference level (DRL) for adult panoramic procedures in Tamil Nadu. **Materials and Methods:** In this study, air kerma on the front side of the secondary collimator was measured with a Black Piranha, RTI Electronics, Sweden and multiplied with the corresponding exposed area to calculate DAP. The obtained DAP values were further analyzed, and DRL was calculated using the Microsoft Excel software. The study was carried out with regular adult exposure parameters. **Results:** The mean, range, and 3rd quartile values for 67 panoramic scanners in Tamil Nadu, India, were calculated as 94 mGycm^2, 41 mGycm^2–165 mGycm^2, and 114.3 mGycm^2, respectively. The results are comparable with other international studies. **Conclusion:** The present study suggests that further optimization can be achieved in many centers by the recruitment of professionally qualified radiographers and conducting periodic training programs on the optimization of exposure parameters. Considering this as the first study for the dental DRL assessment, further studies are suggested to establish national dental DRL in India.

Keywords: Dental radiography, diagnostic reference level, dose area product, radiation protection

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Introduction

Dental radiographic examinations and their associated risks have long been neglected by the dental professionals and the institutions because of the relatively low levels of radiation doses involved,[1] compared to other diagnostic radiology disciplines. However, with the rapid increase in the number of dental facilities, in the last several years, across the country, especially in smaller towns, a huge number of children developing dental problems are undergoing dental X-ray imaging.[2] With the introduction of newer types of dental X-ray units such as the cone-beam (CB) dental computed tomography (CT) and increasing frequency of imaging with such advanced systems, the doses involved in dental imaging have gone up very steeply and are steadily bringing dental radiology into the renewed focus of the professional bodies and regulators. In the last decade, much stricter regulations have been introduced in the field of dental radiography, but not much attention has been given to this discipline, in India, so far. This work is an effort, in this direction, to assess doses in dental radiography facilities and their optimization, in the southern part of India, which can later be extended to other parts of India.

Diagnostic reference level (DRL) is a practical tool that can be used for the optimization of medical exposures.[3-6] A representative number of panoramic X-ray units in the region have to be selected for the establishment of regional DRL in panoramic dental radiography. By comparing the hospital dose with the regional DRL, any hospital in the region can assess whether the doses are consistently higher or lower compared to the regional DRL and then take corrective action. DRL along with the mean observed patient dose values would help to identify the good and bad panoramic practices in dental radiography. It can be used for the elimination of unnecessary radiation exposure that does not contribute to the clinical purpose of the image.[7] The measurement of patient radiation doses during diagnosis procedures is important[8,9] for the assessment of patient risk.

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By establishing zone-wise DRL, in the South, North, East, West, and Central parts of the country and consolidating the data national level DRL can be set. Thus, the objective of the present study, initiated by PSG Institute of Medical Sciences and Research in consultation with and grant from the Atomic Energy Regulatory Board (AERB), is to establish DRL for adult panoramic radiography in the region of Tamil Nadu and compare them with the internationally recommended DRLs.

Materials and Methods

Panoramic scanners

Sixty-seven panoramic dental X-ray machines, including 22 different models were randomly selected based on workload from dental facilities in the Tamil Nadu region, and measurements were performed without the presence of the patient in place. Before commencing the measurements in the hospitals, a questionnaire was sent to collect the radiation safety status, detector type, quality assurance (QA) status, and exposure parameters used for the adult panoramic scans. Measurements were taken after doing the QA testing of the respective scanner. Mechanical, electrical, and radiation quality tests were done for the respective scanners as per the AERB to reconfirm the positional accuracy of the dosimeter. The beam area of the scanner was measured by using a computed radiography (CR) cassette and verified with the machine manual given by the manufacturer. Table 1 shows the average exposure parameters used with each model of panoramic scanners and their active detector beam area.

The CR cassette was kept in front of the secondary collimator and exposed for 1 s to measure the beam area. The procedure was repeated for all the selected machines involved in this study and confirmed the area of the detector.

Dosimeter

A solid-state dosimeter (RTI Black Piranha 557), from RTI electronics, Sweden, that has an active width of 3 mm, was used for the measurement of radiation dose.

Aligning Piranha dosimeter at the secondary collimator is a difficult task as it is heavy and single strap of Transpore tape may not be enough to hold it safely during the measurement. Since there is no laser light in some of the panoramic scanners to replicate the tube slit position at the detector side, positioning of solid-state dosimeter along the narrow tube slit is a tedious task. Thus, the initial positioning of dosimeter may not show an accurate result. Graphs shown in Ocean software helps to identify the inaccurate and accurate position of dosimeter after the radiation exposure [Figure 1]. Piranha holder, specifically configured to hold Piranha 557 dosimeter during the panoramic scan, helps to hold the dosimeter tightly during the scan time [Figure 2]. Minute positional alignment of dosimeter is also possible using piranha holder.

Experiment technique

The Piranha 557 dosimeter used in this study is more convenient to use as compared to the detector used by Lee *et al*.[5] in their study which had an active sensor width of 1.5 mm since its active sensor width is 3 mm. The "OCEAN 2014 connect" software enables the black Piranha to connect directly to the computer through bluetooth. During the measurement, the black Piranha solid-state dosimeter was attached in front of the secondary collimator with a Piranha holder [Figure 3].

Table 1: Average exposure parameters used for different scanners and beam area

Number of scanners	Name of the scanner	Beam area (cm^2)	kVp	mA	Time (s)
1	Newtom Go 3D	0.60*14.6	78	8	12.7
1	Rotograph Evo D	0.60*14.60	72	6	14.4
1	Villa Sistemi, Rotograph plus	0.60*14.3	78	10	17.0
1	HYPERION X-7	0.60*14.60	67	5	9.1
1	Xmind Novus	0.61*14.75	70	7	9.0
1	Gendex Dental Systems	0.60*15.10	70	10	16.0
1	X-MIND PANO D+	0.61*14.75	73	10	17.6
1	CS 9300	0.50*14.9	75	12	14.3
1	GME Pantograph 10	0.61*14.75	75	10	17.0
1	Xtropan 2000	0.60*15.00	70	12	17.0
2	ADVAPEX - DENTOPAN-10	0.69*15.10	70	10	14.0
2	Planmeca ProOne	0.60*14.6	69	7	9.8
2	Soredex	0.61*14.75	73	10	9.0
3	Planmeca proline -EC	0.50*13.6	66	11	16.0
3	ORTHOPHOS XG 3	0.325*13	67	13	14.1
3	Genoray Co. Ltd, EXTOR-P	0.64*15.00	72	11	12.0
4	CS 8100	0.50*13.12	73	11	10.7
5	ASAHI IIIECM roentgen	0.69*15.10	73	10	12.0
6	Vatech Pax-i	0.60*15.04	72	9	13.2
6	Planmeca Promax	0.60*14.70	67	9	15.8
6	ORTHOPHOS XG 5	0.325*13	66	12	14.1
15	Kodak 8000	0.40*12.80	71	10	13.7

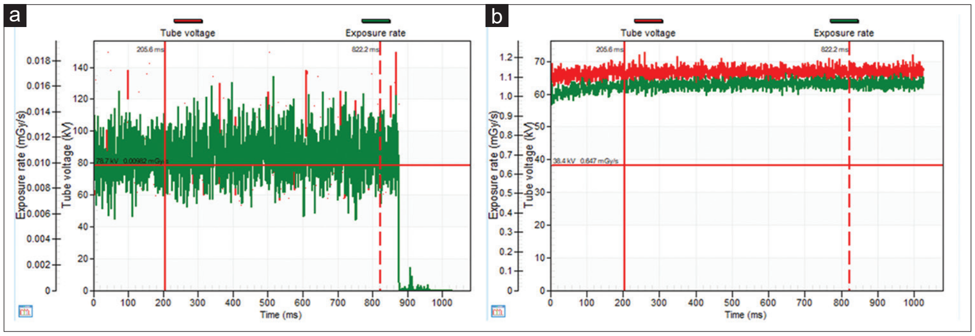

Figure 1: Graphical representation shown in Piranha Ocean software after inaccurate positioning (a) and accurate positioning (b) of dosimeter

Figure 2: Panoramic Piranha holder with Piranha dosimeter

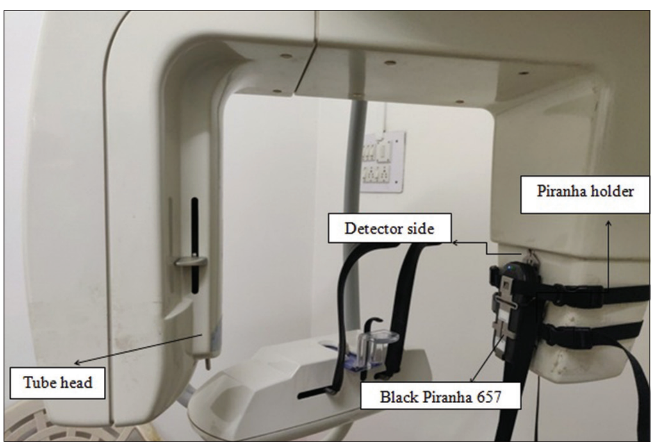

Figure 3: Pictorial representation of experimental procedure

Once the panoramic scanner passed AERB QA test, then that particular machine is included for the DRL study. The regular kVp, mA, and time used for the adult panoramic scan were loaded in the panoramic scanner. Measurements were taken for 20 patient protocols. Figure 4 shows the screenshot image of the reading shown in the software after the exposure. Exposures were repeated without the presence of patients, and radiation doses were noted.

The product of the measured dose with the measured area gives the dose area product (DAP) values. After calculating DAP from 67 panoramic dental scanners, statistical parameters such as average, 3rd quartile values were calculated using Microsoft Excel software. The 3rd quartile value can be suggested as DRL, according to Radiation Protection Document No. 109 of the European Commission.[10]

Results

Verification of DAP calculation was made by comparing the machine DAP and calculated DAP [Figure 5]. Of 38 displayed values from different panoramic scanners, the observed deviation from machine value was well within ± 18%. The maximum deviation observed between machine DAP and calculated DAP was −17.68%.

The assessed DRL value, along with the calculated DAP values, for 67 panoramic radiography units are given in Figure 6. The calculated DAP values ranged from 41 $mGycm^2$ to 165 $mGycm^2$. The lowest and highest DAP values for all procedures were calculated at scanners based on digital and analog type detectors, respectively. However, in many digital type scanners, high radiation doses were observed.

Mean exposure parameters, along with the mean, range, and the 3rd quartile of the DAP values for analog and digital mode of detectors are given in Table 2. There was nearly 3.6-fold difference between the highest (148 $mGycm^2$) and lowest (41 $mGycm^2$) DAP values for the digital detector units. Almost 2.5-fold difference was observed for analog type units between the lowest (65 $mGycm^2$) and highest (165 $mGycm^2$).

The DRL was calculated from DAP values using Microsoft Excel software by the formula "PERCENTILE, (array, k)," where array represents the DAP values and k represents the percentile value (in the present case k is 0.75).

From the findings of the present study, the suggested DRL for adult panoramic procedures in Tamil Nadu region was 114.3 $mGycm^2$.

Discussion

Unlike other dental X-ray units like intraoral and CBCT scanners, the panoramic unit produces a narrow slit beam and tracks a circular path around the patient's head to

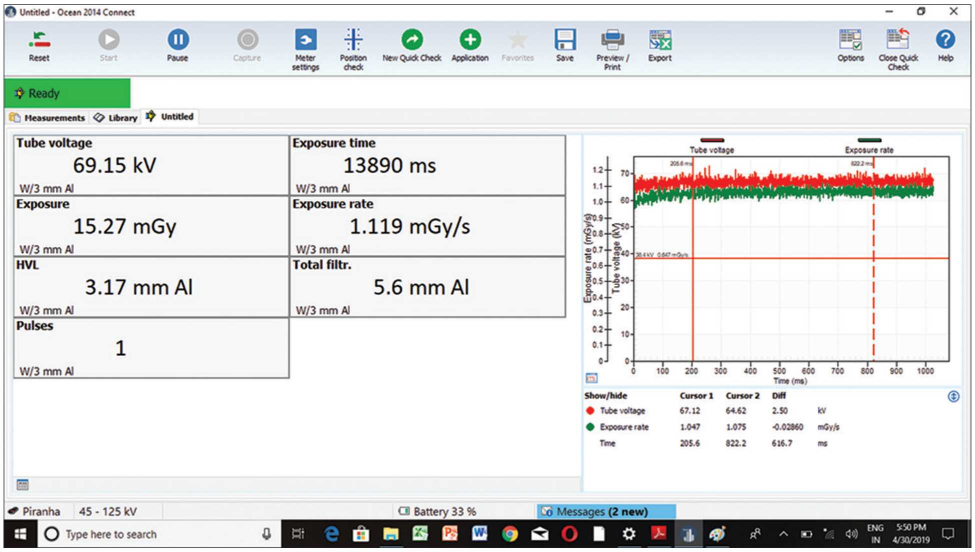

Figure 4: Screenshot of the reading obtained in Ocean 2014 Connect software for exposure parameters of 70 kVp, 10 mA and 13.9 s

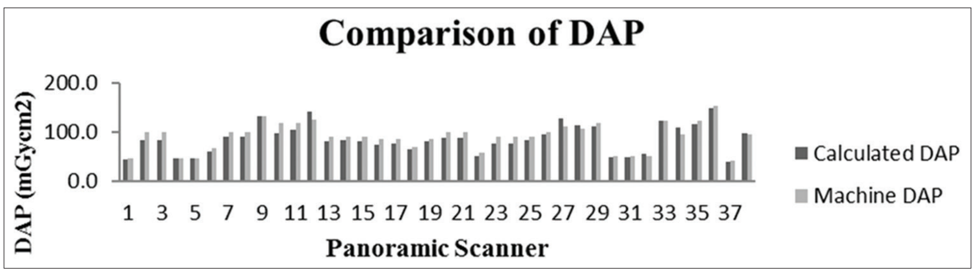

Figure 5: Comparison of machine dose area product and calculated dose area product

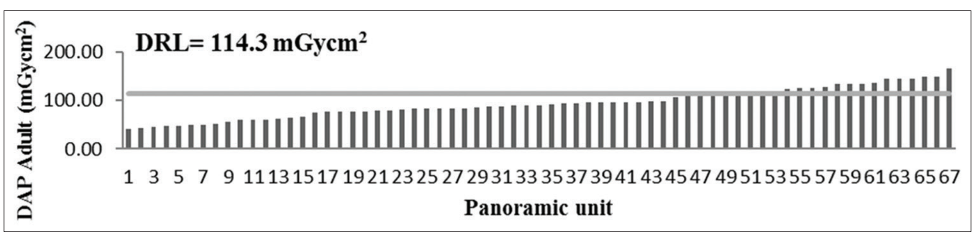

Figure 6: Proposed adult diagnostic reference level and calculated dose area product values of different panoramic units

Table 2: Mean exposure parameters along with range, mean and 3rd quartile of dose area product values for digital and analogue types of units

Type of unit	Exposure mean (kV)	Mean (mA)	Mean exposure time (s)	DAP range (mGycm^2)	Mean DAP (mGycm^2)	DRL (mGycm^2)
Analogue	71.2	10.3	14.4	65-165	105.9	125.5
Digital	70.1	10.0	13.2	41-148	90.7	112.4
Total	70.3	10.0	13.5	41-165	93.6	114.3

DRL: Diagnostic reference level, DAP: Dose area product

obtain the dental X-ray image. For the accurate radiation dose measurement process during panoramic procedure, the dosimeter has to follow the narrow slit beam. Any misalignment of dosimeter may create a huge error. Moreover, the fact that the beam slit is broader at the detector side of the scanner makes it comparatively easy to align the dosimeter for radiation dose measurement. The agreement between the calculated DAP values and machine displayed DAP values further confirms the reasonable accuracy of the machine displayed values [Figure 5]. The observed deviation may be attributed to the difference in the type of dosimeter used, time slab of measurement and experimental technique. For better accuracy, the display values can be calibrated in terms of the measured values.

Figure 7 shows the comparison of other countries' dental panoramic DRL with the present study, the Tamil Nadu DRL. Similar results were published by different authors such as Tierris *et al*.[11] and Han *et al*.[12]

Tierris *et al*.[11] found 101 mGycm^2 and 117 mGycm^2, respectively, as their mean and 3rd quartile values. Careful analysis of the results published by them indicates that there are 18 units that have DAP > 100 mGycm^2 and in that, 8 units have DAP in between 200 mGycm^2 and 250 mGycm^2. Therefore, the DRL of their study was affected by the scanners with higher doses. The average exposure parameter (72.4 kVp, 10.5 mA, and 15.2 s) calculated by them was slightly higher than the average calculated values of the present study (70.3 kVp, 10.0 mA, and 13.5 s). The present study has 23 scanners which are having DAP >100 mGycm^2 and the highest DAP value calculated was 165 mGycm^2.

Han *et al*.[12] have measured DAP using DAP meter (VacuDAP-OEM, Vacutec, Germany) on 42 panoramic scanners. The maximum DAP observed from their study also crossed 200 mGycm^2 with an average of 98.2 mGycm^2 and a corresponding 3rd quartile value of 120.3 mGycm^2. Their average kVp and mAs calculated from different panoramic scanners ranged from 68–82.3 kVp and 110.7–211.2 mAs, respectively. The present study kVp and mAs ranged from 66–78 kVp and 46–204 mAs. Hence, the high DRL in Han *et al*.[12] is influenced by larger exposure parameters.

Williams and Montgomery[13] have assessed DRL from 16 panoramic X-ray units using thermoluminescence dosimeters. The mean DAP and corresponding 3rd quartile values for standard adult examination are 113 and 139 mGycm^2, respectively. The difference in the type of dosimeter and sample size may have influenced their DRL value. This may be the reason for variation in their DRL as compared with the present study.

The DRL assessed by Poppe *et al*.[14] and Hodolli *et al*.[15] are 101.4 and 93 mGycm^2, respectively. A close analysis of the results of their studies shows that the majority of their panoramic X-ray units have DAP lesser than 100 mGycm^2. Therefore, the DRLs of their studies are affected by the scanners with lower doses. The average exposure parameters calculated by Poppe *et al*.[14] and Hodolli *et al*.[15] are 73.1 kVp, 11.6 mA, and 15.3 s and 72.8 kVp, 12.8 mA, and 16.2 s, respectively. Although the exposure parameters are higher than the present study average values, their DAP values are lesser than the current study calculated values. The difference in tube inherent filtration and manufacturing date can result in lesser DAP readings for their studies.

In short DRL values obtained in the present study agree with the corresponding results reported by other countries. The difference in patient physical parameter, equipment exposure parameter, tube inherent filtration, type of dosimeter used for measurement were some of the reasons for slight variation between the DRLs as assessed by the present study and by other investigators referred to here. Although the method used in the present study produces comparable results, direct use of DAP meter is a much easier method.

In setting the DRL, special consideration has to be given for digital type detector scanners for further dose optimization. In the present study, almost 33% of digital detectors were having DAP >100 mGycm^2, whereas 38% analog-type detectors had DAP >100 mGycm^2. The current study also found that many clinics and hospitals were using higher exposure parameters while using digital type detectors and comparable or lesser parameters for analog type scanners. There is always a trend to increase the dose, as higher doses can reduce the image noise to an extent. Thus, high image quality can be obtained easily.[16] Periodic QA is suggested to assess the image quality and for the optimization of exposure parameters. Higher doses obtained from this study indicate that more attention is required toward the radiation protection aspects of digital radiography. While operating the panoramic X-ray units, the operators should ensure that the patient is not

Table 3: Mean exposure parameters for scanners which were operated by professionally and not professionally qualified radiographers

Type	kVp	mA	Time (s)	Average DAP
Scanners operated by professionally qualified and experienced radiographers	67	8	13	74
Scanners NOT operated by professionally qualified and experienced radiographers	71	11	14	102

DAP: Dose area product

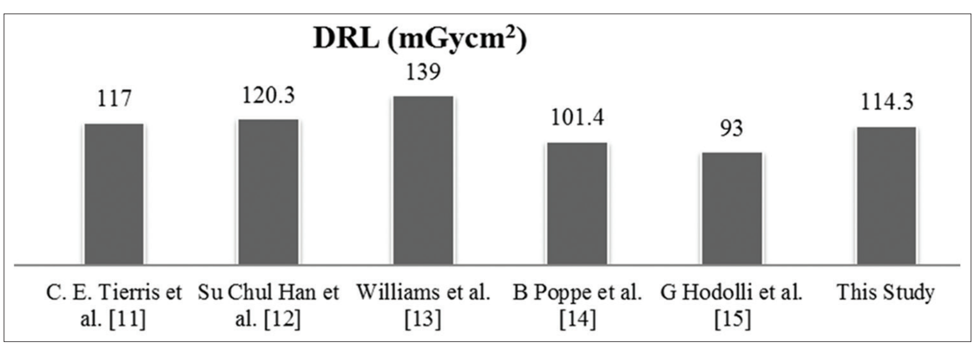

Figure 7: Comparison of other country panoramic diagnostic reference level and the present study diagnostic reference level

exposed to a dose higher than necessary when using digital image receptors.

Table 3 shows the difference in exposure parameters and average DAP values between those panoramic scanners, which were operated by professionally qualified and not professionally qualified operators.

Conclusion

This paper shows dose measurements carried out in almost 50% of the panoramic scanners in the Tamil Nadu region of South India to establish adult panoramic DRL. Although the black Piranha dosimeter consumes time to position it along the narrow slit of the panoramic scanner, its active width of 3 mm enables in reducing the positioning error comparatively. The obtained results were shown to be comparable to another country DRLs. However, the calculated DAP of certain scanners is higher than the assessed DRL value indicating the fact that the exposure parameters used in those scanners are rather high and can be further optimized. Exposure parameters have suggested to further optimize the dose to prevent patient from receiving unnecessary radiation dose from these scanners. Further, it is suggested to conduct training programs for radiographers and dentists to follow the principle of as low as reasonably achievable (ALARA).

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Conflicts of interest

There are no conflicts of interest.

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