Assessment of Regional Pediatric Diagnostic Reference Levels for Panoramic Radiography Using Dose Area Product

Amal Jose, A. Saravana Kumar, K. N. Govindarajan, P. Manimaran

Department of Medical Physics, PSG Institute of Medical Sciences and Research, Coimbatore, Tamil Nadu, India

Abstract

Aim: The current work aims to calculate dose area product (DAP) and to determine regional diagnostic reference level (DRL) for pediatric panoramic radiography in Tamil Nadu. **Materials and Methods:** In this study, DAP was calculated after finding the product of air kerma on the detector side of scanner with the corresponding exposed area. The obtained DAP values were further analyzed, and DRL was calculated using Microsoft Excel. The study was carried out with routine pediatric exposure parameters. **Results:** The obtained mean, range, and third quartile values for pediatric panoramic radiography are found to be 65 $mGycm^2$, 11–148 $mGycm^2$, and 82 $mGycm^2$, respectively. The proposed DRL is comparable with the other countries' DRL. **Conclusion:** Based on the results of the present study, it was observed that there exists a wide difference in mean doses among the panoramic scanners. The variation in radiation doses between the clinics/hospitals and similar scanners suggests a large potential for optimization of panoramic procedures.

Keywords: Diagnostic reference level, dose area product, panoramic radiography, radiation protection

Received on: 12-07-2019 **Review completed on:** 07-05-2020 **Accepted on:** 20-05-2020 **Published on:** 13-10-2020

Introduction

Globally, 480 million diagnostic dental examinations are performed yearly.[1] Although the radiation dose associated with dental radiography is comparatively less, the patient may undergo a dental radiography diagnosis process many times during their life span. While considering the health effects associated with dental radiography, the cumulative doses have to be estimated.[2]

Diagnostic reference level (DRL) is a tool used to optimize the radiation exposure to a level appropriate for the medical imaging task. DRLs can be used for all modes of diagnostic radiology. Several methods have been used for assessing the panoramic reference level.[3-12] Dose width product method used by Napier[3] can be related to dose area product (DAP) by multiplying it with the beam height. Lee *et al*.[13] and Doyle *et al*.[14] used a solid-state dosimeter for dose measurements in panoramic radiography.

Establishing reference levels for dental radiography will ensure a safer diagnosis procedure from the patient's viewpoint. Many radiographers and dentists knew that optimization of the exposure parameter is a key tool for dose reduction. Thus, a reference dose level is required for safe practice. It is an effective method for the significant reduction in collective dose, especially for repeated procedures and in the procedures containing more radiosensitive patients, like children. The present work, initiated by PSG Institute of Medical Sciences and Research in consultation with and grant from the Atomic Energy Regulatory Board (AERB), is a logical extension of the previous study,[15] conducted for the adult panoramic procedures in Tamil Nadu as a part of the establishment of national DRL for dental radiography for the country. Thus, the objective of our study was to calculate DAP for pediatric panoramic radiography to propose DRL and compare it with other country DRL.

Materials and Methods

To establish a regional DRL, it is necessary to sample as many dental hospitals/clinics as possible in the region. The hospitals

Access this article online

Quick Response Code:

Website: www.jmp.org.in

DOI: 10.4103/jmp.JMP_106_19

Address for correspondence: Dr. A. Saravana Kumar, Department of Medical Physics, PSG Institute of Medical Sciences and Research, Coimbatore - 641 004, Tamil Nadu, India. E-mail: sarava87@gmail.com

How to cite this article: Jose A, Kumar AS, Govindarajan KN, Manimaran P. Assessment of regional pediatric diagnostic reference levels for panoramic radiography using dose area product. J Med Phys 2020;45:182-6.

included should be evenly spread across all geopolitical zones of the region. These should encompass all government-owned X-ray centers and major private practitioners since they admit the highest number of patients. The choice of hospitals/clinics for the study was based on convenience and their willingness as opposed to a purely random selection of hospitals. This constraint was accepted because of practical constraints on the time and resources available for the study. The 75 panoramic scanners that have been used for the current study are spread over 18 major cities in Tamil Nadu, as shown in Figure 1. Out of the total, 60 panoramic units used in this study were equipped with a direct digital (digital) image capturing system (charge-coupled devices [CCDs]) and the remaining 15 units were used indirect digital image systems that use computed radiography (CR) cassette (phosphor storage plate) as image receptors. CCD type of image capturing systems helps to get a digital image directly after exposure is made.

A calibrated solid-state dosimeter (Piranha 557, RTI Electronics, Sweden) was used to measure the air kerma from the detector side of the panoramic unit. A questionnaire was prepared, and data about the exposure parameters routinely used for the pediatric procedures, radiation safety status, periodic quality assurance (QA) status, and the detector type used in the panoramic scanners were collected. Table 1 summarizes the panoramic scanners, its beam area, and mean routine pediatric exposure parameters used for the present study.

After the data collection, the dosimeter was connected to the computer using "OCEAN CONNECT 2014 software (RTI Electronics, Sweden)" by Bluetooth or wired connection. The dosimeter was placed on the detector side of the scanner parallel to the slit and positioned visually with the slit [Figure 2].

After the proper positioning of the dosimeter, QA test was performed for each machine, and the results were compared with the AERB-specified QA tolerance limit to ensure the proper working of the scanner as well as to ensure the accurate position of the dosimeter.[15]

The experimental methods were based on Lee *et al*.[13] study and the National Radiological Protection Board assessment of panoramic X-ray sets proposed by Napier.[3] The air kerma was measured for a routine pediatric exposure cycle in the absence of the subject. However, the measured air kerma dose is integrated over the movement of the X-ray beam across the dosimeter. The total air kerma obtained from the Piranha dosimeter is multiplied with the corresponding beam area to calculate DAP with the respective scanners. Most of the digital units were displayed DAP either in the console monitor or in the panoramic scanner itself after every exposure. To verify the consistency of DAP with and without the patient, the machine DAP was analyzed for both the manner and no significant differences were observed. As per ICRP 135 recommendations, the median value was calculated from the obtained range of DAP for proposing the DRL.[16]

The third quartile value was calculated by Microsoft Excel software (Microsoft Corporation, Washington, USA) using the formula "PERCENTILE (array, k)," where the array is the list of median calculated DAP values and k is 0.75 in the present study.

Results and Discussion

The accuracy of calculated DAPs was analyzed by comparing it with the displayed DAP. From Figure 3, it can be observed that the difference between the calculated and measured DAPs has complied well within ±18%. The observed variation may be attributed because of the difference in the type of dosimeter, experimental technique, time slab of measurement, beam quality, and tube filtration.

Figure 4 shows the calculated DAP values and the proposed DRL assessed from 75 dental panoramic X-ray scanners. The horizontal line illustrates the proposed DRL of the present study. The study proposes 82 mGycm^2 as DRL for pediatric panoramic dental radiography in the Tamil Nadu region. Further, a wide range of DAP discloses the difference in the techniques used at various clinics/hospitals. It may be ascribed to the variation in facial sizes of pediatric patients,

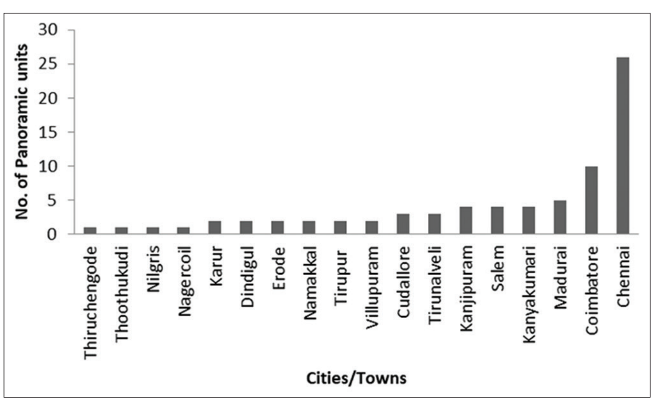

Figure 1: Regional distribution of the panoramic units used in the present study

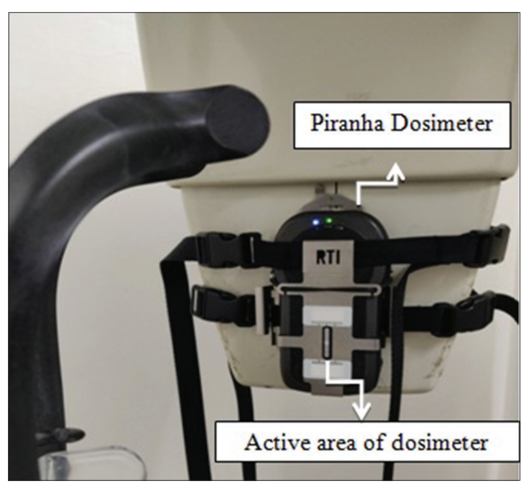

Figure 2: Piranha dosimeter is attached at the detector side of the panoramic unit

Table 1: Average exposure parameters, beam area used for different scanners, and the corresponding calculated dose area product

Number of scanners	Make (model) of the scanners	Type of detectors	Beam area (cm^2)	Mean exposure parameter			Calculated median DAP (mGycm^2)
				kVp	mA	Time (s)	
1	Villa Sistemi Medicali, Buccinasco (Rotograph Evo D)	Digital	0.60×14.60	66	6	14	45
1	Myray (Hyperion X-7)	Digital	0.60×14.60	70	4	7	26
1	Soredex (Xmind Novus)	Digital	0.61×14.75	60	7	9	32
1	Gendex Dental Systems (GXDP 700)	Digital	0.60×15.10	66	5	14	36
1	Soredex (X-Mind Pano D+)	Digital	0.61×14.75	73	10	14	98
1	M/s. Villa Sistemi Medicali, Buccinasco (Rotograph Plus)	CR	0.60×14.3	70	10	17	138
1	Trophy (CS 9300 C)	Digital	0.5×11.9	70	10	14	39
1	GME (Pantograph Digi-10)	CR	0.61×14.75	70	10	17	91
1	Xtronics Imaging Systems (Xtropan 2000)	CR	0.60×15.00	65	12	17	128
2	Soredex (Cranex Novus e)	Digital	0.61×14.75	66	10	9	40
2	Cefla Dental Group Italy (Newtom Go 3D)	Digital	0.6×14.6	76	8	12	115
2	The Samon Imaging Systems (Dentopan-10)	CR	0.69×15.10	65	10	14	78
2	Planmeca OY (Planmeca ProOne)	Digital	0.6×14.6	66	7	9	89
3	Genoray Co. Ltd. (Papaya)	Digital	0.64×15.00	62	5	15	56
3	Sirona Dental Systems (Orthophos XG 3)	Digital	0.32×13	66	8	14	62
4	Trophy (CS 8100)	Digital	0.5×12	68	8	10	71
4	Planmeca OY (Planmeca Proline EC)	CR	0.5×13.6	67	9	17	92
6	Vatech Global Co Ltd (Pax-I PCH-2500)	Digital	0.60×15.04	68	8	12	62
6	Asahi Roentgen Ind. Co. Limited (Auto IIIECM)	CR	0.69×15.10	69	10	12	79
7	Planmeca OY (Planmeca Promax)	Digital	0.60×14.70	61	6	15	72
8	Sirona Dental Systems (Orthophos XG 5)	Digital	0.32×13	63	8	14	47
17	Trophy (Kodak 8000)	Digital	0.4×12.8	68	8	13	52

DAP: Dose area product, CR: Computed radiography, GME: General medical equipments

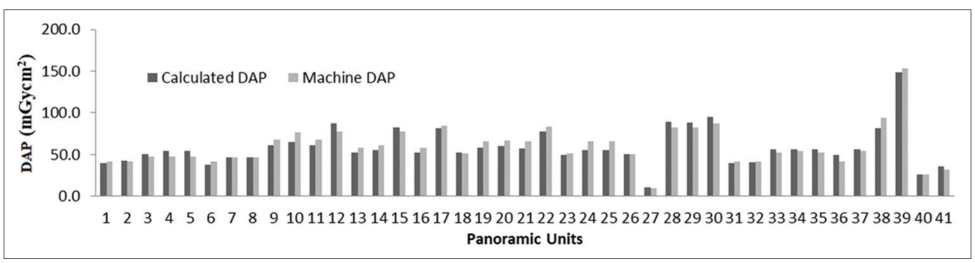

Figure 3: Comparison of machine dose area product and calculated dose area product

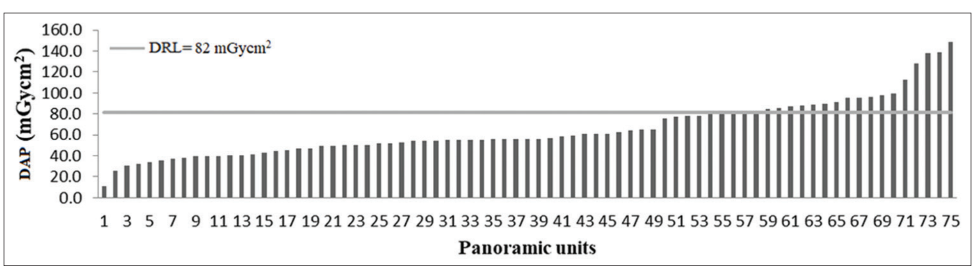

Figure 4: Calculated dose area product values and proposed diagnostic reference level for different panoramic units

X-ray operator experience, preset exposure parameters, beam quality, inherent filters used, manufacturing period, beam area, and type of detectors.

Table 2 shows the number of readings, mean exposure parameters, DAP range and DRL values of CR, and digital and total panoramic scanners obtained from the present study. The number of readings is the product of the total number of units and total air kerma measurements performed for each unit (20 air kerma measurements for each unit). It was noticed that digital DAP values varied from 11 mGycm^2 to 148 mGycm^2. Almost 14-fold difference was observed between the minimum and maximum digital DAP values, whereas

Table 2: Mean exposure parameters, dose area product range, and third quartile values obtained from the present study

Type of Unit	Number of readings	Mean kV (SD)	Mean mA (SD)	Mean exposure time (s) (SD)	DAP range (mGycm²)	Mean DAP (mGycm²)	Calculated DRL (mGycm²)
CR	300 (15×20)	68 (6)	10 (1)	14 (2)	55-139	90	106
Digital	1200 (60×20)	66 (4)	8 (2)	13 (2)	11-148	59	68
Total	1500 (75*20)	67 (4)	8 (2)	13 (2)	11-148	65	82

SD: Standard deviation, DAP: Dose area product, DRL: Diagnostic reference level, SD: Standard deviation, CR: Computed radiography

there is only a 2.5-fold difference between the minimum and maximum values of CR units. The minimum DAP for a digital unit was observed from a scanner that was operating at 60.0 kVp, 2.0 mA, and 8.8 s, whereas comparatively higher exposure parameters (78.0 kVp, 8.0 mA, and 12.7 s) were noted from the digital unit with maximum DAP. Compared to digital units, the difference in exposure parameters between the minimum DAP (60.0 kVp, 10.0 mA, and 12.0 s) and maximum DAP (85.0 kVp, 10.0 mA, and 12.0 s) observed from CR type of detectors was comparatively less. Few digital units were used to make a change in the shape and size of the focal trough automatically while selecting the pediatric mode. All panoramic scanners included in the present study feature preset exposure parameters (separately for adult and pediatric) that can modify manually to fit various patient sizes. However, some of the clinics/hospitals were found using adult exposure parameters or altered adult exposure parameters for pediatric cases. This trend was mainly observed in scanners equipped with digital detectors which were operated by the radiographers who were not professionally qualified.

Tierris *et al*.[7] and Poppe *et al*.[8] have assessed pediatric DRL using DAP meter after attaching it on the X-ray tube head at the exit slit of the beam in the presence and absence of patients, respectively. Tierris *et al*.[7] determined the mean DAP as 68 mGycm² and proposed 77 mGycm² as DRL, and Poppe *et al*.[8] calculated the mean DAP as 59.3 mGycm² and found 75.4 mGycm² as DRL. The proposed DRL value in Great Britain (Hart *et al*.[9]), the UK (HPA[10]), Korea (Kim *et al*.[11]), and Kosovo (Hodolli *et al*.[12]) were 82 mGycm², 67 mGycm², 95.9 mGycm², and 73 mGycm², respectively.

The DAP proposed in the present study is similar to Hart *et al*.,[9] slightly higher than Tierris *et al*.,[7] Poppe *et al*.,[8] G. Hodolli *et al*.,[12] and HPA report[10] and lower than Kim *et al*.[11] reported values. The slight variation was observed because of the difference in the type of dosimeter used for the measurement, manufacturing period, and time slab of the measurement used by other investigators referred to here. The summary of the comparison between the other country DRL and the present study DRL is shown in Table 3.

A notable finding in the present study is the difference in minimum and maximum DAPs observed for the digital type of detectors. Many clinics and hospitals having CR types of detectors expose the patient with comparable or even lower doses than direct digital systems. During patient exposure, overexposure is difficult to observe in digital detectors by the operators as it would not create an argumentative impact on the image.[8] Image noise can also be controlled by increasing the exposure parameter. Thus, there is always an affinity to improve the image quality by increasing the dose.[8] This study agrees further with that inclination of increasing dose to achieve image quality. However, more consideration has to be paid toward dose optimization in digital radiography. Frequent training programs to radiographers and dentists are suggested regarding the dose optimization and radiation protection tools. It is also suggested to conduct dose surveys and QA at regular intervals and also after altering the equipment and methods that affect the patient dose levels.

Table 3: Comparison of the present study diagnostic reference level and other study diagnostic reference level

Authors	Year of study	Country	DRL mGycm² (third quartile)
Tierris *et al*.[7]	2004	Greece	77
Poppe *et al*.[8]	2007	Germany	75.4
Hart *et al*.[9]	2009	Great Britain	82
HPA[10]	2010	UK	67
Kim *et al*.[11]	2014	Korea	95.9
Hodolli *et al*.[12]	2019	Kosovo	73
Present study	2019	India	82

DRL: Diagnostic reference level

However, there is a limitation to the present study. Considering this as a preliminary study for proposing pediatric panoramic DRL in India, the collection of data from a large number of panoramic units installed at different dental facilities in Tamil Nadu over 2 years was limited. A longer timeframe would have allowed more data collection and supported this study.

Conclusion

In this study, the proposed DRL for pediatric panoramic dental radiography was 82 mGycm². More than 80% of the clinics in the current study were working with digital detectors. The DRL obtained in this study is comparable with other countries' DRLs. However, DAP at many clinics/hospitals was comparatively higher. Considering the radiosensitivity of the child to ionizing radiation, the optimization of radiation dose is required at many clinics/hospitals. Although, after considering this as the first study in establishing pediatric panoramic dental DRL in India, many future studies are suggested at different states and regions for establishing criteria for taking quality images with optimal doses.

Financial support and sponsorship

This work was supported by the Atomic Energy Regulatory Board (AERB) of India and PSG Institute of Medical Sciences and Research, Coimbatore.

Conflicts of interest

There are no conflicts of interest.

References

1. United Nations Scientific Committee on Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. Vol. 1 Annex A 1: Medical Radiation Exposures. UNSCEAR 2008 Report. Available from: https://www.unscear.org/docs/reports/2008/09-86753_Report_2008_Annex_A.pdf. [Last accessed on 2019 Dec 06].
2. Looe HK, Pfaffenberger A, Chofor N, Eenboom F, Sering M, Rühmann A, *et al*. Radiation exposure to children in intraoral dental radiology. Radiat Prot Dosimetry 2006;121:461-5.
3. Napier ID. Reference doses for dental radiography. Br Dent J 1999;186:392-6.
4. González L, Vañó E, Fernández R. Reference doses in dental radiodiagnostic facilities. Br J Radiol 2001;74:153-6.
5. Williams JR, Montgomery A. Measurement of dose in panoramic dental radiology. Br J Radiol 2000;73:1002-6.
6. Goldstein A. Exposure and dose in panoramic radiology. Med Phys 1998;25:1033-40.
7. Tierris CE, Yakoumakis EN, Bramis GN, Georgiou E. Dose area product reference levels in dental panoramic radiology. Radiat Prot Dosimetry 2004;111:283-7.
8. Poppe B, Looe HK, Pfaffenberger A, Chofor N, Eenboom F, Sering M, *et al*. Dose-area product measurements in panoramic dental radiology. Radiat Prot Dosimetry 2007;123:131-4.
9. Hart D, Hillier MC, Wall BF. National reference doses for common radiographic, fluoroscopic and dental X-ray examinations in the UK. Br J Radiol 2009;82:1-2.
10. Hart D, Hillier MC, Shrimpton PC. Doses to Patients from Radiographic and Fluoroscopic X-ray Imaging Procedures in the UK-2010 Review. Chilton, Didcot: NRPB; 2012. p. 10-63.
11. Kim YH, Yang BE, Yoon SJ, Kang BC, Lee JS. Diagnostic reference levels for panoramic and lateral cephalometric radiography of Korean children. Health Phys 2014;107:111-6.
12. Hodolli G, Kadiri S, Nafezi G, Bahtijari M, Syla N. Diagnostic reference levels at intraoral and dental panoramic examinations. Int J Radiat Res 2019;17:147-50.
13. Lee JS, Kim YH, Yoon SJ, Kang BC. Reference dose levels for dental panoramic radiography in Gwangju, South Korea. Radiat Prot Dosimetry 2010;142:184-90.
14. Doyle P, Martin CJ, Robertson J. Techniques for measurement of dose width product in panoramic dental radiography. Br J Radiol 2006;79:142-7.
15. Jose A, Kumar AS, Govindarajan KN, Devanand B, Elango N. Assessment of adult diagnostic reference levels for panoramic radiography in Tamil Nadu region. J Med Phys 2019;44:292-7.
16. International Commission on Radiological Protection. Diagnostic Reference Levels in Medical Imaging. ICRP Publication 135. Ann. ICRP 46(1). Oxford: Pergamon Press; 2017.