Assessment of Regional Diagnostic Reference Levels in Dental Radiography in Tamil Nadu

Amal Jose, A. Saravana Kumar, K. N. Govindarajan, Sunil Dutt Sharma

Department of Medical Physics, PSG Institute of Medical Sciences and Research, Coimbatore, Tamil Nadu, Radiological Physics and Advisory Division, Bhabha Atomic Research Centre, Anushaktinagar, Mumbai, Maharashtra, India

Abstract

Aim: The aim of this article is to assess Tamil Nadu adult diagnostic reference levels (DRLs) by collecting radiation dose data from the four different dental modalities. Materials and Methods: The study was carried out using routine adult exposure settings in 131 intraoral, 75 panoramic, 35 cephalometric, and 10 dental cone beam computed tomography (CBCT) X-ray devices. DRLs were assessed for intraoral and extraoral (panoramic, cephalometric, and CBCT) examinations in terms of incident air kerma (K_i) and kerma area product (P_{KA}). Air kerma measurements, for all dental units, were made using calibrated RTI black Piranha 557 dosimeter (RTI Electronics AB, Sweden). The dosimeter was kept at the exit cone of the X-ray tube and on the detector side of the X-ray unit for intraoral and extraoral air kerma measurements, respectively. The obtained air kerma in extraoral modalities is multiplied with the beam area to evaluate P_{KA}. Results: The third quartile values calculated from the median for adult intraoral (mandibular molar), panoramic, cephalometric, and CBCT were 1.5 mGy, 116 mGy cm\(^2\), 40 mGy cm\(^2\), and 532 mGy cm\(^2\), respectively. The proposed DRL in the present study was comparable to those reported in Germany, Greece, the UK, Japan, and Korea. Conclusion: This study revealed the need for dose management and radiation dose optimization, in various dental facilities in the state. It was also found that dental facilities employed with the digital type of detector are not always related to lower exposure.

Keywords: Cephalometric radiography, diagnostic reference levels, intraoral radiography, panoramic radiography

INTRODUCTION

According to the United Nations Scientific Committee on the Effect of Atomic Radiation 2008 report, dental radiography is one of the most frequently used radiological procedures. Moreover, dentists prefer to use radiographs more frequently than any other health professional. Although radiation doses from dental exams are low and the associated health risk is stochastic, repeated dental exposures may lead to unnecessary patient exposure, leading to increased population dose and population risk. The radiation dose optimization during dental radiography is now an important concern for dental professionals and regulatory bodies.

Diagnostic reference levels (DRL) is an important dose optimization tool used in medical imaging recommended by many professional and international organizations, including the International Commission on Radiological Protection (ICRP), American College of Radiology, American Association of Physicists in Medicine, Health Protection Agency, and the International Atomic Energy Agency. DRLs for dental radiography, as in other imaging modalities, are usually set at the 75\(^{th}\) percentile of the median values from the survey of radiation doses.

The development in imaging technology and the modifications of examination protocols may produce sufficient image quality at lower doses. Thus, dose surveys may show variations in radiation doses between different dental facilities for the same examination and similar patient groups. DRLs are the standard tool for finding unusually high or low radiation dose levels, which calls for local review if constantly surpassed.

Several countries and organizations have already proposed DRL in dental radiography. Similar DRL studies in other regions of the country have been implemented, and results are comparable to those in different countries.

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: saravas@gmail.com

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKLHRPMedknow_reprints@wolterskluwer.com

How to cite this article: Jose A, Kumar AS, Govindarajan KN, Sharma SD. Assessment of regional diagnostic reference levels in dental radiography in Tamil Nadu. J Med Phys 2022;47:86-92.
were undertaken by our group too, in India, in computed tomography (CT),[11] but so far no serious studies have been undertaken in dental radiography. Hence, our group at PSG Institute of Medical Sciences and Research, Coimbatore, extended the DRL work to the field of dental radiography, in consultation with and a grant from the Atomic Energy Regulatory Board of India.

MATERIALS AND METHODS

Selection of dental facilities
DRL assessments were performed on 131 intraoral, 75 panoramic, 35 cephalometric, and 10 cone-beam CT (CBCT) units installed in dental clinics, colleges, and hospitals, spread across Tamil Nadu, India. These dental facilities were chosen based on their workload, clinical experience, and willingness to participate in the study for the establishment of dental DRLs in the country. Of the dental facilities surveyed, 89 facilities from more than 20 major cities in Tamil Nadu, having a total of 251 dental X-ray units, met our selection criteria and participated in the study. Before initiating the measurements in dental facilities, a questionnaire was posted to the various centers to collect data regarding the exposure parameters routinely used for imaging, radiation safety status, and type of detectors (film or digital) in use. The DRL studies were performed on all the units over a period of 2 years, between 2018 and 2020.

Dosimeter selection
Air kerma measurements, for all dental units, were made using calibrated RTI black Piranha 557 dosimeter (RTI Electronics AB, Sweden). The dosimeter, apart from air kerma, also displays the air kerma rate, tube voltage, exposure time, half-value layer, and total filtration. The calibration range of the dosimeter was suitable for the diagnostic range (35–155 kV) for all modes of dental X-ray examinations, as the Piranha readings are accurate to ± 1.5%.[12]

Quality assurance tests
Quality assurance (QA) tests were performed on all selected X-ray units before commencing the DRL assessment work. During the QA tests, parameters such as accuracy of exposure time, operating potential, the linearity of tube current (mA/mAs), consistency of radiation output, and radiation leakage level from X-ray tube housing were checked. DRL assessments were performed only on those units that passed the QA tests.

Intraoral radiography
Out of 131 intraoral units manufactured by 22 different vendors involved in the study, 64 were digital (storage phosphor-based/charge-coupled device [CCD] based), and the remaining were analog using films (E/F speed films) as image receptors. The majority of the X-ray units selected for this study were operating at 70 kV [Figure 1]. Out of the total, 91 units have preset exposure parameters. Cone lengths of X-ray units varied from 20 to 22 cm and the majority of units (126) used circular cones with 6 cm diameter (The remaining 5 units were equipped with rectangular field size having an area of 16 cm²).

The experimental method for DRL evaluation in intraoral radiography was based on the studies performed by Izawa et al.[13] and Poppe et al.[14]. The dosimeter was kept at the exit cone of the X-ray tube and the sensitive area of the dosimeter is fully covered by the primary beam as shown in Figure 2a. After positioning the dosimeter, Kₐᵢ (intraoral) measurements were taken using routine exposure parameters in the absence of patients. The dosimeter has a lead backing that blocks surface backscattering and gives accurate Kₐᵢ values.

Diagnostic reference levels quantities
In the present study, DRL in the intraoral (maxillary molar) examination was determined in terms of Incident air kerma (Kᵢ), expressed in mGy. On the other hand, DRLs in panoramic, cephalometric, and CBCT (small FOV) radiographs were determined in terms of Kerma Area Product (P_{KA}), expressed in mGycm², which, along with the air kerma, also takes into account the area of exposure. After finding Kᵢ (intraoral), and P_{KA} (extraoral) for the sample population from each center, the median value of the dose distribution was estimated for proposing the DRL.[4]
Extraoral radiography
Sixty of the 75 panoramic units, 27 of the 35 cephalometric units, and the entire CBCT units were equipped with direct digital (digital) (CCDs and complementary metal-oxide semiconductor) imaging systems. The remaining panoramic and cephalometric units were operating with a storage phosphor plate and using computed radiography (CR) cassettes as image receptors. In this study, 22, 8, and 5 different models of panoramic, cephalometric, and CBCT units, respectively were included.

The experimental methods for panoramic radiography were based on Lee et al.\cite{17} and the National Radiological Protection Board assessment of panoramic X-ray sets as proposed by Napier;\cite{18} The same method was also used in our previous studies for evaluating DRLs in panoramic radiography.\cite{17,18}

For the air kerma measurements, the solid-state dosimeter was placed directly at the detector side of the X-ray unit as shown in Figure 2b-d. It is significant that the dosimeter is positioned precisely with respect to the X-ray beam. The positional accuracy of the dosimeter was verified with the RTI’s Ocean 2014 software (that connects Piranha 557 directly to the computer). After placing the dosimeter, the standard patient exposure parameter was simulated and the air kerma was recorded over a standard adult exposure cycle (Minimum 20 procedures from each dental unit). For the entire study, the air kerma was measured in the absence of the patient. The measured air kerma is then multiplied by the exposed beam area (measured) at the detector position. CR cassette was used to capture the image of the X-ray field size by placing it at the detector position. The indirectly measured P_{KA} value is then compared with the displayed P_{KA}, either in the console monitor or in the extraoral unit itself, after every exposure. The same methods were followed for the DRL evaluation with cephalometric and CBCT units too.

Statistical method
Following the guidelines of ICRP 135,\cite{15} the present study has found the median value from each dental X-ray unit (median from minimum 20 readings). From these obtained median readings, the DRLs were found at the 75th percentile using Microsoft spreadsheets by the formula “PERCENTILE (array, k),” where the array represents the list of median indirectly measured P_{KA} or K_{i,1} values and k denotes 0.75 in the present study.

Results and Discussion
Typical exposure parameters used by the various dental facilities are shown in Table 1.

As shown in Table 2, it was observed that, in intraoral radiography, K_{i,1} ranged from 0.1 to 6.0 mGy with an average of 1.0 mGy (standard deviation [SD] = 1.0 mGy) for digital units and 0.2–5.2 mGy with an average of 1.6 mGy (SD = 1.1 mGy) for film based units. Notably, the maximum K_{i,1} (6 mGy) was observed from a digital unit that was functioning with no preset exposure parameter. The existences of 60 fold variation between the minimum (0.1 mGy) and maximum (6.0 mGy) K_{i,1} can be ascribed to the absence of an optimized preset exposure parameter, variation in the type of image receptors, exposure techniques, beam quality, inherent filters, cone length, and age of the unit. The trained X-ray engineer (who is installing the equipment) or medical physicist should educate the dentists/radiographers regarding the optimized use of exposure parameters if the preset exposure parameter is not present.

The second observation is that for panoramic radiography, the P_{KA} values of direct digital units ranged from 40.5 to 149.1 mGy cm^2 with an average of 91.4 mGy cm^2 (SD = 30.5 mGy cm^2), whereas the P_{KA} of CR type of units ranged from 64.9 to 165.1 mGy cm^2 with an average of 108.9 mGy cm^2 (SD = 28.9 mGy cm^2). Twenty-seven units (36%) were assessed with P_{KA} >100 mGy cm^2, suggesting the requirement of necessary attention to be paid by the manufacturers when setting the adult standard mode of exposure parameters. The average median P_{KA} was almost 19% higher in CR systems than digital systems. This difference can be mainly ascribed to the absence of an optimized preset exposure parameter, variation in the type of image receptors, exposure techniques, beam quality, inherent filters, cone length, and age of the unit. The trained X-ray engineer (who is installing the equipment) or medical physicist should educate the dentists/radiographers regarding the optimized use of exposure parameters if the preset exposure parameter is not present.

In cephalometric radiography, almost a 6-fold difference was observed between the minimum (12.3 mGy cm^2) and
Jose, et al.: Dental DRL in Tamil Nadu region

Table 2: Median and proposed diagnostic reference levels values for different dental examinations

| Parameters | Intraoral (K_{a,i} in mGy) | Panoramic (P_{KA} in mGycm^2) | Cephalometric (P_{KA} in mGycm^2) | CBCT (P_{KA} in mGycm^2) |
|------------|----------------------------|-------------------------------|----------------------------------|---------------------------|
| Median K_{a,i} (mGy) | Film | Digital | CR | Digital | CR | Digital | CR | Digital | CR | Digital | Digital |
| Range (average) | 0.2-5.2 (1.6) | 0.1-6.0 (1.0) | - | - | - | - | - | - | - | - |
| SD | 1.1 | 1.0 | - | - | - | - | - | - | - | - |
| Median P_{KA} (mGycm^2) | - | - | 64.9-165.1 (108.9) | 40.5-149.1 (91.4) | 19.4-42.4 (33.4) | 12.3-79.0 (34.2) | 176.1-890.5 (460.4) |
| SD | - | - | 28.9 | 30.5 | 7.2 | 12.7 | 240.6 |
| DRL (3rd quartile) | - | - | K_{a,i} (mGy) | 2 | 1 | - | - | - | - | - |
| P_{KA} (mGycm^2) | - | - | 135 | 113 | 39 | 40 | 532 |
| Deviation range (%) between console P_{KA} and indirectly measured P_{KA} | - | ±18 | - | -8-12 | - | -15-5 |
| SD | - | - | 28.9 | 30.5 | 7.2 | 12.7 | 240.6 |

Table 3: Comparison of present studies' and other countries' diagnostic reference levels for dental radiography

| Type of dental radiography | Country | Year | Number of units | DRL (3rd quartile) |
|----------------------------|---------|------|-----------------|-------------------|
| Intraoral (mandibular molar) (K_{a,i} in mGy) | Japan[13] | 2017 | 3 | 1.51 |
| Germany[14] | 2006 | 60 | 1.5 |
| Cyprus[21] | 2016 | 20 | 4.75 |
| Korea[22] | 2012 | 102 | 3.1 |
| Peru[23] | 2021 | 254 | 4.21 |
| This study | 2021 | 131 | 1.5 |
| Panoramic (P_{KA} in mGycm^2) | Greece[24] | 2004 | 62 | 117 |
| Korea[25] | 2011 | 42 | 120.3 |
| UK[26] | 2000 | 16 | 139 |
| Germany[27] | 2006 | 50 | 101 |
| Kosovo[28] | 2019 | 21 | 93 |
| This study | 2021 | 75 | 116 |
| Cephalometric (P_{KA} in mGycm^2) | Germany[29] | 2007 | 20 | 32.6 |
| UK[30] | 2011 | 42 | 41 |
| This study | 2021 | 35 | 40 |
| CBCT (P_{KA} in mGycm^2) | Portugal[31] | 2020 | 69 | 580 |
| Finland[32] | 2016 | 47 | 360 |
| UK[33] | 2017 | 214 | 265 |
| This study | 2021 | 10 | 532 |

CBCT: Cone beam computed tomography, DRL: Diagnostic reference level, K_{a,i}: Incident air kerma, P_{KA}: Kerma area product

maximum (79.0 mGycm^2) direct digital P_{KA} values whereas, there is only a 2-fold difference between the minimum (19.4 mGycm^2) and maximum (42.4 mGycm^2) values of CR units. This difference can be mainly attributed to the difference in exposure parameters, beam area, inherent filters, and the tube age. Further, the deviation between console displayed and indirectly measured P_{KA} values varied from −8% to 12% (25 units).

Following the division proposed by Ludlow[20] small FOVs, in CBCT, are defined as any field with a height ≤ of 10 cm. All operators used small FOV in the present study. The majority of CBCT units (7 units) are operating at 86–90 kVp. The P_{KA} values of CBCT units ranged from 176.1 to 890.5 mGycm^2 with an average of 460.4 mGycm^2 (SD = 240.6 mGycm^2) [Table 2]. The difference in tube rotation time, preset exposure parameters, voxel size, and FOV might also result in variation in P_{KA}. It was observed that different FOVs were set at various dental facilities by the X-ray engineer for the same CBCT units and the same examination, resulting in unnecessary radiation exposure to anatomical regions not related to the diagnostic examination. Apart from that, the lack of training for the X-ray operators in radiation protection also makes them use the same FOV size, independent of the anatomic region, during the X-ray procedure. Regarding the P_{KA} values shown by the equipment, all the equipment have P_{KA}-meter included, and the deviation range between console P_{KA} and indirectly measured P_{KA} values were between -15% and 5% for CBCT units.
The third quartile $K_a$ value for mandibular molar intraoral radiography was 1.5 mGy (For Film, DRL = 2 mGy and for Digital, DRL = 1 mGy). The third quartile $P_{KA}$ values for panoramic, cephalometric, and CBCT radiography were 116 mGycm$^2$ (For CR, DRL = 135 mGycm$^2$ and for Digital, DRL = 113 mGycm$^2$), 40 mGycm$^2$ (For CR, DRL = 39 mGycm$^2$ and for Digital 40 mGycm$^2$) and 532 mGycm$^2$, respectively.

Figure 3 shows the graphical representation of proposed DRLs for intraoral, panoramic, cephalometric, and CBCT examinations. The third quartile values of all the examinations are marked in the figure. Alongside with the $P_{KA}$ values, the image detectors used are also indicated in the graphs. There exists a large difference between the radiation doses of dissimilar X-ray units for the same examination. As an example, the assessed $P_{KA}$ values for panoramic examinations varied from 40.5 to 165.1 mGycm$^2$.

Based on the questionnaire study, it was observed that the majority of dental units included in this study were digital detector-based and, many participants (dentists and radiographers) were unwilling to adjust the exposure parameters according to the tooth location and patient size. However, the higher radiation dose observed in many digital-based dental units in the present study further confirms that after replacing film/screen with digital systems, the exposure parameters were not changed effectively to achieve dose optimization.

The variation in dose quantity values among different dental facilities indicates the scope for publishing technical guidelines and image quality criteria for dental radiography modalities. The observed differences between indirectly measured $P_{KA}$ and the console $P_{KA}$ [Table 2] were less than the tolerance interval ($\pm 30\%$) and the observed variation can be attributed to the difference in the measurement method and dosimetry.
Comparison of the third quartile value of $K_{\alpha}$ for the intraoral procedure, with the other countries’ DRLs [Table 3], reveals that the values obtained in this study are close to values obtained in studies in Japan (1.51 mGy) and Germany (1.5 mGy), and lower than values obtained in Cyprus (4.75 mGy), Korea (3.1 mGy), and Peru (4.21 mGy). The vast use of fast-speed films and digital detectors may also have contributed to the lower DRLs in the present study.

Our results in panoramic radiography were similar to the results of Greece, and Korea, lower than the results of the UK and higher than Germany and Kosova results [Table 3]. In cephalometric radiography, the measured $P_{K\alpha}$ values were comparable to the values in Germany and the UK. The variation in the present study $P_{K\alpha}$ may be attributed to the difference in patient physical parameters, exposure parameters, tube inherent filtration, type of dosimeter and the method of use, and the year of study (older and newer units).

DRL studies for CBCT radiography have been carried out only in some countries such as Portugal, Finland and the UK [Table 3]. Finland and the UK chose the data without adapting the values to the most used FOV. The DRL for small FOV in Portugal is comparable with the present study.

The previous study done by our team has used mean value rather than the median for proposing DRL in panoramic radiography as per the earlier recommendations. However, the latest ICRP recommendation on DRL (ICRP 135, 2017) recommends the use of a facility’s median value (rather than mean value) for calculating the 75th percentile as this is renowned to be more robust and representative of the patient population.

The constraint of this study is the limited number of X-ray devices studied. However, it is suggested to include a representative number of dental X-ray facilities for the assessment of national DRLs in dental radiography.

**Conclusion**

Dental DRLs were proposed in intraoral, panoramic, cephalometric, and CBCT dental radiography in India. The proposed DRLs are comparable with the other countries’ DRLs. The selection of suitable exposure parameters for dental radiography should be driven by the clinical suggestion from the dentists. However, the wide dose distribution obtained in the present study indicates the need to improve the radiation dose optimization without affecting the image quality. Further surveys are suggested at different states across the country to propose the national DRL as well as to establish criteria for optimal levels of image quality considering patient dose. It is suggested to conduct more training programs in the use of image receptors and dose optimization in dental radiography for radiographers and dentists.

**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 the Effects of Atomic Radiation (UNSCEAR). Sources and effect of ionizing radiation. UNSCEAR 2008 Report. Vol. 1. New York, USA: UNSCEAR Publications; 2010.
2. Shahab S, Kavosi A, Nazarinia H, Mehralizadeh S, Mohammadpour M, Emami M. Compliance of Iranian dentists with safety standards of oral radiology. Dentomaxillofac Radiol 2012;41:159-64.
3. Lee BD, Ludlow JB. Attitude of the Korean dentists towards radiation safety and selection criteria. Imaging Sci Dent 2013;43:179-84.
4. Vahé E, Miller DL, Martin CJ, Rehani MM, Kang K, Rosenstein M, et al. ICRP publication 135: Diagnostic reference levels in medical imaging. Ann ICRP 2017;46:1-144.
5. American College of Radiology (ACR). ACR-AAPM Practice Parameter for Diagnostic Reference Levels and Achievable Doses in Medical X-Ray Imaging – Revised 2018 (Resolution 40). Available from: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/diag-ref-levels.pdf?la=en. [Last accessed on 2020 Jul 02].
6. Hart D, Hillier MC, Wall BF. Doses to Patients from Radiographic and Fluoroscopic X-Ray Imaging Procedures in the UK – 2005 Review. HPA-RPD-029. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/431134/HPA-RPD-029.pdf. [Last accessed on 2020 Jul 01].
7. International Atomic Energy Agency. Diagnostic Reference Levels. Available from: https://www.iaea.org/resources/rpop/health-professionals/radiology/diagnostic-reference-levels. [Last accessed on 26 Jun 20].
8. Alcaraz M, Velasco F, Martínez-Beneyto Y, Alcaraz-Saura M, Velasco E, Achel GD, et al. Evolution of diagnostic reference levels in Spanish intraoral radiology. Radiat Prot Dosimetry 2012;151:166-71.
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;82:1-12.
10. European Commission. Guidance on Diagnostic Reference Levels (DRLs) for medical exposures. In: Radiation Protection 109. Luxembourg: Office for Official Publications of the European Communities; 1999.
11. Saravanakumar A, Vaideki K,Govindarajan KN, Jayakumar S. Establishment of diagnostic reference levels in computed tomography for select procedures in Puducherry, India. J Med Phys 2014;39:50-5.
12. RTI Electronics AB. Piranha Specifications. Molndal, Sweden: RADIOQUA; 2014.
13. Izzawi M, Harata Y, Shiba N, Koizumi N, Ozawa T, Takahashi N, et al. Establishment of local diagnostic reference levels for quality control in intraoral radiography. Oral Radiol 2017;33:38-44.
14. Poppe B, Loose HK, Pfaffenberger A, Eenboom F, Choñor N, Sering M, et al. Radiation exposure and dose evaluation in intraoral dental radiology. Radiat Prot Dosimetry 2007;123:262-7.
15. Lee JS, Kim YH, Yoon SJ, Kang BC. Reference dose levels for dental panoramic radiography in Gwangju, South Korea. Radiat Prot Dosim 2010;142:184-90.
16. Napier ID. Reference doses for dental radiography. Br Dent J 1999;186:392-6.
17. 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.
18. 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.
19. Granlund C, Thilander-Klang A, Ylhan B, Lothfag-Hansen S, Ekestubbe A. Absorbed organ and effective doses from digital intra-oral and panoramic radiography applying the ICRP 103 recommendations for effective dose estimations. Br J Radiol 2016;89:1-9.
20. Ludlow JB. Dose and risk in dental diagnostic imaging: With emphasis on dosimetry of CBCT. Kor J Oral Maxillofac Radiol 2009;39:175-84.
21. Christofides S, Priti E, Lampaskis M, Papaefstathiou C. Local diagnostic reference levels for intraoral dental radiography in the public hospitals of Cyprus. Phys Med 2016;32:1437-43.

22. Kim EK, Han WJ, Choi JW, Jung YH, Yoon SJ, Lee JS. Diagnostic reference levels in intraoral dental radiography in Korea. Imaging Sci Dent 2012;42:237-42.

23. Portocarrero Bonifaz A, Camarena Rodriguez CS, Palma Esparza R. Diagnostic reference levels for common X-ray procedures in Peru. Cereus 2021;13:e18566.

24. Tierris CE, Yakoumakis EN, Bramis GN, Georgiou E. Dose area product reference levels in dental panoramic radiology. Radiat Prot Dosimetry 2004;111:283-7.

25. Han S, Lee B, Shin G, Choi J, Kim J, Park C, et al. Dose area product measurement for diagnostic reference levels and analysis of patient dose in dental radiography. Radiat Prot Dosimetry 2012;150:523-31.

26. Williams JR, Montgomery A. Measurement of dose in panoramic dental radiology. Br J Radiol 2000;73:1002-6.

27. Poppe B, Looe HK, Pfaffenberger A, Chofer N, Eenboon F, Sering M, et al. Dose-area product measurements in panoramic dental radiology. Radiat Prot Dosimetry 2007;123:131-4.

28. 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.

29. Looe HK, Eenboom F, Chofer N, Pfaffenberger A, Sering M, Rühmann A, et al. Dose-area product measurements and determination of conversion coefficients for the estimation of effective dose in dental lateral cephalometric radiology. Radiat Prot Dosimetry 2007;124:181-6.

30. Holroyd JR. National reference doses for dental cephalometric radiography. Br J Radiol 2011;84:1121-4.

31. Trindade H, Morais I, Moreira A. Extraoral and CBCT dental exposures in Portugal. Radiat Prot Dosimetry 2020;190:283-8.

32. Turnbull-Smith S. Cone-beam computed tomography examinations of the head and neck region in Finland: indications and patient radiation dose. 2016. Available from: http://urn.fi/URN:NBN:fi:ttly-201608264465. [Last accessed on 2020 April 10].

33. Public Health England. Dose to patients from dental radiographic X-ray imaging procedures in the UK. 2017. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/817972/2019_dental_NDRL_report.pdf. [Last accessed on 2020 May 03].

34. Deleu M, Dagnan D, Berg I, Bize J, Dula K, Lenoir V, et al. Establishment of national diagnostic reference levels in dental cone beam computed tomography in Switzerland. Dentomaxillofac Radiol 2020;49:1-8.

35. Vassileva J, Rehani M. Diagnostic reference levels. Am J Roentgenol 2015;204:w1-3.

36. Rehani MM. Limitations of Diagnostic Reference Level (DRL) and introduction of Acceptable Quality Dose (AQD). Br J Radiol 2015;88:1-3.