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Estimation Of Entrance Surface Dose Of Patients In Intraoral Dental Radiography At Mcdan Dental Clinic, Ado-Ekiti, Ekiti State, Nigeria

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ABSTRACT
The safe and effective use of radiography depends on optimizing radiation exposure to achieve diagnostic image quality while minimizing patient dose. Inadequate exposure may compromise image quality and diagnostic accuracy, whereas excessive exposure unnecessarily increases radiation risk. Entrance Surface Dose (ESD) and Diagnostic Reference Levels (DRLs) are key indicators for evaluating and optimizing patient radiation exposure. In intraoral dental radiography, ESD is particularly important because radiosensitive organs, such as the thyroid and salivary glands, are located close to the X-ray beam. Although pioneering Nigerian studies have reported radiation doses to selected organs, comprehensive evaluations of patient ESD during intraoral dental radiography remain limited. This highlights the need for routine patient dose audits in Nigerian dental clinics, supported by the integration of Radiation and Medical Physicists to strengthen dose optimization, quality assurance, and radiation protection. This study aims to estimate the doses delivered to patients during Intraoral dental radiography at McDan Dental Clinic, Ado-Ekiti, Ekiti state, Nigeria and employed a clinic-based prospective cross-sectional observational design. The data were collected on 46 patients using Ai Ray Digital Dental X-ray machine including their socio-demographic data (sex, age, location). The general ESDs were calculated using Davies model via exposure parameters (kVp, mAs, FFD) and mean value obtained was 1.75±0.17 mGy; found to be within the internationally recommended diagnostic reference range of 1-3 mGy according to IAEA and also when compared to similar studies in Africa and other continents. This reinforces the importance of maintaining strict optimization in radiographic practices to avoid unnecessary patient exposure.

Keywords:
Diagnostic reference levels (DRLs),
Entrance surface dose (ESD),
Exposure parameters,
Intraoral dental radiography.

INTRODUCTION

Dental radiography is the use of X-ray imaging to visualize the teeth, jaws, and surrounding structures. The safe and effective use of radiography hinges on the optimization of radiation dose as too little exposure compromises image quality and diagnostic confidence, while excessive exposure increases patient risk. Two key metrics in this optimization are the entrance surface dose (ESD) and diagnostic reference levels (DRLs).

ESD is particularly relevant in intraoral radiography due to the proximity of sensitive organs such as the thyroid and salivary glands. Although the Nigeria Nuclear Regulatory Authority (NNRA) and academic institutions contribute to radiation safety through continuing professional education, there is still a lack of nationally endorsed DRLs for dental radiography. NNRA responsibilities are implemented through regulatory instruments such as the Nigerian Basic Ionizing Radiation

Regulations (2023), which are consistent with the IAEA Basic Safety Standards.

International bodies like the IAEA and ICRP recommend general ESD surveys to support the development of DRL and quality assurance in clinical practice (IAEA 2014; ICRP 2007). In contrast, Nigeria lacks robust data on general ESD values in dental radiography settings, limiting national dose optimization efforts. Without these benchmarks, practitioners have no standard against which to compare their practices. The absence of periodic general audits (which is greatly achievable by the combination of three professionals – dentist, radiographer, and medical physicist) and dose reporting requirements further weakens the drive toward radiation protection.

A significant challenge in Nigeria's dental radiography practice is the lack of a national database for general radiation exposure, such as Diagnostic Reference Levels (DRLs), which would guide practitioners in optimizing patient radiation doses. Furthermore, many dental practitioners in Nigeria still lack sufficient training in dosimetry and radiation protection protocols, which can lead to unnecessary radiation exposure for patients. The integration of Radiation and Medical Physicists into the dental healthcare system is currently underdeveloped, contributing to the absence of effective radiation safety measures in many practices.

Published studies from different regions of the world demonstrate that patient radiation doses during intraoral dental radiography vary according to equipment characteristics, detector technology, exposure parameters, operator experience, and quality assurance practices. However, most countries implementing routine optimization programmes report mean Entrance Surface Dose (ESD) values within the internationally accepted range of 1-3 mGy for adult intraoral examinations. For example, reported ESD values include 1.20 mGy in the United Kingdom (Public Health England, 2017), 1.50 mGy in Germany and Japan (Lee et al., 2019), 2.00 mGy in Western Australia (Storm & Nezich, 2023), 2.87 mGy in Sudan (Ahmed, 2021) and so on. These variations largely reflect differences in digital imaging systems, beam filtration, collimation, exposure protocols, and compliance with quality assurance programmes. Such international data provide valuable benchmarks for evaluating local practice and establishing Diagnostic Reference Levels in countries where national reference values are not yet available.

While some pioneering Nigerian studies, such as Jibiri et al. (2017) and Agboje et al. (2020) have provided crucial organ-based insights, none assessed overall general ESD, that is, the total dose received at skin entry during routine intraoral dental imaging. The work of Jibiri et al. (2017) employed Thermoluminescent Dosimeters (TLDs) on 40 adult patients in Ibadan to measure ESD delivered to thyroid, eye, and parotid glands during intraoral radiography. Mean doses ranged approximately 0.18 mGy (thyroid), 0.22 mGy (parotid), and 0.22 mGy (eye), all well below thresholds for deterministic injury (Jibiri et al., 2017). Their findings helped establish initial Nigerian based data for potential Diagnostic Reference Levels (DRLs) for those organs.

Agboje et al. (2020) extended this work in Aba with 55 patients, using the same methodology – that is, placing TLDs on thyroid and parotid and parotid glands. They reported mean ESD values of 1.07 ± 0.62 mGy (parotid) and 1.05 ± 0.82 mGy (thyroid), which are within recommended safety margins but significantly higher than Jibiri's values, likely due to differences in equipment, positioning, or exposure protocols (Agboje et al., 2020). These studies underscore the importance of organ-level dosimetry and highlight variability across settings. Since Nigeria lacks robust data on general ESD values in dental radiography settings, limiting national dose optimization efforts, there is a pressing need to estimate patient doses in Nigerian dental clinics with the intervention of medical physicists.

Patient radiation dose may be evaluated using either dosimetric measurement such as Thermoluminiscent dosimeters (TLDs) or mathematical models based on radiographic exposure parameters which provide a practical and reliable approach for estimating patient dose. One, in particular, is the Davies model, which estimates Entrance Surface Dose (ESD) using obtainable exposure parameters such as tube voltage (kVp), tube loading (mAs), tube output, focus-to-skin distance (FSD) and backscatter factor (Davies et al., 1997). The model has been successfully applied in several diagnostic radiology studies because of its simplicity, reproducibility, and suitability for clinical dose audits.

This paper is aimed at estimating the doses delivered to patients during intraoral dental examinations at McDan Dental Clinic, Ado-Ekiti, Ekiti State, Nigeria. This is going to be achieved by (i) determining the socio-demographic characteristics and exposure parameters of patients undergoing intraoral dental radiography;(ii) estimating the Entrance Surface Dose (ESD) delivered to patients using a suitable theoretical and mathematical model of dose calculation based on recorded exposure parameters; (iii) comparing the estimated patient doses with those reported in similar studies from other regions or countries, taking into account local realities and contextual factors such as equipment type, operator experience, and radiographic protocols.

MATERIALS AND METHODS

The study employed a clinic-based prospective cross-sectional observational design and took place between April and May 2025 at McDan Dental Clinic, Adehun area, Iworoko road, Ado-Ekiti, Ekiti state, Nigeria. This clinic was equipped with an Ai Ray Handheld Digital

Dental X-Ray Machine whose maximum voltage was around 70 kV.

Target

Included in this study were the adult patients of McDan Dental Clinic, irrespective of sex and age, who had undergone intraoral dental radiographic examination during the period. According to ICRP (2023), sample size for a unit like this for clinical audit is at least 20 patients for radiography to assure confidence in the determination of dose and 46 patients were used in this study.

Collection and Statistical Analysis

The information was collected using a sheet adapted according to the model of the Institute of Radiation Protection and Nuclear Safety (IRPNS) dosimetric evaluation (Guiswe et al., 2019). The irradiation parameters (kVp, mAs), the geometric parameters (FFD, FSD), the socio-demographic (age, sex, and location) and anthropometric data (body thickness) were analyzed. The calculations of the entrance surface dose (ESD) of patients, range, mean, frequency, percentage, and the standard deviation were done mathematically.

Calculation of the Dose

The irradiation and geometric parameters involved in the calculation of the entrance surface dose were measured and calculated. Then, the calculation of the entrance surface dose for each patient was done according to the Davies model. This model was chosen because it integrates all the elements directly, involved in the realization of radiographic examinations and the definition of the dose at the entrance of the skin (Guiswe et al., 2019).

Ethical Approval

Ethical approval was granted by the clinic where the research took place and only images of good qualities accepted for interpretation were considered.

Other data concerning the machine is provided for in table 1 below and was gotten from the machine manual.

Table 1: X-ray Machine Specific Data

X-ray Center	X-ray Tube Model	Output (mGy/mAs)	Year of Installation	Additional filtration (mm Al)	Total filtration (mm Al)
McDan Dental Clinic	KL11-0.4-70	0.1866	August 2023	0.8	1.6

The Davies model of Entrance Surface Dose (ESD) *(Davies et al., 1997)* calculation is given as;

$$ESD(mGy) = (OP) \times \left(\frac{kV}{80}\right)^2 \times mAs \times \left(\frac{100}{FSD}\right)^2 \times BSF \qquad (1)$$

Where ESD = Entrance Surface Dose in mGy

OP = Tube Output

kV = Tube Potential (kilovolt)

mAs = Tube Intensity (milliamperage second)

BSF = Back Scatter Factor = 1.35

FSD = Focus Skin Distance in cm

The Davies model normalizes output to a reference tube potential of 80 kV. This reference value was established from empirical measurements of diagnostic X-ray tube output and serves as a standardization point for estimating tube output across different operating voltages. In the model, the term $\left(\frac{kV}{80}\right)^2$ accounts for the dependence of X-ray tube output on tube potential, assuming that tube output is approximately proportional to the square of the applied voltage under typical diagnostic radiography conditions (Davies et al., 1997).

Tube Output was gotten from the machine manual. kV and mAs were read from the machine, FSD was determined from the subtraction of FFD and Body thickness. FFD was measured with tape; the distance between the projection area and the machine. Body thickness was measured on the computer with the aid of a Ruler tool on software called HandyDentist. The use of BSF of 1.35 was used because the value is consistent with internationally accepted dosimetric practice, appropriate for intraoral dental radiology performed at 70 kVp, contributes minimally to the overall uncertainty of the ESD estimates and comparable to values reported in previous diagnostic radiology studies (Davies et al., 1997 & ICRP, 2007).

RESULTS AND DISCUSSION

Socio-demographic Data

The socio-demographic data involved in this study include the sex/gender, age, and location of a total of 46 adult patients, comprising of 24 males (52.17%) and 22 female patients (47.83%). After evaluation, the summary of the socio-demographic data was presented in the table 2. As shown, the mean age for male patients is 30.16 years, while that of female patients is 38.72 years. The overall mean age of the patients is 34.26 years old.

Overall Knowledge of the Irradiation Parameters Used during Exams

The parameters presented in this study are those that made it possible to calculate the doses of the patients in accordance with the knowledge and laws of Physics, Mathematics and Medical Science. These parameters are very important in the process of estimating the dose delivered. After calculation, the mean ESD was 1.75 mGy and the standard deviation was ±0.17. The minimum and maximum entrance surface dose ranged from 1.17 mGy to 1.91 mGy in this Intraoral Dental Radiography.

Study of Comparative Values

The value obtained (mGy) was compared with those obtained elsewhere by the same approaches across the continents. This comparison was done in order to validate the findings in this study by placing them in a broader context and to determine its alignment with international standards.

Table 2: Summary of Socio-Demographic Data

Variables	Category	Frequency (n)	Percentage (%)	Mean ± SD	Range
Gender	Male	24	52.17%		
	Female	22	47.83%		
Age (Years)	Total	-	-	34.26 ± 0.52	18-89
	Male	-	-	30.16 ± 0.34	18-61
	Female	-	-	38.72 ± 0.69	19-89
Body Thickness (cm)	Total	-	-	2.12	1.9-2.5
	Male	-	-	2.08	1.9-2.5
	Female	-	-	2.16	1.9-2.5
Location	Ado	36	78.26%	-	-
	Iworoko	5	10.87%	-	-
	Oye	2	4.35%	-	-
	Ifaki	1	2.1%	-	-
	Ikere	1	2.1%	-	-
	Omuo	1	2.1%	-	-
Total		46	100%		

Estimation of the Entrance Surface Dose (ESD) delivered to patients

The parameters presented in this study are those that made it possible to calculate the doses of the patients in accordance with the application of physics, mathematics and medical science. These parameters are very important in the process of estimating the dose delivered. After estimation, the mean ESD was 1.75 mGy and the standard deviation was ±0.17. The minimum and maximum entrance surface dose ranged from 1.17 mGy to 1.91 mGy in this Intraoral Dental Radiography. Table 3 shows the technical parameters used in the estimation of the ESD, while table 4 gives the summary of ESD values as estimated.

Table 3: Technical Parameters Used

Exam	Number of Patients	kVp	mAs Range	Mean mAs	FSD Range	Mean FSD	Age Range	Mean Age
Intraoral	46	70	0.48 - 0.75	0.70	27.5 - 28.1	27.87	18 – 89	34.26

Table 4: Summary of ESD values

Subjects	Examination Type	ESD Range (mGy)	Mean ESD (mGy)	Standard Deviation
Adult patients	Intraoral	1.17 – 1.91 mGy	1.75 mGy	±0.17 mGy

Implication of the Result

The mean Entrance Surface Dose (ESD) of 1.75 ± 0.17 mGy indicates that patient radiation exposure during intraoral dental radiography at McDan Dental Clinic was within internationally reported reference ranges for similar examinations. This suggests that the exposure parameters used in the clinic generally achieved an appropriate balance between obtaining diagnostic image quality and minimizing patient radiation exposure. The findings therefore reflect satisfactory implementation of the principle of radiation dose optimization (ALARA), even though opportunities remain for further improvement through routine quality assurance and periodic equipment performance evaluation.

The findings also demonstrate the usefulness of mathematical dose estimation methods, such as the Davies model, in settings where direct dosimetry equipment is unavailable. In many developing countries, including Nigeria, limited access to dosimeters and quality control instruments often restricts routine patient dose assessment. The successful application of the Davies model in this study provides a practical and cost-effective approach for conducting radiation dose audits and monitoring patient exposure in resource-constrained environments.

Furthermore, this study reinforces the need for greater involvement of medical physicists in dental radiology services. Medical physicists play a critical role in patient dosimetry, quality assurance, optimization of exposure parameters, equipment performance evaluation, and the establishment of Diagnostic Reference Levels. Their integration into dental imaging practice would strengthen radiation safety programmes and improve compliance with national and international radiation protection standards.

Finally, the study supports continued collaboration among dentists, radiographers, medical physicists, and regulatory agencies such as the Nigerian Nuclear Regulatory Authority (NNRA) to promote routine clinical audits, optimize patient doses, and improve radiation protection practices. Such multidisciplinary efforts will contribute to safer dental imaging services and provide evidence for the development of national policies and dose optimization strategies in Nigeria.

Comparison of Mean ESD with other Comparative Studies

The value obtained (mGy) was compared with those obtained elsewhere by the same approaches across the continents as shown in table 5. This comparison was done in order to validate the findings in this study by placing them in a broader context and to determine its alignment with international standards. Recall that intraoral examinations typically range from 1 mGy to 3 mGy, as stipulated by both the IAEA and ICRP.

Table 5: Comparison of mean ESD (mGy) with other works

Exam	CS	IND	JPN	GER	KOR	UK	POL	W. AUS	SDN	SAF
Intraoral	1.75	1.5[a]	1.51[a]	1.5[a]	1.3[b]	1.2[c]	1.96[d]	2.0[e]	2.87[f]	2.1[g]

[Note: [a]Amal et al. (2022); [b]Min Young et al. (2019); [c]Public Health (2017); [d]Bekas & Pachocki (2013); [e]Storm & Nezich (2023); [f]Hanaa (2021), [g]Moodley et al (2016)].

(Meaning of Notations: CS – Current study, IND – India, JPN – Japan, KOR – Korea, GER – Germany, UK – United Kingdom, POL – Poland, W. AUS – Western Australia, SDN – Sudan, SAF – South Africa).

Interpretation of Differences in ESD Values

The Entrance Surface Dose (ESD) of 1.75 ± 0.17 mGy observed in the present study was higher than values reported in Korea and the United Kingdom, but lower than those reported in Sudan and South Africa. These variations are expected because patient radiation dose in dental radiography is influenced by several technical, equipment-related, and patient-specific factors.

One important factor is the type and technological capability of the X-ray equipment. Modern digital intraoral X-ray systems equipped with high-frequency generators and advanced image receptors generally require lower exposure settings to produce diagnostically acceptable images than older or less efficient systems.

Differences in exposure parameters, particularly tube potential (kVp), tube current (mA), and exposure time, also contribute to variations in ESD. The present study employed a fixed tube potential of 70 kVp and tube current of 3 mA, with exposure times adjusted according to the tooth being examined. Studies using higher beam energy combined with shorter exposure times or more efficient digital receptors may achieve lower patient doses because the X-ray beam penetrates tissues more effectively, thereby reducing the amount of radiation absorbed at the skin surface. On the other hand, longer exposure times or less efficient imaging systems may increase ESD.

CONCLUSION

This study successfully estimated the mean Entrance Surface Dose (ESD) for intraoral dental radiography at McDan Dental Clinic, yielding a value of 1.75 mGy. This outcome demonstrates a commendable level of radiation and patient safety in the facility. A critical factor contributing to this optimal ESD is the use of a digital dental X-ray system, which inherently supports dose reduction. Although the study was limited by its single-centre design, the result of this study can be useful as a baseline of DRLs by the Nigerian Nuclear Regulatory Authority (NNRA) and Federal Ministry of Health to support future multicentre studies and establishment of local and national Diagnostic Reference Levels for dental radiography in Nigeria.

This study recommends the continued use of Digital X-ray Systems at it plays a vital role in achieving and sustaining low patient doses. It also recommends that similar dose assessment studies be conducted across other dental clinics in Nigeria to establish a national Diagnostic Reference Level (DRL), tailored to Nigeria's clinical and environmental context. Furthermore, to enhance radiation safety and promote evidence-based optimization, the recruitment and integration of qualified radiation and medical physicists into dental and radiology practices should be made a regulatory priority in Nigeria. Their expertise will support patient dose auditing, equipment calibration, staff training, and policy development. Lastly, National regulatory bodies such as the Nigerian Nuclear Regulatory Authority (NNRA) and the Federal Ministry of Health should update and enforce guidelines that ensure compliance with current ICRP and IAEA recommendations.

REFERENCES

Ahmed, H. M. B. (2021). Estimation of Entrance Surface of X-ray Dose during Dental Examination. Global Journal of Research and Review, Vol. 8, No. 4:73. https://www.imedpub.com/articles/estimation-of-entrance-surface-of-xray-dose-during-dental-examination.php

Agboje, A. A., Robinson, E. D., Onwuchukwu, U., & Nzotta, C. C. (2020). Radiation dose to the parotid and thyroid glands in intraoral radiography. EAS Journal of Radiology & Imaging Technology, 2(2), 32-37. https://doi.org/10.36349/EASJRIT.2020.v02i02.004

Amal, J., Saravana Kumar, A., Govindarajan, K. N., Sunil S. D. (2022). Assessment of regional diagnostic reference levels in dental radiography in Tamil Nadu. Journal of Medical Physics, Volume 47(1), 34-40. https://doi.org/10.4103/jmp.jmp_100_21

Bekas M. and Pachocki K. A. (2013). The dose received by patients during dental X-ray examination and the technical condition of radiological equipment. Medycyna Pracy; 64(6): 755-759. http://dx.doi.org/10.13075/mp.5893.2013.00074

Davies, M., McCallum, H., White, G., & Brown, J. (1997). Patient dose audit in diagnostic radiography using custom designed software. Radiography, 3(1), 17-25. https://doi.org/10.1016/S1078-8174(97)80021-1

Guiswe, G., Fouda H. P. E., Amvene J.M., and Guena M. N. (2019). Exposure Levels of Adult Patients during Radiographic Examinations: Sinuses and Coastal Grill Cases at the Ngaoundere Regional Hospital, Cameroon. Radiology Research and Practice Volume 2019, Article ID 5452149, 5 pages. https://doi.org/10.1155/2019/5452149

IAEA (2014). Radiation Protection in Dental Radiology. Safety Reports Series No. 61. https://www.iaea.org/resources/rpop/health-professionals/dentistry/radiation-protection-in-dental-radiology

ICRP (2007). ICRP Publication 103: The 2007 Recommendations of the International Commission on Radiological Protection. Annals of the ICRP, 37(2–4). https://doi.org/10.1016/j.icrp.2007.10.003

International Commission on Radiological Protection (ICRP). (2023). Optimization of Radiological Protection in Digital Radiology Techniques for Medical Imaging (ICRP Publication 154). Annals of the ICRP. https://doi.org/10.1177/01466453231210646

Jibiri, N. N., Adeleye, B., & Kolude, B. (2017). Radiation dose to the thyroid, eyes and parotid glands of patients undergoing intra-oral radiographic procedures in a teaching hospital in Ibadan, Oyo state Nigeria. International Journal of Radiation Research, 15(1), 101-106. https://doi.org/10.18869/acadpub.ijrr.15.1.101

Lee, M. Y., Kim, W. J., Park, I., Nam, H. W., Kim, K. P. (2019). Calculation of Effective Dose for Intraoral Dental Radiography using Monte-Carlo Simulation in Korea. Research of Korea Centers for Disease Control and Prevention, Kyung Hee University. https://doi.org/10.1093/rpd/ncz177

Moodley, M., Moodley, S., & Nxumalo, M. P. (2016). Patient radiation dose during intraoral radiography at dental practices in Durban. South African Dental Journal, 71(2), 58-62. https://www.sadj.co.za

Nigerian Nuclear Regulatory Authority (NNRA). (2023). Nigerian Basic Ionizing Radiation Regulations, 2023. https://nnra.gov.ng

Public Health (2017). Dose to patients from dental radiographic X-ray imaging procedures in the UK. Review: England, PHE-CRCR-59. https://www.gov.uk/government/publications/patient-dose-in-dental-radiography

Storm, C., & Nezich, R. (2023). Establishment of a local diagnostic reference level for dental intraoral bitewing X-rays. Physical and Engineering Sciences in Medicine, 46(2), 747-751. https://pubmed.ncbi.nlm.nih.gov/37016185