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ASSESSMENT OF OCCUPATIONAL RADIATION EXPOSURE IN DENTAL CLINICS USING THERMOLUMISCENCE DOSIMETERS

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Abstract

Occupational exposure to ionizing radiation in dental clinics is gradually increasing due to the rapid increase in the use of Dental Radiography (DR) for diagnostic purposes. This study aims to estimate the scattered radiation dose received by the Operator of a dental x-ray unit during routine DR with Thermoluminescence Dosimeters (TLDs). A total of 15 dental clinics, located in the cities of Lagos and Abeokuta, were considered in this study. Annealed TLDS, each in a holder, was placed at strategic positions, where the operator stayed during the procedure. A control TLD was placed outside the radiation area of each centre to account for background. The exposed TLDs were retrieved after five consecutive imaging procedures and subsequently processed to determine the radiation dose received by the respective operators. These values were used to extrapolate their annual dose and compared with the International recommended dose limit for radiation workers. The weekly radiation dose received by the operators across all centres was less than 1 mSv, while the extrapolated annual dose ranged from 0.32 to 15 mSv, which is also below the recommended annual limit of 50 mSv. The results suggest that, notwithstanding variations in clinical and patient workflow, the risk of excessive radiation exposure to dental personnel is minimal under current operating conditions. Nevertheless, the observed inconsistency in the use of personal protective and monitoring devices in some centres underscores the necessity for strict compliance with established radiation protection practices to reduce the stochastic effects of ionizing radiation.

Keywords: Scattered Radiation, Thermoluminescence Dosimeter, Dental Radiography, Occupational Exposure, Stochastic Effect of Radiation, Radiation Protection.

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INTRODUCTION

Dental radiography remains a key part of modern dental diagnostics, regularly used to identify oral diseases, evaluate treatment results, and aid clinical decision making. Intraoral radiographic units are among the most common imaging tools in dental practice because of their diagnostic accuracy and convenience. Despite their clinical advantages, intraoral radiographic units emit ionizing radiation, which can pose health risks, especially if proper safety measures are not followed (ICRP, 2007)

The development of advanced radiographic techniques such as digital radiography and Cone-Beam Computed Tomography (CBCT) has led to a corresponding increase in potential radiation exposure among dental health care personnel (Benavides et al., 2020*)*. Regulatory bodies such as the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA), Vienna, have emphasized the importance of radiation protection and occupational dose monitoring (IAEA, 2014, 2018); (ICRP, 2007). Although ionizing radiation from dental radiographic units is considered to be generally low in quantity, it is not entirely free of radiation risks, especially stochastic effects.

Cumulative exposure to small amounts of radiation can potentially lead to stochastic effects, such as DNA damage, which may increase the risk of developing cancers like leukemia and solid tumors in sensitive organs of the trunk, such as the thyroid, parotid glands, and brain (White et al., 2014).

The use of ionizing radiation in dental clinics may present potential biological risks, particularly when radiation protection measures are inadequate or are not followed strictly. Although dental radiation typically involves low-dose exposures, scattered radiation within the dental room during the procedure can lead to cumulative doses to operators, who work for between eight and nine hours per day (ICRP, 2007)

Despite the routine use of radiographic procedures in dental clinics, there is often inadequate awareness and monitoring of scattered radiation dose levels. Many dental clinics lack proper radiation shielding, radiation monitoring devices and some do not adhere to the International recommended standard of radiation practices (IAEA, 2018). Some personnel in dental clinics often argue about the need for radiation exposure in dental clinics and some are unaware of their cumulative radiation exposure over time. With the frequent use of radiographic dental imaging, this study is conducted to estimate the scattered radiation dose accumulated per annum for personnel operating the dental X-ray unit with Thermoluminescence Dosimeters (TLDs).The findings from this study will stimulate and enhance awareness among dental professionals and operators of dental X-ray units, regarding the importance of radiation protection in dental clinics.

MATERIALS AND METHOD

This study employed the use of Thermoluminescence Dosimetry system - TLD-100 (LiF: Mg, Ti) chips, TLD reader (Thermo Scientific 4500) and Nitrogen generator (Parker Balston), to measure scattered radiation dose during dental imaging procedures at selected 15 dental radiographic centres within the City of Lagos and Abeokuta, Nigeria. These centres have varying dental X-ray room layouts/design, radiation shielding and personnel monitoring protocols, which made them a representative sample of dental imaging centres/clinics in our nation. The centres were equipped with dedicated dental X-ray units and their descriptions are presented in Table 1. A typical wall mounted dental X-ray unit is shown in Figure 1. The frequently used exposure parameters, based on clinical requirements for each patient, at each centre were presented in Table 2.

The TLDs-100 used for radiation dose measurement were chosen because of their sensitivity to low doses of ionizing radiation, typical of dental X-ray units, and their high tissue equivalency (Sadeghi et al., 2015); (Liuzzi et al.,2020). TLD has the potential to assess the dose to shallow depth (skin, hand and feet), Hp (0.07) and deep depth (for assessment of deep organs and control of effective dose), Hp (10) (IAEA, 2014). The deep dose values obtained were used to estimate effective dose received by the operators.

All procedures were conducted in accordance with radiation safety protocols established by the Nigerian Nuclear Regulatory Authority (NNRA, 2019).

The Prior to use, the TLDs were annealed at temperature of 300ºC to erase previous radiation history and remove background radiation and calibration was done using a standard radiation source in a secondary standard dosimetry laboratory, ensuring each TLD's response factor was known in accordance with the International Atomic Energy Agency, IAEA, protocols for dosimetry Calibration (IAEA, 2000). The study ensures that each TLD was labelled, exposed and removed after five consecutive intra-oral dental procedures for appreciable accumulated scattered doses at each centre. This took between 2 to 5 days based on the overflow of patients at the centre. The TLDs were placed at strategic positions within the dental rooms to mimic the location of Operators or imaging personnel, who sometimes do not wear monitoring devices, during the procedures. These locations were also based on the layout of the room.

A control TLD was placed outside the radiation area of each clinic to account for background radiation. All exposed TLDs were processed with the TLD reader shown in Fig. 2 and a sample of its glow curve is shown in Figure 3. During data analysis, the readings from the control TLDs were subtracted from the deep dose values of TLDs to obtain net radiation doses attributable to scattered radiation at each centre. The dose values obtained per week were used to estimate annual dose, calculated over 50 weeks (excluding public holidays and weekends) according to the ICRP report 103 and compared with the recommended annual dose limit for radiation workers (IAEA, 2014).

All data were analyzed using descriptive statistics in Microsoft Excel 2016 and results were presented in Tables and figures.

This study adhered to ethical principles of radiation safety and research involving human environments. In addition, approval was obtained from the Management of the respective dental clinics.

Fig. 1: Wall- Mounted Intra-Oral X-ray Unit at One of the Centres

Fig.2: TLD Reader (Thermo Scientific 4500) used for Analysis of Exposed TLDs-100

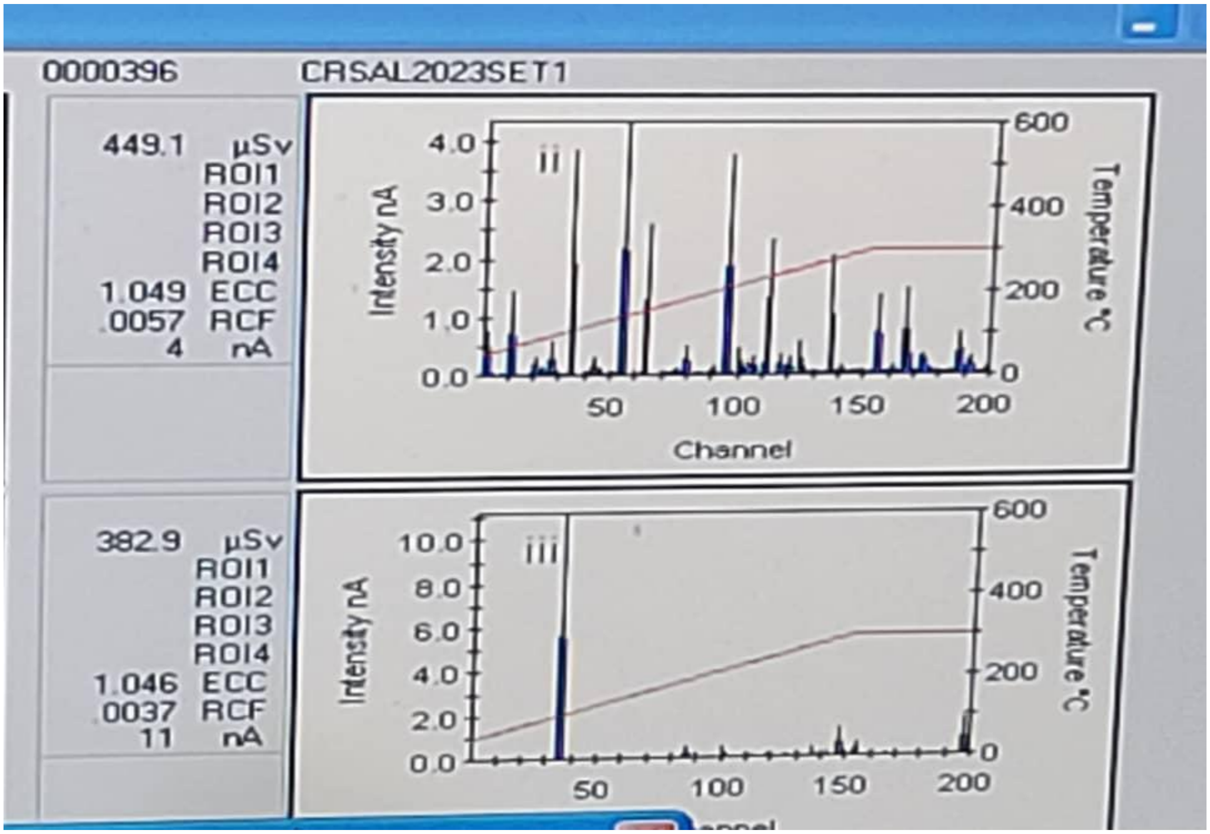

Fig.3: Sample of TLD-100 Processing Glow Curve

RESULTS

Table 1:

Specification of Dental X-ray machines at the Selected Centre

Dental Clinic ID	Location (LGA)	Model	Year of manufacture	Type of X-ray Unit	Description
ABCH	Ikorodu	CS 2200	2013	Intraoral	Wall mounted, HF & LDU
DEFH	Ikorodu	JYF-10D	2023	Intraoral	ILR Unit
XYZH	Ikorodu	Timex 70C	2018	Intraoral	Portable
GHEH	Ikorodu	CS 2100	2017	Intraoral	Floor-mounted, & HFU
LFCH	Ikorodu	JYF-10D	2023	Intraoral	ILR Unit
ADFH	Ikorodu	HN-08	2022	Intraoral	Fixed & HFU
BCBH	Ikorodu	HN-08	2022	Intraoral	Fixed & HFU
AYMH	Abeokuta	HN-08	2022	Intraoral	Fixed & HFU
LUSH	Abeokuta	JYF-10D	2023	Intraoral	ILR Unit
DUSH	Abeokuta	CS 2200	2013	Intraoral	ILR Unit
AEDH	Abeokuta	JYF-10D	2023	Intraoral	ILR Unit
IMEH	Abeokuta	JYF-10D	2023	Intraoral	ILR Unit
DORH	Abeokuta	CS 2100	2017	Intraoral	Floor-mounted & HFU
XORH	Abeokuta	HN-08	2022	Intraoral	Fixed & HFU
AFOH	Abeokuta	JYF-10D	2023	Intraoral	ILR Unit

HF: High frequency; LDU: Low Dose Unit; ILR: Integrated Low Radiation; LGA: Local Govt. Area

Table 2:

Estimated Scattered Radiation Dose Per 5 Exposures at the Selected Centre

Dental Clinic ID	Period of Exposure (Day)	kV	mA	Exposure time (sec)	Deep Dose, H_p (10) (mSv)	Shallow Dose, H_p (0.07) (mSv)	Net Radiation Dose (mSv)
ABCH	2	65	8	0.80 - 1.00	0.4502	0.3343	0.0215
DEFH	2	60	8	0.80 - 1.00	0.4491	0.3829	0.0204
XYZH	2	60	8	0.80- 1.00	0.3640	0.3225	0.0647
GHEH	5	65	8	2.50	0.4327	0.4186	0.0040
LFCH	5	70	8	0.50 - 1.00	0.5552	0.5422	0.1265
ADFH	4	70	8	1.91 - 2.84	0.4786	0.5858	0.0499
BCBH	5	60	8	0.80 - 1.00	0.2156	0.1823	0.2131
AYMH	2	60	8	0.80 - 1.00	0.5009	0.5581	0.0722
LUSH	5	70	8	0.50 - 1.00	0.4688	0.4888	0.0401
DUSH	5	60	8	0.50 - 1.00	0.3510	0.5233	0.0777
AEDH	5	60	8	0.80 - 1.00	0.2139	0.1497	0.2148
IMEH	5	60	8	0.50 - 1.00	0.3870	0.1961	0.0417
DORH	5	60	8	0.80 - 1.00	0.3594	0.3681	0.0693
XORH	5	75	8	1.00	0.5866	0.4238	0.1579
AFOH	5	70	8	0.50 - 1.00	0.5686	0.4328	0.1399

Table 3:

Estimated Operators' Annual Dose from Scattered Radiation Per Centre

Dental Clinic ID	Measured Dose per 5 Exposures (mSv)	Average No of Exposure per Week	Annual DOSE (mSv)
ABCH	0.0215	50	10.75
DEFH	0.0204	50	10.20
XYZH	0.0647	5	3.24
GHEH	0.0040	8	0.32
LFCH	0.1265	6	7.59
ADFH	0.0499	8	3.99
BCBH	0.2131	6	12.79
AYMH	0.0722	15	10.83
LUSH	0.0401	7	2.83
DUSH	0.0777	6	4.662
AEDH	0.2148	7	15.04
IMEH	0.0417	7	2.92
DORH	0.0693	6	4.16
XORH	0.1579	7	11.05
AFOH	0.1399	7	9.79

DISCUSSION

This study assessed radiation practices in 15 selected clinics across Nigeria, with 47% located in Lagos and 53% in Abeokuta, Ogun State. All clinics were equipped with dedicated Intra-Oral X-ray units, where the imaging film is placed inside the patient's mouth during the procedure. This is a common radiographic procedure for oral imaging. (de Haan and van Aken. 1990) The average number of dental imaging performed per week at these centres ranged from 5 – 50 exposures. It was observed that the centres that had the highest estimated annual dose (15.1 mSv) were not the ones with the highest number of exposure (50) per week. This could be due to the range of exposure parameters selected for the procedures at these centres. In addition, some patients often require several radiographs per day, and the number of radiographs performed daily must not be mistaken for the total number of patients seen per day (Abdinian et al., 2024).

It was observed that the overall mean dose values (0.425 mSv) per week obtained at some centres is an indication that without adequate protective measures, cumulative exposure at those centres could potentially exceed the ICRP recommended dose limit of 50 mSv per year for occupational exposure. These variations could be attributed to multiple factors including differences in the x-ray unit specifications, operational parameters, and the implementation of radiation protection protocols.

Another area of concern found in this study was the number of dental radiographic exposures carried out per week which stood at an average of 50 in some clinics and this has the potential to increase the personnel overall exposure and pose substantial risks to their health. A positive correlation has been reported by Sulieman et al., (2019); Tamam et al., (2021); Abdinian et al. *(*2024) between weekly exposure frequency and projected annual dose, suggesting that increased procedural volume could elevate radiation exposure risks.

The strong positive relationship (R^2 = 0.924) observed between deep dose measurements and estimated annual dose indicated that scattered radiation dose towards the dental x-ray unit operators is a reliable predictor of their cumulative occupational exposure. Also of note is the correlations (R^2 = 0.748) between the exposure parameters (kV and mAs) and the deep dose measurements, confirming the relationship between technical parameters and radiation output (Hoogeveen et al., 2021); (Asha, 2015).

The linear relationship (R^2 = 0.5591) obtained between x-ray tube voltage and deep dose provided insight into how technical factors influence radiation exposure. The higher the kV settings, the higher the scattered radiation levels. This is aligned with radiation physics principles that higher tube voltages produce more penetrating radiation with increased scatter potential (Hoogeveen et al., 2021); (Okano and Sur, 2012); (Bushong, 2021).

CONCLUSION

Although the estimated annual dose to the operator from scattered radiation during dental radiography is below the international recommended occupational dose limits, strict compliance with principles of radiation protection, such as training of personnel on radiation protection and regular equipment maintenance should be encouraged, especially in those dental clinics with high-volume of exposure per week, where cumulative exposure to the Operator could exceed recommended dose limit.

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