Regular Evaluation of Radiation Exposure Among Dental Personnel at Usman Danfodiyo University Teaching Hospital, Sokoto, Nigeria

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Abstract

The evaluation of occupational exposure to external ionizing radiation in diagnostic and therapeutic applications is essential for understanding regulatory compliance and technological progress. This research presents an analysis of occupational radiation exposure in the Dental department of Usman Danfodiyo University Teaching Hospital(UDUTH) Sokoto, comparing it with relevant studies. A total of 14 TLDS were collected from the Dental unit, each assigned a TLD code instead of worker names. Parameters, including Average Annual Effective Dose (AAED), Annual Collective Dose (ACD), and Probability of Cancer Lifetime Risks (LFTR), were analyzed using SPSS version 21.0. Dental workers showed an AAED of 0.76 ± 0.61 mSv and an ACD of 1064 ± 0.61 man mSv. 91.89% of Dental workers received doses exceeding 1 mSv, while none exceeded 10 and 15 mSv. The LFTR for all medical radiation workers at UDUTH was less than 1mil, suggesting low cancer lifetime risks. Overall, the dose distribution trend indicates a move towards lower levels, emphasizing the maintenance of adequate radiation protection protocols by the majority of the workers.

1 Introduction

X-rays and gamma rays, invisible energies like tiny superheroes, can zip through materials and leave their mark. In the world of medicine and research, they offer incredible benefits, but like any powerful tool, handling them with care is essential [5]. They interact with matter, and sometimes, this interaction can affect living cells. While this might sound scary, it's important to remember that [2] the risks exist within a context: We encounter different kinds of risks every day, and understanding how radiation's potential hazards compare to these familiar ones can help put things in perspective.

Knowledge is power: By learning about how these "invisible forces" work and the ways to minimize exposure, we can harness their benefits while keeping everyone safe [2]. Occupational exposure, referring to radiation exposures during work, involves individual radiation dose assessment [16]. Individual radiation monitoring programs have dual objectives. They furnish information on the effectiveness of protection measures, crucial for operational decisions based on the optimization principle [10]. Additionally, these programs aim to demonstrate compliance with relevant dose limits set by national regulations and international recommendations [8]. The annual effective dose for occupationally exposed workers, as recommended by regulatory bodies, should not exceed 20 mSv averaged over five consecutive years, with an additional provision that the individual dose does not surpass 50 mSv in any single year.

Regular assessment of occupational radiation exposures and the analysis of related trends are vital for scrutinizing changes over time due to regulatory operations or technological advancements. Despite the undeniable benefits of ionizing radiation in medical practices, the associated biological hazards cannot be ignored. The use of ionizing radiation in diagnostic and therapeutic applications offers significant advantages to human health but poses risks to workers, contributing to approximately one-fifth of the collective effective dose globally [14].

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1.1 The effects of radiation on humans

Despite significant research on chemicals like insecticides and fungicides, understanding radiation's effects remains far ahead. This is crucial, as even small doses from x-rays can alter genes and potentially trigger cancer [7].

1.2 The biological effects of contamination

X-rays and gamma rays are widely used in therapeutic diagnosis and treatment, as well as in various industries and research fields. They are powerful tools, but also come with the unavoidable risk of radiation exposure. The key challenge lies in determining how much radiation exposure is acceptable, considering both its benefits and potential risks compared to other everyday hazards [15].

The International Commission on Radiation Protection (ICRP) is a global body of experts tasked with understanding the effects of radiation on humans. They regularly analyze data and issue "recommended limits of radiation exposure" deemed safe and reasonable.

1.3 The badges

To monitor individual radiation exposure, small, chip-filled badges are worn for a three-month period. These detect even tiny amounts of radiation and, upon return, reveal the wearer's total dose for that time frame [10].

1.4 Scope of the Study

To ensure the well-being of medical personnel at Usman Danfodiyo University Teaching Hospital (UDUTH), Sokoto, this research sheds light on current occupational radiation exposure in Radiotherapy, Radiology, and Dental units. Through meticulous comparisons with previous records, the study aims to identify potential concerns, optimize safety measures, and contribute to a safer radiation environment for all staff [5].

2 Related Work

Numerous studies worldwide have investigated radiation exposure levels for nuclear medicine workers, focusing on annual and quarterly doses for whole body or specific organs, and ensuring compliance with regulations.

Pakistani studies in 2007-2011 reported annual whole-body doses ranging from 0.51 to 1.91 mSv, falling within regulated limits and comparable to other countries like China (1.4 mSv), Australia (0.75 mSv), and Canada (1.96 mSv) [10].

Further Pakistani studies in 2003-2012 revealed annual doses between 0.3 and 0.97 mSv. Other countries like Saudi Arabia also showed varying annual doses within acceptable limits[10].

Interestingly, a Kuwaiti study observed a decrease in doses from 2008 (1.06 mSv for physicians, 1.07 mSv for technologists) to 2009 (1.01 mSv for physicians, 1.00 mSv for technologists)[11].

In contrast, a Polish study reported higher doses for nurses (2-9.5 mSv) compared to technicians and radio pharmacy technicians (0.8-3.7 mSv)[15].

A Portuguese study highlighted variations in effective doses across different occupational groups, with medical doctors, technicians, and nurses receiving the highest doses[14].

3 Calculation

To ensure accurate assessment of radiation exposure, this study embraced the established methodology of Rahman et al. (2016). Their equations (Equations 1, 2, and 3) account for various factors such as equivalent dose, tissue type, and radiation weighting, allowing for precise calculation of both absorbed dose and subsequent effective, collective and individual doses distribution ratios.

$$D = (\frac{H_T}{W_R}) \tag{1}$$

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Where
D is the absorbed dose in mSv,
H_T is the equivalent dose,
W_R is the radiation weighing factor.
The absorbed dose is calculated by dividing the radiation equivalent with radiation weighing factor.

3.1 Total radiation dose incurred by population

Total radiation dose incurred by population is

$$S = \sum_i E_i \times N_i \tag{2}$$

Where
E_i : is the annual effective dose received by the worker
N_i : Is the total number of workers monitored
The collective dose (S) is calculated by multiplying the effective dose with the population size.

3.2 Individual annual effective dose

Risk related parameter, taking relative radio sensitivity of each organ or tissue into account.

$$E_i(Sv) = \sum_T W_T \times H_T \qquad (EPA2009) \tag{3}$$

W_T: tissue weighing factor for organ T
H_T: equivalent dose received by organ or tissue T
The effective dose E_i is calculated by multiplying the tissue weighing factor with equivalent dose.

3.3 The individual dose distribution

The individual dose distribution ratio is giving by relation

$$NR_E = \frac{N(>E)}{N} \tag{4}$$

$N(>E)$: Represents the count of workers receiving an annual dose surpassing E mSv in this study. NRE was examined for E values of 15, 10, 5, and 1 mSv in accordance with the UNSCEAR Protocol.

$$LFTR = AAED \ \times \ Probabilty\ coefficient \tag{5}$$

4 Research Methodology

4.1 Research Design

Prioritizing ethical research practices, this study on radiation exposure in Usman Danfodiyo University Teaching Hospital's dental department (Sokoto, Nigeria) utilized anonymous annual dose records from 2014 to 2018. Upholding HREB guidelines, the researchers protected worker identities by assigning TLD codes and analyzing de-identified data, including both quarterly and total yearly whole-body doses for each participant.

4.2 Participants

A convenient sampling method was employed for the study. The sample for the study consisted of 14 Dentists of Usman Danfodiyo University Teaching Hospital Sokoto.

4.3 Instruments

All the data collected was represented using TLD codes.

5 Results and Discussion

5.1 DN Surgeons

The data obtained from the Figure 1, focusing on DN Surgeons, presents a detailed analysis of the Average Annual Effective Dose (AAED), Annual Collective Dose (ACD), and the probability of cancer lifetime risk. The results for DN Surgeon DN36 in 2016 and DN01 in 2018 indicate AAED ranging from 1.23 to 2.64 mSv, ACD ranging from 2.46 to 5.28 man mSv, and a probability of cancer lifetime risk ranging from 0.0615 to 0.132 mil. The observed fluctuations in the results may be attributed to an increase in workload or non-compliance with radiation protection protocols [1].

Table 1: Dental Surgeons with their AAED, ACD and LFTR.

	2014	2015	2016	2017	2018
DN01					
AAED	0.00	1.50	1.60	0.00	2.64
ACD	0.00	3.00	3.20	0.00	5.28
LFTR	0.00	0.75	0.008	0.00	0.132
DN36					
AAED	0.00	0.00	1.23	0.00	0.00
ACD	0.00	0.00	2.46	0.00	0.00
LFTR	0.00	0.00	0.0615	0.00	0.00

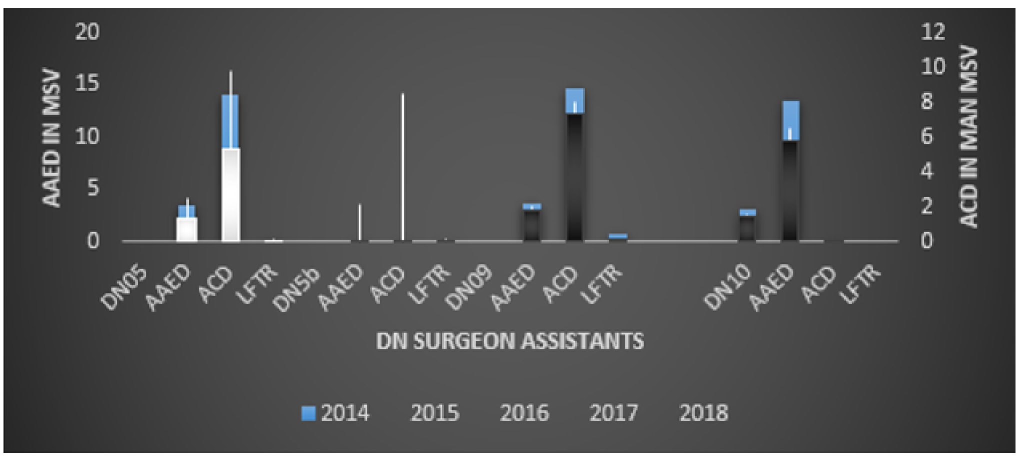

Figure 1: DN Surgeon Assistant Radiation doses.

The one-way ANOVA test results showed no statistical significance for the pairwise comparisons ($p < 0.05$). Further analysis revealed that approximately 40% of DN Surgeons received AAED exceeding 1 mSv, while 60% received lower than 1 mSv. None of the DN Surgeons received doses exceeding 5, 10, and 15 mSv, aligning with UNSCEAR (2008) recommendations.

The study demonstrated that the probability of cancer lifetime risks increased with the rise in dose. However, the risk of cancer induction at Usman Danfodiyo University Teaching Hospital Sokoto (UDUTH) for exposed workers was five times lower than the risk in Kuwait (Al-Abdulsalam et al., 2014). The results indicated that the two DN Surgeons monitored had induced cancer risks below 1 mil, highlighting an improvement in the radiation protection protocol at UDUTH.

While acknowledging the potential risks associated with long-term exposure, the assessment suggested that building confidence among DN Surgeon workers at UDUTH could be achieved by minimizing the risk of cancer induction through workload management. The linear relationship between the probability of LFTR and exposure time emphasized the importance of effective management strategies, allowing for the minimization of the risk of cancer induction in the case of overexposure by reducing workload.

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5.2 DN Surgeon Assistants

The results obtained from the Figure 2, specifically focusing on DN Surgeon Assistants, provide comprehensive insights into the Average Annual Effective Dose (AAED), Annual Collective Dose (ACD), and the probability of cancer lifetime risk. The data for DN Surgeon Assistants showed AAED ranging from 1.26 to 3.64 mSv, ACD ranging from 5.04 to 14.56 man mSv, and a probability of cancer lifetime risk ranging from 0.065 to 0.665 mil, recorded by DN5b and DN09 in 2016 and 2014, respectively. It is noteworthy that DN5b recorded the highest doses [16].

Table 2: Dental Surgeon Assistants with their AAED, ACD and LFTR.

	2014	2015	2016	2017	2018
DN05					
AAED	3.52	0.00	1.30	2.44	1.32
ACD	14.08	0.00	5.20	9.76	5.28
LFTR	0.176	0.00	0.065	0.122	0.066
DN09					
AAED	3.64	1.84	2.00	0.00	0.00
ACD	14.56	7.36	8.00	0.00	0.00
LFTR	0.662	0.092	0.10	0.00	0.00
DN10					
AAED	3.12	1.44	1.61	0.00	0.00
ACD	12.48	5.76	6.44	0.00	0.00
LFTR	0.156	0.072	0.081	0.00	0.00
DN5b					
AAED	0.00	0.00	1.26	2.12	0.00
ACD	0.00	0.00	9.04	8.48	0.00
LFTR	0.00	0.00	0.063	0.106	0.00

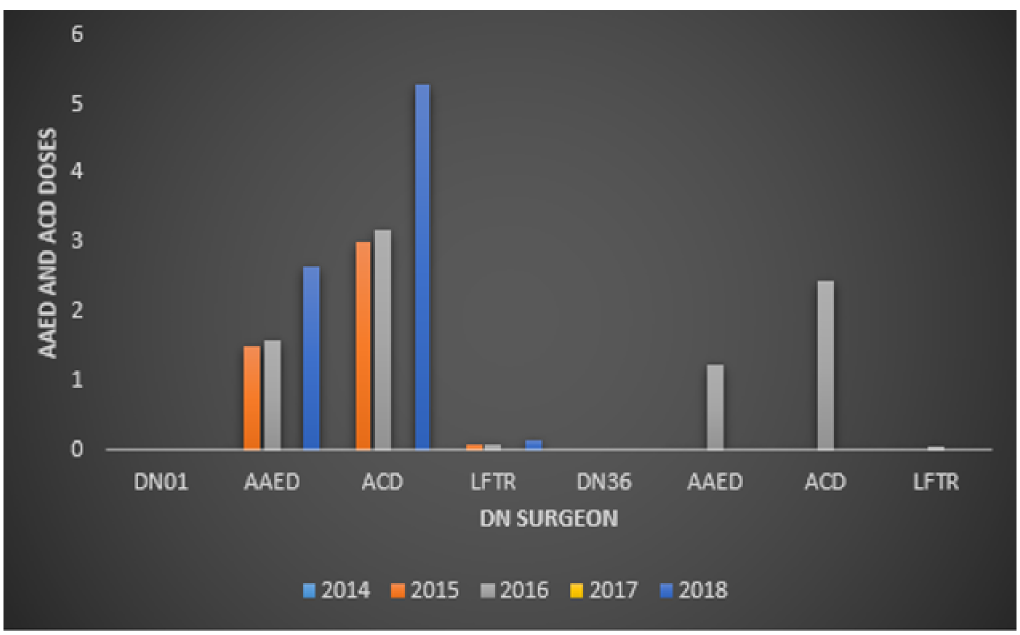

Figure 2: DN Surgeon Radiation doses.

Comparing these results with global benchmarks, RD71's doses were greater than the 0.35 mSv recorded in Canada [16], yet lower than the 1.34 mSv and 20 mSv world records in 1990-1994 and the UNSCEAR

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(2008) recommendations. The observed fluctuations in the results may be attributed to an increase in workload or non-compliance with radiation protection protocols.

The one-way ANOVA test results indicated no statistical significance for the pairwise comparisons ($p < 0.05$). Further analysis revealed that approximately 60% of DN Surgeon Assistants received AAED exceeding 1 mSv, while 40% received lower than 1 mSv. None of the DN Surgeon Assistants received doses exceeding 5, 10, and 15 mSv, aligning with UNSCEAR (2008) recommendations.

The study demonstrated that the probability of cancer lifetime risks increased with the rise in dose. However, the risk of cancer induction at Usman Danfodiyo University Teaching Hospital Sokoto (UDUTH) for exposed workers was five times lower than the risk in Kuwait (Al-Abdulsalam et al., 2014). The results indicated that the four DN Surgeon Assistants monitored had induced cancer risks below 1 mil, highlighting an improvement in the radiation protection protocol at UDUTH. While acknowledging the potential risks associated with long-term exposure, the assessment suggested that building confidence among DN Surgeon Assistants workers at UDUTH could be achieved by minimizing the risk of cancer induction through workload management.

Additionally, the information underscored the linear relationship between the probability of LFTR and exposure time. If anyone gets overexposed, the risk of cancer induction can be minimized by reducing workload, emphasizing the importance of effective management strategies.

5.3 DN Technologists

The data obtained from the Figure 3 provide a comprehensive analysis of the Average Annual Effective Dose (AAED), Annual Collective Dose (ACD), and the probability of cancer lifetime risk for 8 DN Technologists in 2015 and 2016. The results indicate that AAED ranged from 1.18 to 3.36 mSv, with LFTR ranging from 0.059 to 0.088 mil, while ACD ranged from 9.44 to 14.08 man mSv[14].

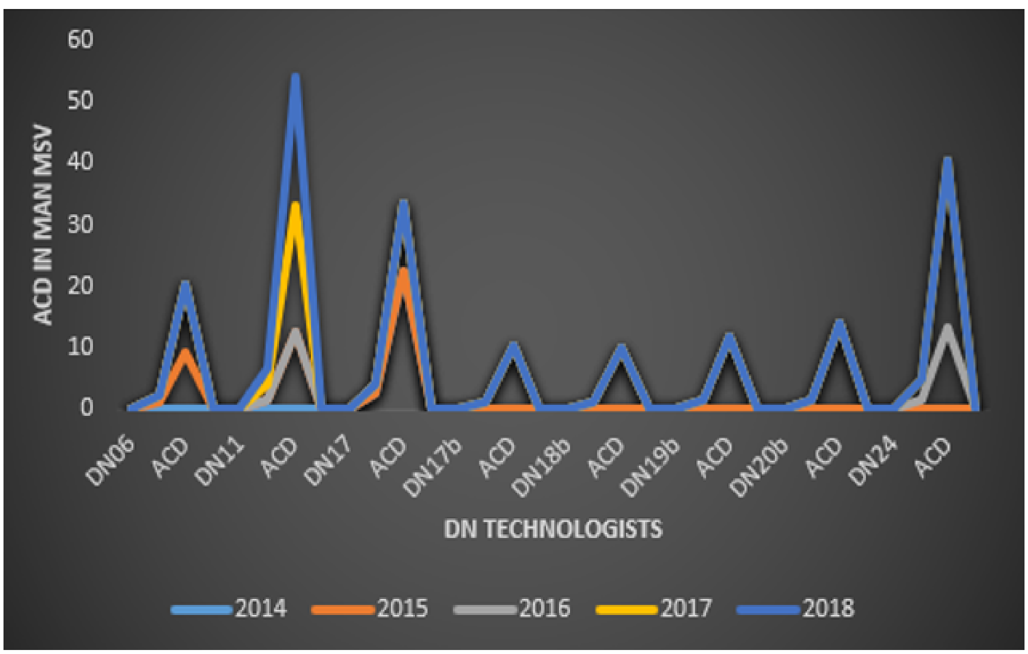

Figure 3: DN Technologists Radiation doses.

The one-way ANOVA test results revealed no statistical significance for the pairwise comparisons (p ¡ 0.05). Further analysis showed that approximately 32.5% of DN Technologists received AAED exceeding 1 mSv, while 67.5% received lower than 1 mSv. None of the DN Technologists received doses exceeding 5, 10, and 15 mSv, aligning with UNSCEAR (2008) recommendations.

The study demonstrated that the probability of cancer lifetime risks increased with the rise in dose. However, the risk of cancer induction at Usman Danfodiyo University Teaching Hospital Sokoto (UDUTH)

Table 3: Dental Technologists with their AAED, ACD and LFTR.

	2014	2015	2016	2017	2018
DN06					
AAED	0.00	1.18	1.36	0.00	0.00
ACD	0.00	9.44	10.88	0.00	0.00
LFTR	0.00	0.059	0.068	0.00	0.00
DN11					
AAED	0.00	1.60	0.00	2.52	2.64
ACD	0.00	12.80	0.00	20.16	21.12
LFTR	0.00	0.08	0.00	0.126	0.132
DN17					
AAED	2.80	0.00	1.40	0.00	0.00
ACD	22.4	0.00	11.20	0.00	0.00
LFTR	0.14	0.00	0.07	0.00	0.00
DN17b					
AAED	0.00	0.00	1.32	0.00	0.00
ACD	0.00	0.00	10.56	0.00	0.00
LFTR	0.00	0.00	0.066	0.00	0.00
DN18b					
AAED	0.00	0.00	1.24	0.00	0.00
ACD	0.00	0.00	9.92	0.00	0.00
LFTR	0.00	0.00	0.062	0.00	0.00
DN19b					
AAED	0.00	0.00	1.48	0.00	0.00
ACD	0.00	0.00	11.84	0.00	0.00
LFTR	0.00	0.00	0.074	0.00	0.00
DN20b					
AAED	0.00	0.00	1.76	0.00	0.00
ACD	0.00	0.00	14.08	0.00	0.00
LFTR	0.00	0.00	0.088	0.00	0.00
DN24					
AAED	0.00	0.00	1.68	0.00	0.00
ACD	0.00	0.00	13.44	0.00	0.00
LFTR	0.00	0.00	0.084	0.00	0.00

for exposed workers was five times lower than the risk in Kuwait (Al-Abdulsalam et al., 2014). The results indicated that the 8 DN Technologists monitored had induced cancer risks below 1 mil, showcasing an improvement in the radiation protection protocol at UDUTH.

While acknowledging the potential risks associated with long-term exposure, the assessment suggested that building confidence among DN Technologist workers at UDUTH could be achieved by minimizing the risk of cancer induction through workload management. The linear relationship between the probability of LFTR and exposure time emphasized the importance of effective management strategies, allowing for the minimization of the risk of cancer induction in the case of overexposure by reducing workload [11].

5.4 Comparisons of Dental Cadres AAED

The provided results indicate that Dental Surgeons exhibited the highest Annual Average Effective Dose (AAED) over the five-year period, while Technologists received the lowest. This outcome suggests significant differences in radiation exposure among these two groups within the healthcare setting. Here is an extensive discussion [11].

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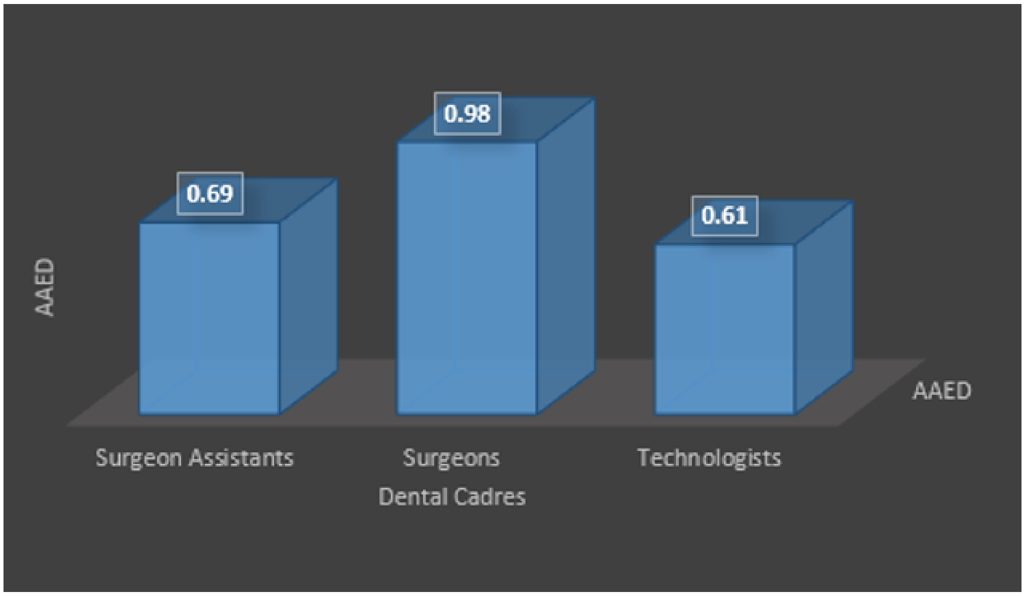

Figure 4: Comparisons of different cadres in Dental department.

5.5 Dental Surgeons

High AAED: The fact that Dental Surgeons received the highest AAED raises concerns about the potential sources of radiation exposure in dental practices. It is crucial to investigate the specific procedures, equipment, or working conditions contributing to this elevated dose.

Diagnostic Procedures: Dental professionals often use X-ray imaging for diagnostic purposes, such as dental radiographs or cone-beam computed tomography (CBCT). The higher AAED among Dental Surgeons could be linked to the nature and frequency of these procedures.

Protective Measures: Given their potential for increased radiation exposure, it is essential for Dental Surgeons to adhere to strict radiation protection protocols, including the use of lead aprons, thyroid collars, and other shielding measures.

5.6 Technologists

Lowest AAED: The results indicating that Technologists received the lowest AAED suggest that their occupational practices or work settings may result in comparatively lower radiation exposure. This could be attributed to the nature of their tasks, which might involve less direct interaction with radiation sources.

Role and Responsibilities: Understanding the specific roles and responsibilities of Technologists is essential. If they are less directly involved in high-dose procedures or if their tasks are more administrative or supportive in nature, it could explain the lower AAED.

Safety Protocols: While lower radiation exposure is positive, it is important to ensure that Technologists are still following proper safety protocols. Periodic training, awareness programs, and adherence to safety guidelines contribute to maintaining a culture of safety in healthcare environments

6 Conclusion and Recommendation

Good news for dental staff at Usman Danfodiyo University Teaching Hospital! Based on our research, no dental employees exceeded the recommended annual radiation exposure limits. This means their annual doses stayed well below the 20 mSv threshold advised by UNSCEAR (2008).

While these findings are reassuring for dental staff, it's crucial to remember that ionizing radiation use is widespread across various medical departments at Usman Danfodiyo University Teaching Hospital. Therefore, further assessment of radiation exposure among other personnel like radiotherapists, radiologists, and porters is essential.

Here are some recommendations to further enhance radiation safety at the hospital:

- Regular calibration: Ensure the Harshaw 4500 manual TLD reader used in this study is consistently calibrated with 137Cs beam exposure before each use.
- Upgrade technology: Consider utilizing the Harshaw automatic TLD reader models 8800/6600 for future studies due to their improved precision and accuracy.
- Expand monitoring: Extend radiation exposure assessment to other relevant staff beyond dentists.
- Workload management: Implement strategies to reduce workloads on radiation workers, minimizing human error risks. This could involve feasible scheduling adjustments.
- Cancer detection: Invest in developing models capable of detecting cancer in radiosensitive organs early on.
- TLD reading: To avoid chip fading (especially in Sokoto's climate), ensure TLDs are read within a month of exposure.
- Staffing: Consider increasing staffing levels within departments to ease workload pressures.

By implementing these recommendations and conducting comprehensive radiation exposure assessments across all relevant departments, Usman Danfodiyo University Teaching Hospital can foster a safer and healthier work environment for its staff and patients.

7 Acknowledgements

From the outset to the culmination of this research, I was sustained by the unwavering grace of Almighty Allah. My sincerest thanks go to my dedicated lecturers who meticulously reviewed my work, and to American journal of Physics, whose unwavering support has helped me blossom academically.

8 Data Availability Statement

Focusing on a Nigerian hospital department heavily reliant on ionizing radiation, this research analyzed quarterly data from 2014 to 2018 to shed light on potential radiation exposure risks faced by its dental personnel.

9 Copyright Notice

10 References

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