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Original Article

Assessment of knowledge of radiation protection and biological effects of ionising radiation among clinical dental undergraduate students at Bayero University Kano, Nigeria

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Abstract

Background: Dental radiography is an essential diagnostic tool in clinical dentistry; however, ionising radiation poses significant biological hazards when appropriate protection measures are not observed. Adequate knowledge of radiation protection principles among dental students is essential, as these students represent the future clinicians responsible for patient and occupational radiation safety. **Objectives:** To assess the knowledge of clinical dental undergraduate students at Bayero University Kano regarding radiation protection practices, the biological effects of ionising radiation, and awareness of radiation protection regulatory bodies. **Methodology:** A descriptive cross-sectional study was conducted among 74 clinical dental undergraduate students in the Department of Dental Surgery, Faculty of Dentistry, Bayero University Kano. Data were collected using a self-administered structured questionnaire whose items were adapted from validated instruments used in comparable published studies. Results were analysed using SPSS version 20 and presented as frequencies and percentages. **Results:** Most participants (62.2%) were male, with most (62.2%) aged 21 to 25 years. Overall knowledge was variable: 87.8% reported standing behind a protective barrier during exposures, and 73.0% reported consistent use of lead aprons and thyroid shields. However, significant knowledge gaps were identified: only 27.0% correctly identified rectangular collimation as the dose-reducing collimator type, and 89.2% could not identify any radiation protection regulatory body. **Conclusion:** Clinical dental undergraduate students at Bayero University Kano demonstrated moderate knowledge of some fundamental radiation safety practices but showed significant deficits in technical radiation protection knowledge and were unaware of radiation protection regulatory frameworks. Curriculum reinforcement through targeted educational interventions is recommended.

Keywords: *Biological effects, Dental students, Ionising radiation, Knowledge, Nigeria, Radiation protection, Undergraduate education*

Introduction

The discovery of X-rays by Wilhelm Conrad Rontgen in 1895 transformed the practice of medicine and dentistry. In contemporary dentistry, radiographic examination is an essential and frequently utilised diagnostic tool, aiding in the detection of carious lesions, periapical infections, odontogenic cysts and tumours, and a wide range of maxillofacial conditions.[1]

The International Commission on Radiological Protection (ICRP) provides the foundational principles governing radiation safety globally, organised around three core principles: justification, optimisation, and dose limitation. The ALARA (As Low As Reasonably Achievable) principle, embedded within the optimisation framework, mandates that radiation doses be reduced to the lowest level practicable. Dose limits are set at 20 mSv per year averaged over five years (with no single year exceeding 50 mSv) for classified occupational radiation workers, and 1 mSv per year for the general public; dental

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students are not classified as occupational radiation workers and therefore fall under the public dose limit, though an understanding of occupational limits remains relevant for their future professional practice.[2] National bodies such as the National Council on Radiation Protection and Measurements (NCRP) further operationalise these principles, including specifying that operators should stand a minimum of 6 feet (approximately 1.83 m) from the X-ray source, at an angle of 90° to 135° to the primary beam, during dental radiographic exposures.[3]

The biological effects of ionising radiation are broadly classified as deterministic and stochastic. Deterministic effects occur only above specific dose thresholds and are characterised by severity proportional to dose. Stochastic effects, principally carcinogenesis and heritable genetic mutations, have no established dose threshold, and their probability increases with cumulative exposure. These stochastic risks are of relevance in dental radiography, as the radiosensitive thyroid gland and gonads lie within or near typical dental radiation fields.[1,4]

Despite the availability of effective protection measures (including high-speed film, rectangular collimation, film-holding devices, lead aprons, thyroid shields, and adherence to position-distance rules), multiple studies have consistently documented inadequate radiation protection knowledge among dental students and practitioners. Simmarasan et al.[5] found in Tamil Nadu, India, that nearly half of participants (48.06%) incorrectly believed that high-speed film did not reduce radiation dose. Similarly, Prabhat et al.[6] reported that third-year dental students performed markedly worse than final-year students and interns across nearly all radiation protection domains, while Rela,[7] documented in eastern India that overall knowledge, awareness, and practice were not uniformly adequate, particularly for technical radiation protection measures.

Comparable deficits have been reported across other regions. Garg and Kapoor, [8] found in Nepal that 85% of fourth-year dental students demonstrated good overall knowledge of radiation physics, protection, and hazards, though the majority of those who passed scored in the lower range of the good category, suggesting that knowledge may be adequate but not uniformly deep. Elmukhtar[9] reported in Sudan that 72% of dentists did not know the safe operator-source distance and 66% lacked knowledge of the relationship between collimation and patient dose. In Saudi Arabia, Hagi and Khafaji,[10] demonstrated that a single three-hour lecture significantly improved medical students' radiation knowledge scores by 31 percentage points, underscoring the modifiability of such deficits through targeted education. Research on factors determining radiation protection practices among practitioners further suggests that both educational level and type of practice independently influence protection behaviour,[11] reinforcing the argument that foundational training during undergraduate study is critical. However, Lasune et al.[12] and Motwani et al.[13] confirmed in separate cross-sectional studies that dental interns consistently outperformed junior students, while Watmode et al.[14] and Salih et al.[15] established that comparable knowledge gaps extend to nursing students, indicating a system-wide educational deficit across health professions curricula.

However, in Nigeria, data specifically targeting radiation protection knowledge among clinical dental students remain limited, as confirmed by the literature review. Sidi and Yusuf[16] reported poor radiation knowledge among medical students at Bayero University Kano, but a focused assessment of clinical dental undergraduates, who routinely prescribe and perform radiographic procedures, had not been undertaken. Therefore, this study aims to assess the knowledge of clinical dental undergraduate students at Bayero University Kano regarding radiation protection practices, the biological effects of ionising radiation, and awareness of radiation protection regulatory bodies.

Materials and methods

2.1. Study Design and Setting

A descriptive cross-sectional study was conducted in the Department of Dental Surgery, Faculty of Dentistry, College of Health Sciences, Bayero University Kano, Nigeria.

2.2. Study Population and Sampling

The study population comprised all clinical dental undergraduate students enrolled at 400, 500, and 600 levels in the Department of Dental Surgery. In the Nigerian dental training system, 400-level students are typically in their first year of clinical training, 500-level in their second, and 600-level in their final year, following three years of pre-clinical instruction; this context is provided for the benefit of international readers. Pre-clinical students, dental interns, clinical dental practitioners, and dental technicians were excluded. A convenience sampling technique was employed; all eligible students present during the scheduled data collection sessions were invited to participate. Of the 84 students enrolled across the three academic levels, 74 were available and consented to participate during the data collection period and constitute the study sample. Sample size was calculated using Taro Yamane's formula[17]:

$$n = N / [1 + N(e)^2]$$

where N = 84 (total eligible population) and e = 0.05 (margin of error at 95% confidence level), yielding a calculated minimum sample of 70. The achieved sample of 74 exceeded this minimum and was therefore considered adequate.

2.3. Data Collection Instrument

A structured, self-administered questionnaire comprising 17 items was used for data collection. Questionnaire items were adapted from validated instruments used in comparable published studies on radiation protection knowledge among dental undergraduates[6,18,11] The questionnaire was organized into three sections: (1) socio-demographic data (age, gender, and academic level); (2) knowledge regarding radiation protection practices (10 items covering cone length, film speed, collimator type, use of protective barriers, operator-source distance, lead apron and thyroid shield use, methods of dose reduction, radiographic views, imaging in pregnancy, and clinical importance of dental imaging); and (3) knowledge of the biological effects of ionizing radiation and awareness of radiation protection regulatory bodies (4 items). Participants were instructed not to consult external resources.

2.4. Ethical Consideration

Ethical approval was obtained from the College of Health Sciences Research Ethics Committee, Bayero University Kano (Reference: BUK/CHS/REC/VII/20). Written informed consent was obtained from all participants. Anonymity and confidentiality were maintained throughout data collection, management, and reporting. Also, permission to conduct the study was obtained from the Head of the Department of Dental Surgery prior to commencement.

2.5. Data Analysis

Completed questionnaires were entered into and analysed using IBM SPSS Statistics version 20 (IBM Corp., Armonk, NY, USA). Descriptive statistics are reported as frequencies and percentages. Consistent with the study's design as a descriptive survey, no inferential statistical tests were applied. The primary objective was to document the current state of radiation protection knowledge in this population rather than to draw inferential comparisons between subgroups. This approach is appropriate given the exploratory nature of the study. The descriptive scope of the analysis is acknowledged as a limitation.

Results

3.1. Demographic Characteristics

A total of 74 clinical dental students participated in the study. The demographic distribution of participants is illustrated in Figures 1 to 3. The majority were aged 21 to 25 years (46/74; 62.2%), followed by 26 to 30 years (23/74; 31.1%) and 31 to 35 years (5/74; 6.8%). Male participants constituted 62.2% (46/74) and female participants 37.8% (28/74) of the sample. By academic level, 500-level students formed the largest group (40/74; 54.1%), followed by 600-level (20/74; 27.0%) and 400-level students

(14/74; 18.9%).

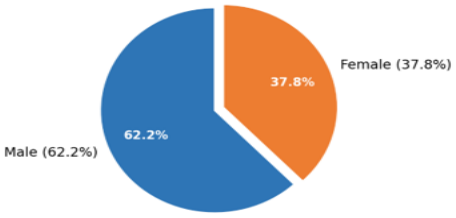

Figure 1. Gender distribution of study participants (n = 74)

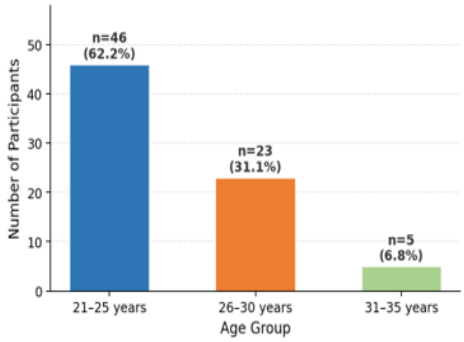

Figure 2. Age group distribution of study participants (n = 74)

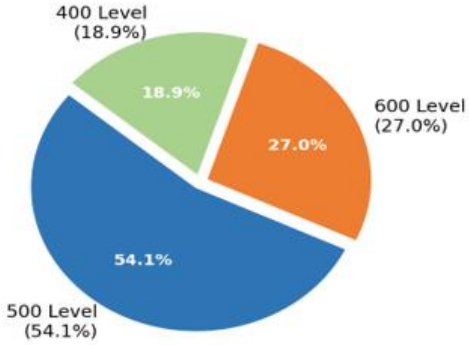

Figure 3. Distribution of participants by academic level (n = 74)

3.2. Knowledge of Radiation Protection Practices

Results of participants' knowledge toward radiation protection practices are presented in Table 1. Regarding the effect of cone length on patient dose, of 74 participants, 40 (54.1%) correctly stated that cone length affects patient dose. Among these, 32 (43.2% of the total sample) correctly identified the long cone as reducing dose, while 12 (16.2%) incorrectly chose the short cone, and 30 (40.5%) did not specify a cone type. With respect to film speed, 67.6% (50/74) agreed that film speed affects dose reduction; of these, 44.6% (33/74) correctly identified fast-speed film as delivering lower radiation, while 21.6% (16/74) incorrectly identified slow-speed film.

For collimator type, 50.0% (37/74) of students recognised that collimation affects patient dose. Of these 37 respondents, 54.1% (20/37) correctly identified rectangular collimation as superior, 27.0% (10/37) selected the round collimator, and 18.9% (7/37) did not specify a type. Only 27.0% correctly identified rectangular collimation, 13.5% chose round, and the remaining 50.0% who denied or were uncertain of any dose effect from collimation (together with the 9.5% who acknowledged dose dependence but could not specify a type) account for the 59.5% of total participants who did not correctly identify the rectangular collimator.

A total of 87.8% (65/74) of students reported standing behind a protective barrier during radiation exposure. The majority (73.0%; 54/74) stated they always use lead aprons and thyroid shields for patient protection, with 21.6% (16/74) using them only occasionally.

Most participants (70.3%; 52/74) were aware that shielding, distance, and time limitation should all be applied in combination to reduce exposure. On the question of which radiographic procedure delivers a higher cumulative dose, 48.6% (36/74) incorrectly identified the panoramic radiograph, while 41.9% (31/74) correctly identified the full-mouth periapical series as delivering the higher cumulative dose. Regarding pregnancy and dental radiography, 59.5% (44/74) stated that periapical radiography may be performed only under specific clinical conditions, while 24.3% (18/74) stated it should not be performed at all and 6.8% (5/74) had no objection. The majority (60.8%; 45/74) considered dental imaging to be of very high importance in clinical practice.

Table 1. Respondents' knowledge of radiation protection practices (n = 74)

Item / Response	n	% of total (n = 74)
Cone length — effect on patient dose		
Correct: Long cone reduces dose	32	43.2
Incorrect: Short cone selected	12	16.2
Don't know / Did not respond	30	40.5
Film speed — effect on patient dose		
Correct: Fast-speed film reduces dose	33	44.6
Incorrect: Slow-speed film selected	16	21.6
Don't know / Did not respond	25	33.8
Collimator type — effect on patient dose		
Correct: Rectangular collimator	20	27.0
Incorrect: Round collimator selected	10	13.5
Don't know / Did not respond	44	59.5
Protective barrier — would stand behind during exposure.		
Yes	65	87.8
No	9	12.2
Lead aprons and thyroid shield — frequency of use		
Always	54	73.0
Occasionally	16	21.6
Never	4	5.4
Three protection methods (shielding, distance, time) applied in combination.		
Correct: All three combined	52	70.3
Incorrect / Incomplete answer	22	29.7
Cumulative dose — which procedure delivers higher dose		
Correct: Full-mouth periapical series	31	41.9
Incorrect: Panoramic radiograph selected	36	48.6
Don't know / Did not respond	7	9.5
Periapical radiography in pregnancy		
Conditional only (correct)	44	59.5
Should not be performed at all	18	24.3
No objection	5	6.8
Don't know / Did not respond	7	9.5
Importance of dental imaging in clinical practice		
Very high importance	45	60.8
Moderate / Low importance	29	39.2

3.3. Knowledge of Biological Effects of Ionising Radiation

Results regarding knowledge of radiation biology are presented in Table 2. Regarding the most radiosensitive organ in the context of dental radiography, 47.3% (35/74) correctly identified the thyroid gland, while 21.6% (16/74) named the gonads, 16.2% (12/74) selected bone marrow, and 9.5% (7/74) chose skin. All participants were aware that ionising radiation can cause genetic mutation; while encouraging, this universal agreement is noted as a potential ceiling-effect item offering limited discriminatory value. A large majority (78.4%; 58/74) correctly recognised both stochastic and deterministic radiation effects, while 21.6% (16/74) were unaware of this distinction.

Table 2. Respondents' knowledge of biology effects of ionising radiation (n = 74)

Item / Response	n	% of total (74)
Most radiosensitive organs in dental radiography		
→ Thyroid gland (correct)	35	47.3
→ Gonad	16	21.6
→ Bone marrow	12	16.2
→ Skin	7	9.5
→ Did not respond	4	5.4
Ionising radiation causes mutation: Yes (all participants)	74	100.0
Aware of stochastic and deterministic effects: Yes	58	78.4
→ No	16	21.6

3.4. Knowledge of Radiation Protection Regulatory Bodies

As shown in Table 3, knowledge of radiation protection regulatory bodies was markedly deficient. The overwhelming majority of participants (89.2%; 66/74) could not identify any regulatory body whatsoever. Only 5.4% (4/74) named the ICRP, while single respondents (1.4% each) mentioned the IAEA, a combined ICNIRP/WHO, the International Nuclear and Atomic Radiation Agency alongside the Nigerian Nuclear Regulatory Agency, and the International Radiation Protection Agency, respectively.

Table 3. Respondents' awareness of radiation protection regulatory bodies (n = 74)

Response	n	% of total (74)
Could not identify any regulatory body	66	89.2
ICRP	4	5.4
IAEA	1	1.4
ICNIRP / WHO	1	1.4
International Nuclear and Atomic Radiation Agency / Nigerian Nuclear Regulatory Agency	1	1.4
International Radiation Protection Agency	1	1.4

Note. ICRP = International Commission on Radiological Protection; IAEA = International Atomic Energy Agency; WHO = World Health Organisation.

Discussion

This cross-sectional study assessed the knowledge of clinical dental undergraduate students at Bayero University Kano regarding radiation protection, the biological effects of ionising radiation, and awareness of radiation protection regulatory bodies. The findings reveal a pattern broadly consistent with comparable studies from other low- and middle-income countries: adequate awareness of some fundamental protection practices coexisting with critical deficits in technical radiation protection knowledge and near-total absence of awareness of regulatory governance frameworks.[8,7,12]

The finding that 87.8% of participants reported standing behind a protective barrier during radiation exposure is encouraging. Lasune et al.[12] found that close to 100% of dental students in Latur, Maharashtra endorsed this practice, while the 73.0% of participants who reported always using lead aprons and thyroid shields in the present study compares favorably with Uganda,

where Mutyabule and Whaites,[19] reported 77% lead apron use, and considerably surpasses findings from Indian studies where lead apron use rates as low as 40% were documented.[20] These findings indicate that some elements of patient protection practice are adopted during clinical training.

Conversely, the marked deficit in technical radiation protection knowledge is of clinical concern. Only 27.0% of all participants correctly identified rectangular collimation as the preferred dose-reducing option, broadly comparable to the 29.7% of interns found by Lasune et al.[12] in India and consistent with knowledge gaps documented across comparable settings[8]. Rectangular collimation reduces the effective dose by approximately 60% compared to round collimation without compromising image quality,[2] making collimator selection a critical competency. Similarly, only 44.6% correctly identified fast-speed film as reducing patient dose, comparable to Elmukhtar[9,] who reported 44% in Sudan, and lower than the 90.2% found among fourth-year dental students by Prabhat et al.[6] in India. Simmarasan et al.[5] similarly noted that 48.06% of participants failed to recognise that high-speed film reduces radiation exposure, confirming this knowledge gap is not unique to the Nigerian context.

Only 47.3% of participants correctly identified the thyroid gland as the most radiosensitive organ in the head and neck region, which is consistent with the 49% reported by Elmukhtar[9] in Sudan and broadly in line with findings from comparable studies in other low- and middle-income settings[8]. Both Lasune et al.[12] and Simmarasan et al.[5] found that interns performed better than junior students on thyroid identification, supporting the role of clinical experiential learning. Given the thyroid's established susceptibility to radiation-induced carcinoma and its proximity to dental radiation fields, this gap has direct implications for appropriate use of thyroid collars.[1]

In contrast, the very high awareness of radiation-induced mutation (100%) and the strong recognition of stochastic and deterministic radiation effects (78.4%) represent relative strengths. The 78.4% figure exceeds the 49.6% reported by Swapna et al.[4] in India and the 17.5% found by Khan et al.[18] in Karnataka, suggesting that conceptual radiobiology is better taught in the existing curriculum than its technical and procedural counterparts. The universal awareness of radiation-induced mutation, however, should be interpreted cautiously as a potential ceiling-effect item that offers limited discriminatory value between students with deep versus superficial understanding.

Perhaps the most striking finding is the near-total absence of awareness of radiation protection regulatory bodies, with 89.2% unable to name a single relevant body. This contrasts with 61.3% awareness reported by Khan et al.[18] and 60% by Behal[21] in India, and with Motwani et al.[13], who found that only 24% of medical and 54% of dental participants were aware of NCRP and AERB recommendations. Research among Indian practitioners has shown that knowledge of regulatory standards is independently associated with radiation protection compliance, and that neither educational level alone nor type of practice is sufficient without deliberate training in regulatory frameworks.[11] The near-complete deficit observed in the present study suggests that regulatory content may be absent or underemphasized in the undergraduate dental curriculum at this institution.

Evidence strongly supports structured educational intervention as the primary remedy. Hagi and Khafaji,[10] demonstrated that a single three-hour dedicated lecture improved radiation knowledge scores by 31 percentage points. Lasune et al.[12] and Simmarasan et al.[5] both recommended structured workshops, continuing dental education programs, and earlier curriculum integration of radiation protection content. Partnering with radiography departments for specialist-led sessions, mandating minimum clinical competency requirements in radiographic protection, and embedding radiation protection regulatory content from the third year of the dental curriculum would collectively address the

deficits identified in this study.

This study has several limitations. The convenience sampling technique and single-institution design limit generalizability to other Nigerian dental schools. The cross-sectional design cannot establish causal relationships between curriculum factors and knowledge outcomes. Self-reported attitudinal data are subject to social desirability bias. The data analysis is restricted to descriptive statistics, reporting frequencies and proportions only. The questionnaire was adapted from previously validated instruments used in comparable published studies without formal cultural or contextual validation for Nigerian dental students; however, no internal consistency measure such as Cronbach's alpha was calculated for this specific administration, and no formal pilot testing was conducted before data collection. These limitations are considered in the interpretation of all related results. In accordance with STROBE reporting standards for cross-sectional studies, we note that no formal assessment of potential sources of bias beyond those described above was conducted, and missing data handling was not applicable as all submitted questionnaires were complete.

Conclusion

The near-complete absence of awareness of radiation protection regulatory bodies is particularly concerning and suggests a systemic gap in curriculum content. Clinical dental undergraduate students at Bayero University Kano demonstrated moderate awareness of fundamental radiation protection practices. However, significant and clinically relevant deficits were identified in knowledge of collimator selection, film speed, cone length, and operator-source distance, all of which are directly modifiable determinants of radiation dose to patients and operators. Curriculum reforms are recommended, including earlier integration of radiation protection content, specialist-led practical workshops, minimum clinical competency standards in radiographic protection, and the cultivation of regulatory awareness from the undergraduate stage.

Conflict of Interest

The authors declare no conflict of interest.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions governing patient information collected.

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