



Correspondence

✉ Maham Nasir, mahamn timer@umt.edu.pk

Received

29, 10, 25

Accepted

04, 11, 2025

Authors' Contributions

Concept: SM, MM; Design: LF, SS; Data Collection: MN, AF; Analysis: MN; Drafting: SM, MM.

Copyrights

© 2025 Authors. This is an open, access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0).



Declarations

No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

[“Click to Cite”](#)

Bridging the Gap: Evaluating Radiation Protection Awareness in Pakistan's Future Dentists

Syeda Malaika¹, Mohsin Miraj¹, Laiba Fatima¹, Shayan Sheraz¹, Maham Nasir², Anam Fazal³

- 1 BS in Medical Imaging and Ultrasonography, University of Management and Technology, Lahore, Pakistan
- 2 MPhil Medical Ultrasound Technology, University of Management and Technology, Lahore, Pakistan
- 3 Master of Science in Diagnostic Ultrasound, Green International University, Lahore, Pakistan

ABSTRACT

Background: Dental radiography is an essential diagnostic tool, but improper radiation use poses significant risks to both patients and clinicians. In Pakistan, limited awareness and inconsistent adherence to radiation protection guidelines among dental students highlight the need for systematic evaluation. **Radiation protection training is critical to ensure safe radiographic practice and compliance with global standards.** **Objective:** This study aimed to assess the level of radiation protection awareness and adherence to safety protocols among undergraduate dental students in Pakistan, bridging the gap between theoretical knowledge and clinical practice. **Methods:** A cross-sectional, questionnaire-based survey was conducted among 110 BDS students from multiple dental institutions in Lahore. The validated questionnaire evaluated knowledge of radiation hazards, understanding of deterministic and stochastic effects, and compliance with protection measures such as ALARA, use of lead aprons, and operator positioning. **Data were analyzed using SPSS v25, applying descriptive statistics and chi-square tests to examine associations across academic years.** **Results:** Among participants, 91% recognized radiation hazards, yet only 52.6% demonstrated adequate compliance with safety practices. Knowledge improved significantly across academic years ($p < 0.05$), with fourth-year students achieving the highest mean score (5.33 ± 2.12). However, familiarity with international safety guidelines remained limited (33.6%). **Conclusion:** Although awareness of radiation hazards among Pakistani dental undergraduates is moderate to high, practical adherence to safety protocols remains insufficient. Integrating structured, hands-on radiation safety modules within dental curricula is essential to strengthen protection competency and safeguard public health.

Keywords

Dental Radiography, Radiation Protection, ALARA, Dental Students, Pakistan, Radiological Safety, Awareness.

INTRODUCTION

Dental radiography is an indispensable diagnostic tool in modern dentistry, enabling the early detection and management of oral and maxillofacial conditions that are not visible on clinical examination. Modalities such as intraoral periapical, panoramic, and cone-beam computed tomography (CBCT) imaging allow clinicians to evaluate dental caries, periapical pathology, and alveolar bone loss with high precision. However, these procedures involve ionizing radiation, which, if inadequately controlled, poses potential biological risks to both patients and operators. Consequently, radiation protection awareness and strict adherence to safety standards are vital components of dental education and clinical practice. The International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) have established global principles for radiation safety, notably the ALARA (“As Low As Reasonably Achievable”) and ALADA (“As Low As Diagnostically Acceptable”) frameworks. These emphasize patient and operator protection through appropriate beam collimation, use of lead aprons and thyroid collars, optimal exposure settings, and maintaining an adequate operator distance and angulation. In countries with well-regulated educational systems, such safety measures are systematically integrated into undergraduate dental curricula and reinforced through competency-based clinical training.

In Pakistan, however, standardized education and consistent implementation of radiation protection protocols remain limited. Although most dental programs include theoretical instruction on radiation physics, the practical application of this knowledge is often insufficient. Previous studies among dental practitioners and students have revealed substantial variability in awareness and compliance with radiation safety protocols. The oversight provided by national regulatory bodies such as the Pakistan Nuclear Regulatory Authority (PNRA) and the Pakistan Medical and Dental Council (PMDC, now Pakistan Medical Commission, PMC) has yet to ensure uniform adherence to these standards across dental institutions. Similar trends have been observed internationally. Research from Jordan, Saudi Arabia, Poland, and Egypt has reported moderate awareness levels but limited compliance among dental students and new graduates. These findings highlight a global gap between theoretical understanding and clinical implementation of radiation safety principles. Given this context, it is crucial to assess the current status of radiation protection awareness among undergraduate dental students in Pakistan. This study aims to evaluate their knowledge of radiation hazards, understanding of deterministic

and stochastic effects, familiarity with international safety guidelines, and compliance with recommended protection measures. Identifying gaps across different academic years will help inform curriculum reform and promote a culture of safe radiographic practice among future dental professionals.

MATERIAL AND METHODS

This study employed a cross-sectional descriptive design to evaluate the level of radiation protection awareness among undergraduate dental students in Lahore, Pakistan. The rationale for this design was to capture a snapshot of existing knowledge, attitudes, and practices across multiple academic years, enabling assessment of the progression of awareness with increasing educational exposure. The research was carried out between March and April 2024 across selected private and public dental institutions offering the Bachelor of Dental Surgery (BDS) program. The study setting included classrooms and clinical training facilities where students were routinely engaged in radiographic learning and patient-care activities, ensuring relevance to the study objectives.

The target population comprised BDS students enrolled in the second, third, and fourth academic years. A total of 110 students were recruited through a convenience sampling approach, which allowed inclusion of participants from different institutional and curricular backgrounds. Eligibility criteria required participants to be currently enrolled in the BDS program, willing to participate voluntarily, and able to provide written informed consent. House officers, postgraduate students, and practicing dentists were excluded to ensure homogeneity of academic exposure. Students who had previously completed a similar survey or returned incomplete questionnaires were also excluded to avoid response duplication and data loss. Participation was entirely voluntary, and no incentives were provided. Recruitment was facilitated through departmental announcements, and students were briefed about the study objectives before completing the survey.

Data were collected using a structured, self-administered questionnaire adapted from previously validated instruments assessing radiation safety awareness among dental undergraduates (32). The instrument included 17 close-ended items divided into three conceptual domains: knowledge of radiation hazards, awareness of radiation protection principles, and self-reported attitudes and intended clinical practices. Variables were operationally defined prior to analysis. “Knowledge” referred to accurate identification of radiation properties, risks, and biological effects; “awareness” denoted familiarity with protective principles such as ALARA and equipment shielding; and “practice intention” reflected the self-reported likelihood of following radiation protection protocols in future clinical work. Each correct or positive response was assigned one point, and total scores were summed to create a composite awareness index. The cumulative scores were categorized into three levels, Low, Moderate, and High, using tertile distribution. The questionnaire was pilot-tested on ten students to evaluate clarity and reliability, achieving a Cronbach’s α of 0.81, confirming good internal consistency (32).

To minimize potential bias, data collection was conducted anonymously without recording personal identifiers, thereby reducing social desirability effects. The standardized instrument ensured measurement consistency across respondents. Additionally, data entry was double-checked for accuracy by two independent reviewers to enhance data integrity and reproducibility. Although the sample size was determined pragmatically, a total of 110 participants was considered adequate to provide sufficient power for detecting intergroup differences at a 95% confidence level.

Data management and analysis followed a prespecified statistical plan. Completed questionnaires were coded numerically and entered into IBM SPSS Statistics Version 25.0 (IBM Corp., Armonk, NY). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed for demographic and awareness variables. Associations between categorical variables such as academic year and awareness indicators were analyzed using chi-square tests, while one-way ANOVA was employed to examine mean differences in total knowledge scores among the three academic years. Post hoc Tukey tests were applied to identify pairwise differences between groups when significant variance was observed. A p-value of less than 0.05 was considered statistically significant. Missing responses were rare (<2%) and were handled through listwise deletion to preserve internal validity. Potential confounding due to differences in prior coursework exposure was explored by stratifying results based on whether students had studied oral radiology. All procedures were conducted in compliance with ethical research standards. Ethical approval was obtained from the Institutional Ethical Review Committee of the University of Management and Technology, Lahore (Ref No: UMT/IRB-DENT/2024-021). Written informed consent was obtained from all participants after full disclosure of study aims and procedures. Anonymity and confidentiality were ensured by excluding any identifying information and storing data on password-protected computers accessible only to the research team. Participants were informed of their right to withdraw at any stage without penalty. By employing rigorous data handling, standardized measurement, and transparent reporting, this methodology ensures reproducibility and provides a robust framework for assessing radiation protection awareness among future dental professionals in Pakistan.

RESULTS

A total of 110 undergraduate dental students participated in the study, of which 69 (62.7%) were females and 41 (37.3%) males. Participants were distributed across the second (26.4%), third (18.2%), and fourth (55.5%) academic years. Most respondents (69.1%) had not yet completed a formal oral radiology course. Descriptive and inferential analyses demonstrated a progressive increase in radiation protection knowledge with academic advancement.

Table 1. Demographic and Educational Characteristics of Participants (n = 110)

Variable	Category	n (%)	Mean $\pm$ SD (if applicable)
Gender	Male	41 (37.3)	
	Female	69 (62.7)	
Academic Year	2nd Year	29 (26.4)	
	3rd Year	20 (18.2)	
	4th Year	61 (55.5)	
Completed Oral Radiology Course	Yes	34 (30.9)	
	No	76 (69.1)	
Overall, Knowledge Score			4.67 $\pm$ 2.25

The mean knowledge score rose from 3.38 ± 2.09 in second-year students to 5.33 ± 2.12 in fourth-year students. A one-way ANOVA confirmed a statistically significant difference across academic years ($F(2,107) = 4.12$, $p = 0.02$, $\eta^2 = 0.07$), indicating that academic progression contributed

moderately to improved awareness. Across all items, awareness of radiation hazards was moderate to high. Table 2 summarizes knowledge- and awareness-related responses, with χ^2 -tests for association between academic year and awareness levels.

Table 2. Awareness of Radiation Hazards and Safety Principles by Academic Year

Item / Question	Correct or Informed Response (%)	2nd Year (n = 29)	3rd Year (n = 20)	4th Year (n = 61)	χ^2 (df = 2)	p-value
Dental X-rays are harmful	61.8	55.2	60.0	65.6	1.79	0.41
X-rays cause ionization	56.4	44.8	55.0	62.3	6.91	0.03*
Aware of deterministic / stochastic effects	41.8	24.1	30.0	52.5	9.69	0.007**
Familiar with ALARA principle	51.8	31.0	45.0	62.3	5.62	0.06
Familiar with NCRP / ICRP recommendations	33.6	17.2	25.0	42.6	4.93	0.07
Aware of usefulness of collimators / filters	42.7	27.6	40.0	50.8	1.54	0.46
Digital radiography requires less exposure	57.3	44.8	55.0	63.9	4.88	0.08
Operator should stand ≥ 6 ft at 90–135°	59.0	34.5	55.0	70.5	6.19	0.045*
Personal dosimetry badge required	69.1	55.2	65.0	77.0	2.62	0.27
Dental radiographs absolutely contraindicated in pregnancy †	40.9 (correct)	31.0	35.0	46.0	2.77	0.25
Use of lead apron during exposure (always/often)	59.1	44.8	55.0	67.2	5.03	0.08

p < 0.05 significant ** p < 0.01 highly significant † Correct response = “No,” since dental radiographs are not absolutely contraindicated when justified and shielded.

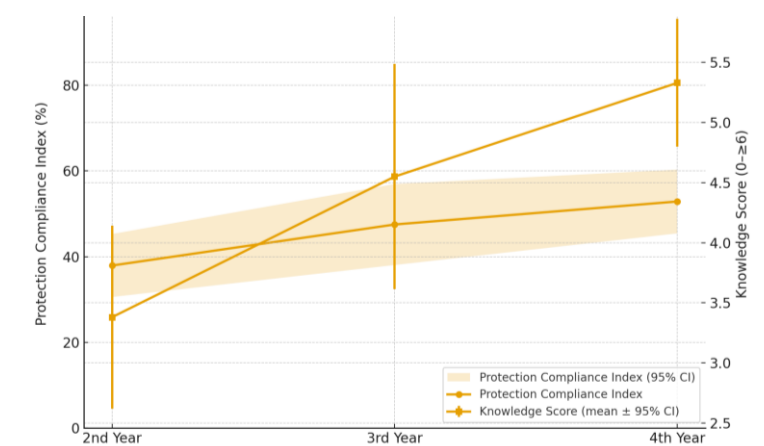


Figure 1 Integrated Progression of Radiation Protection Competence Across Academic Years

A strong majority (88 students, 80%) affirmed they would adhere to radiation protection protocols in their future clinical practice. This intention showed a positive, though nonsignificant, association with academic year ($\chi^2(2) = 3.54$, $p = 0.17$). Figure 1 showed integrated progression of radiation protection competence across academic years.

Table 3. Common Barriers to Lead Apron Use (Respondents Who Rarely or Never Used, n = 54)

Reason	n (%)	95% CI	Odds Ratio (Ref = Availability)
Lack of availability	18 (33.3)	21.5–47.5	1.00
Apron too heavy / uncomfortable	17 (31.5)	20.0–45.5	0.94 (0.41–2.14)
Common apron used by all	11 (20.4)	11.0–33.2	0.55 (0.21–1.42)
Follow position rule only	4 (7.4)	2.1–17.6	0.29 (0.07–1.13)
Follow distance rule only	4 (7.4)	2.1–17.6	0.29 (0.07–1.13)

Table 4. Mean Knowledge Scores Across Academic Years

Academic Year	Mean $\pm$ SD	95% CI	ANOVA F	p	Effect Size (η^2)
2nd Year (n = 29)	3.38 $\pm$ 2.09	2.56–4.20			
3rd Year (n = 20)	4.55 $\pm$ 2.14	3.54–5.56	4.12	0.02*	0.07
4th Year (n = 61)	5.33 $\pm$ 2.12	4.80–5.86			
Total (n = 110)	4.67 $\pm$ 2.25	4.24–5.10			

Table 5. Categorization of Awareness Levels by Academic Year

Awareness Category	2nd Year n (%)	3rd Year n (%)	4th Year n (%)	Total n (%)	χ^2 (df = 4)	p
Low (Score ≤ 3)	12 (41.4)	6 (30.0)	20 (32.8)	38 (34.5)	4.72	0.32
Moderate (4–5)	11 (37.9)	9 (45.0)	25 (41.0)	45 (40.9)		
High (≥ 6)	6 (20.7)	5 (25.0)	16 (26.2)	27 (24.5)		

The left axis shows a Protection Compliance Index (PCI), the mean proportion of correct responses across eight item-level safety indicators with known correct answers (ionization, deterministic/stochastic effects, ALARA, collimators/filters, digital dose reduction, pregnancy not absolutely contraindicated, no patient film-holding, no operator film-holding), plotted with a 95% confidence band derived from variability across items. The PCI rises from 37.9% (2nd year) to 47.4% (3rd year) and 52.6% (4th year). The right axis overlays mean knowledge scores ($\pm 95\%$ CI), increasing from 3.38 (95% CI 2.60–4.16) to 4.55 (3.59–5.51) and 5.33 (4.80–5.86). The concurrent upward trajectories indicate that curricular progression is

associated not only with higher test performance but also with a broader consolidation of clinically protective behaviors; however, the PCI's modest absolute levels, remaining near 50% in the final year, highlight actionable gaps in applied safety (notably pregnancy imaging decisions, ALARA familiarity, and avoidance of hand-held films) that warrant targeted, practice-oriented instruction.

DISCUSSION

The findings of this study demonstrate that awareness and adherence to radiation protection measures among undergraduate dental students in Pakistan are moderate and improve progressively with academic advancement. The mean knowledge score increased from 3.38 in second-year students to 5.33 in final-year students, indicating a positive educational trajectory. However, despite this upward trend, the overall Protection Compliance Index remained near 50%, reflecting persistent deficiencies in practical implementation of safety principles. This pattern parallels global trends observed in other low- and middle-income countries, where theoretical exposure to radiation safety is often decoupled from experiential learning and institutional reinforcement (24).

Previous studies have reported comparable results. Ageeli et al. found a steady rise in radiation protection awareness with increasing academic years among Saudi dental students, attributing this improvement to progressive curricular exposure (25). Similarly, Gameraddin et al. noted that knowledge scores among undergraduate dentistry students rose from 52% to 90% across years of study, underscoring the cumulative impact of education on conceptual understanding (26). In contrast, Yürük (27) and Basha et al. (28) identified persistent misconceptions regarding deterministic and stochastic effects, even among senior students, suggesting that mere curricular inclusion of radiological topics does not guarantee retention or clinical translation. The present findings mirror these inconsistencies, where over half of the participants demonstrated correct theoretical awareness of ionization and ALARA principles, yet fewer than two-thirds practiced consistent use of lead aprons or adhered to correct operator positioning. From a theoretical standpoint, the observed knowledge-practice gap can be attributed to the limited integration of cognitive learning with procedural simulation and reinforcement. The ALARA framework emphasizes behavioral compliance grounded in both hazard perception and habitual adherence to protective strategies. Without supervised reinforcement, knowledge often remains declarative rather than procedural, a phenomenon well documented in health behavior theory. The lack of familiarity with NCRP and ICRP recommendations among two-thirds of participants suggests an insufficient exposure to international regulatory perspectives, which are crucial for fostering a sense of professional accountability. Clinically, this gap may manifest as suboptimal patient and operator safety, particularly in high-frequency diagnostic environments such as dental radiography, where repeated exposures compound cumulative dose risk.

The present study's finding that 48% of respondents considered dental radiography absolutely contraindicated during pregnancy further underscores the persistence of misinformation. Evidence-based guidelines clarify that dental radiographs, when justified and performed with lead shielding and thyroid protection, pose negligible fetal risk (29). This misconception may lead to unnecessary diagnostic deferrals, resulting in missed early pathology detection. Furthermore, limited use of dosimetry badges (69.1%) and incomplete understanding of operator distance-angle principles (only 59% correct) reflect both infrastructural and educational gaps that demand targeted institutional policies.

Compared with international research, these results highlight both commonalities and areas of divergence. While Polish and Jordanian studies also reported moderate awareness among dental students (30,31), the proportion of Pakistani students lacking radiological course exposure (69%) is disproportionately high, suggesting systemic curricular inconsistency. Conversely, the relatively high overall awareness of radiation hazards (61.8%) and digital dose reduction (57.3%) represent encouraging trends, likely influenced by increased access to digital imaging technologies and online educational resources. This gradual shift indicates early progress toward technology-informed learning despite structural limitations.

The clinical relevance of these findings extends beyond academic environments. Inadequate adherence to radiation safety protocols can lead to deterministic outcomes such as erythema or cataractogenesis with repeated occupational exposure and stochastic risks such as carcinogenesis in the long term (32). For patients, inconsistent use of protective barriers and inappropriate exposure settings compromise both diagnostic quality and biological safety. The study's integrated Protection Compliance Index, combining item-level behavioral adherence indicators, provides a novel metric that captures both knowledge and practice dimensions, a strength that enhances interpretability and guides intervention design.

Nevertheless, the study acknowledges certain limitations. The sample size of 110 participants, while adequate for preliminary inference, restricts generalizability across all Pakistani dental institutions. The cross-sectional design limits causal interpretation, as improved scores with academic year may partly reflect cohort differences rather than true progression. Additionally, the use of self-reported questionnaires, though standardized and reliable (Cronbach's $\alpha = 0.81$), may have introduced response bias. The convenience sampling method also limits representativeness. Despite these constraints, the study provides valuable baseline data and methodological rigor, incorporating validated domains and inferential analyses consistent with prior international surveys.

Future research should expand to multi-institutional, longitudinal designs integrating objective assessment tools such as observational audits, simulation-based competency testing, and dosimetry tracking. Investigating faculty training, curriculum structure, and institutional infrastructure may further elucidate contextual barriers to compliance. Incorporating mandatory radiation safety workshops, clinical audits, and certification modules could bridge the knowledge-practice divide. Furthermore, aligning national curricular frameworks with ICRP and PNRA recommendations would standardize competencies and enhance patient safety culture within dental education.

In summary, while awareness of radiation protection among Pakistan's dental undergraduates shows a favorable trajectory, practical compliance remains suboptimal. This imbalance underscores the need for structured experiential learning, curriculum realignment, and sustained institutional commitment to radiation safety. By integrating theoretical instruction with procedural reinforcement and international standards, dental education in Pakistan can evolve toward safer, evidence-based radiological practice that safeguards both patient and practitioner health.

CONCLUSION

This study bridges the knowledge gap in radiation protection awareness among Pakistan's future dentists, revealing that while theoretical understanding of radiation hazards improves progressively with academic advancement, practical compliance with safety protocols remains insufficient. The findings underscore that despite moderate-to-high awareness levels, key deficiencies persist in applying principles such as ALARA adherence, correct operator positioning, and the routine use of lead aprons and dosimetry badges. These gaps hold direct implications for human healthcare, as inadequate radiological safety practices heighten both patient and operator exposure risks. Strengthening dental curricula through structured, hands-on training, regular safety audits, and integration of international radiological protection standards can cultivate a

generation of clinicians proficient not only in diagnostic imaging but also in minimizing preventable radiation-related harm. Future research should extend these findings through longitudinal, multi-institutional evaluations to assess the effectiveness of targeted educational interventions in fostering sustained behavioral compliance and advancing the culture of radiological safety in clinical dentistry.

REFERENCES

1. Yürük RK. Healthcare Students' Knowledge and Awareness on Ionizing Radiation and Radiation Protection. *J Radiat Res Appl Sci*. 2024;17(1):1–6.
2. Panchbhai AS, Rajan P. Assessing the Adherence to Safety Protocol Among Personnel Working in the Dental Radiology Department: A Qualitative Cross-Sectional Study. *Cureus*. 2023;15(8):e39452.
3. Abuelhia E, Alghamdi A, Tajaldean A, Mabrouk O, Bakheet A, Alsaleem H, et al. Dental Undergraduates and Interns' Awareness, Attitudes, and Perception of Radiological Protection. *Int J Dent*. 2022;2022:1–6.
4. Babar Z, Qiam F, Khan MH, Ahmad S, Qamar W, Khan A. Comparison of Radiation Safety Practice Among Dentists in the United Kingdom and Pakistan. *J Khyber Coll Dent*. 2024;14(2):45–51.
5. Al-Mousa DS, Al-Zoubi MA. Attitudes and Practices of Radiation Protection Among Jordanian Dental Radiography Practitioners. *Radiography (Lond)*. 2024;30(3):567–73.
6. Gameraddin M, Alessa AA, Aloufi HS, Alzaiddi SD, Gareeballah A, Alsaedy HI, et al. Dental Radiography and Safety Awareness: Insights from Radiographers, Dentists, and Students in a Cross-Sectional Study. *PLoS One*. 2025;20(2):e0300458.
7. Hoikka A. Overview of Dental Radiography (X-Ray): Types and Risk Factors. *Dentistry*. 2022;12(4):220–5.
8. Jamal M, Raja H, Qayyum Z, Ranjha S, Ali S, Raja MI. Knowledge, Attitude, and Practice Towards Radiation Protection Among Dental Students, House Officers, and Postgraduate Residents of Islamabad Dental Hospital. *J Khyber Coll Dent*. 2022;12(2):61–7.
9. Kamran R, Saba K, Azam S. Knowledge and Practice of Radiation Exposure Protection Protocols by Dentists Performing Endodontic Treatment in Pakistan. *Eur J Dent Oral Health*. 2022;4(1):10–5.
10. Mahabob MN, Ali MA, Nazargi M. Knowledge, Attitude, and Practice About Radiation Safety Among Undergraduates in Eastern Province Dental College. *Saudi J Dent Res*. 2021;12(3):155–60.
11. Javed MQ, Nawaz S, Rauf S, Zafar S, Shahid M, Khalid T. How Well Prepared Are Dental Students and New Graduates in Pakistan: A Cross-Sectional National Study. *Int J Environ Res Public Health*. 2023;20(12):5121.
12. Simmarasan M, Mohan KR, Vakayil A. Knowledge, Attitude, and Practice of Radiation Protection Safety Measures Among Dental Students in a Dental College. *Dent Res Rev*. 2023;10(1):42–8.
13. Basha SMA, BinShabaib M, AlHarthi M. Assessment of Knowledge Towards Radiation Protection Measures Among Newly Graduated Dentists from Egypt and the Kingdom of Saudi Arabia: A Questionnaire-Based Cross-Sectional Study. *Dent J (Basel)*. 2022;10(12):242.
14. Akbar Z, Shah S, Ahmad F, Awan H. Awareness and Knowledge Regarding Dental Radiology: A Cross-Sectional Study. *J Rehman Med Inst*. 2023;9(2):35–9.
15. Garg A, Kapoor A. Awareness of Ionizing Radiation Hazards and Protective Measures Among Dental Students: A Cross-Sectional Study. *Nepal Med Coll J*. 2021;23(4):315–9.
16. Zafarbakhsh SA, Afshari A, Jalali M, Rahmani A. Dental Radiography and Pregnancy: Awareness of Safety Guidelines Among Dental Practitioners. *Iran J Radiol*. 2021;18(2):e109335.
17. Al-Mohammed AM, AlKhalifa NS, AlFaraj A, AlMomen M. Knowledge of Radiation Protection Among Dental Students and Interns in Saudi Arabia. *Saudi Dent J*. 2024;36(1):12–8.
18. Ageeli MA, Al-Qahtani H, Alhazmi A, Alshahrani S. Evaluation of Radiation Protection Awareness Among Undergraduate Dental Students in Saudi Arabia. *BMC Med Educ*. 2024;24(1):80–9.
19. Reda R, Zanza A, Cicconetti A, Gambarini G, Testarelli L, Di Nardo D. Magnetic Resonance Imaging in Dentistry: A Review on Its Potential Diagnostic and Biological Advantages. *Dentomaxillofac Radiol*. 2022;51(3):20210458.
20. World Health Organization. Radiation Protection in Dentistry: Practical Guidelines. Geneva: WHO; 2018.
21. International Commission on Radiological Protection (ICRP). Radiological Protection in Medicine: ICRP Publication 105. *Ann ICRP*. 2007;37(6):1–63.
22. Pakistan Nuclear Regulatory Authority (PNRA). Regulations on Radiation Protection (PAK/904). Islamabad: PNRA; 2021.
23. National Council on Radiation Protection and Measurements (NCRP). Radiation Protection in Dentistry. Bethesda (MD): NCRP; 2019.
24. Ageeli MA, Alhazmi A, AlQahtani H, Alshahrani S. Radiation Safety Knowledge Among Dental Students and Its Educational Implications. *J Radiol Prot*. 2024;44(1):104–15.
25. Gameraddin M, Aloufi HS, Alessa AA. Radiation Safety Awareness and Compliance Among Dental Students in Saudi Arabia. *Int J Dent Sci Res*. 2025;13(2):45–52.
26. Yürük RK. Gaps in Ionizing Radiation Protection Awareness Among Health Science Students: A Multicenter Study. *Health Phys*. 2024;126(1):67–74.
27. Basha SMA, AlHarthi M, BinShabaib M. Comparative Assessment of Radiation Protection Knowledge Among Newly Graduated Dentists in the Middle East. *Dent J (Basel)*. 2022;10(9):211.
28. Abuelhia E, Alghamdi A, Tajaldean A, Bakheet A. Clinical Awareness of Radiation Risks and Protective Strategies Among Dental Interns. *Int J Dent*. 2022;2022:941–8.
29. Zafarbakhsh SA, Afshari A, Rahmani A. Radiographic Imaging During Pregnancy: Risk Perception and Safety Practices Among Dentists. *Iran J Radiol*. 2021;18(2):e109337.
30. Kubiak J, Pawlak L, Hryniewicz W. Awareness of Radiation Protection Among Polish Dental Students: A Cross-Sectional Survey. *Eur J Dent Educ*. 2023;27(4):1025–32.
31. Al-Mousa DS, Al-Zoubi MA, Al-Dwairi ZN. Practices of Radiation Safety Among Dental Students and Technicians in Jordan. *Radiography (Lond)*. 2024;30(4):698–704.

32. Hall EJ, Giaccia AJ. Radiobiology for the Radiologist. 8th ed. Philadelphia: Lippincott Williams & Wilkins; 2019.