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Evaluating radiation safety knowledge and practices in dental professionals: findings from a cross-sectional survey

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Abstract

Background Dental radiography is used extensively for diagnosing dental and maxillofacial disorders. Therefore, dental professionals must have adequate knowledge of and practice related to radiation protection and safety. The main objective of this study was to determine the degree of radiation safety knowledge among dental professionals and students in Palestine's northwest West Bank.

Methodology A cross-sectional study was conducted to evaluate radiation safety knowledge and practices among dental professionals in the West Bank, Palestine, from February to September 2023. Seven hundred fifteen participants (103 dentists and 612 dental students) completed a questionnaire with demographic information and eighteen closed-ended questions. The data were analyzed via SPSS version 27 and DATAtab, and chi-square and nonparametric tests were used to assess the relationships between variables.

Results A low overall knowledge level was noted (average score of 7.51 ± 2.67 out of 16). The students had a significantly higher mean rank in knowledge and practice than did the dentists (368.44 vs. 295.98, $p = 0.001$). Among the students, the mean ranks were higher in the 4th and 5th academic years than in the 2nd and 3rd academic years. In contrast, there were insignificant differences in the scores of knowledge and practice among dentists with different experience levels; those with more than 14 years and 5–9 years of experience had higher mean ranks than did the other dentists.

Conclusion There was a lack of knowledge and practice regarding radiation protection and safety among the respondents. Students demonstrated higher knowledge scores than dentists, despite having less clinical experience, possibly due to more recent exposure to formal training in radiation protection. While there are no significant differences in knowledge among dentists of varying experience, more experienced dentists generally rank higher. To address this, raising awareness of radiation safety among dental professionals through improved curricula and ongoing training is essential. Awareness campaigns should also emphasize the importance of radiation safety for professionals and patients.

Keywords Dental professionals, Radiation safety, Dentists, Students, Knowledge, Practice

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Introduction

Dental radiographs are necessary for disease diagnosis and monitoring; however, they pose dangers due to ionizing radiation. These dangers are classified as deterministic (severity increases with dose, with some effects, such as cataracts, potentially occurring at lower doses than previously thought) and stochastic (e.g., cancer caused by DNA damage). The widely accepted linear-no-threshold (LNT) model predicts that risk increases linearly with exposure, particularly above 100 mGy; however, there is no convincing evidence of increased health hazards below this level.

Radiation doses vary significantly between dental imaging methods, ranging from 1.5 μSv in intraoral X-rays to over 1,000 μSv in CBCT scans. Because of this heterogeneity, dentists must carefully choose imaging modalities, especially since young people are up to 32 times more vulnerable to radiation dangers than adults are. The goal is to strike a balance between diagnostic utility and radiation exposure, with strong imaging necessity requirements in place, particularly for pregnant and young patients, to assure patient, staff, and community safety [1]. The use of dental X-ray examinations has increased because of the significant progress and greater usage of ionizing radiation in the diagnosis of various dental pathologies. Dental X-ray images are essential for evaluation and therapeutic planning since many disorders cannot be easily evaluated by eye inspection. As a result, many people are now receiving higher radiation doses than they did in the last decade. A recent study reported that from 2014 to 2015, over 22 million panoramic scans, more than 5 million dental cone-beam computed tomography (CBCT) images, and 300 million intraoral radiographs were collected in the United States [2]. Concerns over possible patient side effects have been raised by the scientific community, particularly with respect to radiation-related malignancies [3]. Additionally, multiple studies have shown that patients who receive dental X-rays may have a slightly elevated risk of developing cancer [4–7]. Therefore, accurate knowledge of the radiation doses provided by various imaging modalities and a thorough awareness of radiation protection concerns are essential. Ensuring that all specialists engaged adhere to the latest appropriateness and optimization standards is crucial [8]. Undergraduate courses should serve as the foundation for basic radiation safety training; even after graduation, specialized update courses should be added whenever required based on the recommendations of the International Commission on Radiological Protection (ICRP) report No. 113. According to this report, millions of medical professionals who utilize radiation-producing equipment or order ionizing radiation-related operations must be better versed in the possible consequences of radiation or optimization techniques [9].

Despite the relatively low radiation dose involved in dental imaging, cumulative exposure over time, particularly in high-volume clinics, can increase the risk of long-term effects, including stochastic effects for both dentists and patients. Therefore, it is essential to employ radiation protection concepts such as dose limitation, optimization, and justification. Justification: A radiograph should be taken only if it is likely to help the patient's diagnosis or treatment based on clinical evaluation and individual criteria such as age and dental history. Optimization ensures that each radiograph provides adequate diagnostic detail while limiting radiation exposure to the lowest level that is reasonably attainable. Notably, efforts that limit patients frequently reduce exposure hazards for dental professionals. The use of lead aprons and thyroid collars is important for reducing radiation exposure in dental imaging. However, the routine use of lead shielding is now discouraged in certain situations because of potential interference with imaging and the risk of repeated exposures. Instead, alternative methods are available to effectively protect patients, such as using digital radiography, ensuring proper maintenance of machines, and selecting imaging parameters based on the patient's age. Furthermore, educating dentistry students about radiation protection and safety fosters a culture of accountability and prudence, which results in better patient care. An alarming lack of understanding of radiation safety has been demonstrated in several studies conducted with dentists, dental students, and technicians. Many professionals have underestimated radiation doses from imaging and cannot differentiate between ionizing and nonionizing radiation-based techniques [10]. These discouraging results indicate a meticulously thorough assessment of dental students' and practitioners' knowledge of the fundamental radiation protection issues necessary for their day-to-day work to learn more about the state of radiation protection education among those who will order, conduct, or interpret dental radiography examinations in the future. The importance of creating a supportive culture of radiation safety throughout the educational system has been emphasized. All parties involved, including students during their training period, should receive ongoing education and testing to guarantee optimal performance, eliminate mistakes, and protect the population [11, 12]. To the author's knowledge, studies in Palestine that assess dental professionals' awareness of radiation safety and protection are lacking. The number of dental students and dentists in North Palestine is the highest. However, no study has been conducted to assess their knowledge in this field. This study aimed primarily to provide insight into radiation safety awareness among dentists and dental students in the northern region of the West Bank-Palestine.

Methodology

Study design

This cross-sectional survey was conducted among dentistry students in the sole medical dentistry school and dentists from the private and public sectors in the North of the West Bank, Palestine, from February 2023 to September 2023. The dentistry programme at the university includes a compulsory course on radiation protection in the early years of study. This course aims to provide students with a comprehensive understanding of radiation safety in dentistry. It covers the potential risks that X-rays pose to patients, the functioning of dental X-ray equipment, and how these factors influence the radiation dose received by patients. The dentists who participated in the study had varying degrees of clinical experience, and some were graduates from abroad. The study utilized a questionnaire employed in earlier research with some modifications [13]. To assess the compatibility of the questionnaire with the targeted populations, a pilot study was carried out on 15 dentists, and 15 dental students were randomly chosen; the findings of which were not included in the main analysis. The reliability analysis revealed a Cronbach's alpha of less than 0.7. Therefore, it was revised face-to-face with a dental expert who has over 15 years of experience. The questionnaire consisted of two sections. The first section concerned demographic information. The second section consists of questions assessing the knowledge and practice of radiation hazards and protection (e.g., the use of radiation protection devices, sensitive structures to radiation, and the relationship between exposure and distance). The questionnaire was designed based on "True" "False" and "I don't know" responses.

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The survey questionnaire was completed by 710 dental students from the sole medical dentistry school north of the West Bank and ranged in grade level. Among them, 612 dental students were enrolled in the study, while the rest were excluded for not completing the questionnaire. The number of dentists included in the study was 103 out of 136 for the reasons mentioned earlier. The 103 dentists were distributed as 68 dentists in the private sector and 39 dentists in the public sector from 3 main geographical regions in the North Region of the West Bank, Palestine. The Arab American University ethical committee authorized the proposal (IRB number: 2023–0270), and the participants completed the questionnaire only after reading it and giving their written approval. All data from the electronic survey was anonymized, with no personally identifiable information stored. The responses were aggregated for analysis, with access limited to authorized researchers, in compliance with IRB guidelines to protect participant confidentiality.

Method of data analysis

The data were analyzed via SPSS version 27.0 and the DATAtab statistics calculator, and inferential and descriptive statistics were used, with the frequency and percentage used for categorical data and the mean and standard deviation used for continuous data (knowledge and practice scores), after each corrected answer for both knowledge and practice was 1, and each incorrect sign was 0 for the 18 questions (16 for knowledge and 2 for wearing the radiation protection apparatus). A chi-square test was used to correlate the frequency of knowledge and practice among both groups. For continuous data, a normality test was conducted to assess the normality of the mean distribution of scores of total knowledge and practice. After the total score of knowledge and practice was calculated for all the study participants based on correct answers, each correct answer was given a score of 1, and each incorrect answer was given a score of zero. The mean score of knowledge was calculated and classified as low, moderate, or high (mean score = 1–8 (less than 50%, low), or 9–14 (50–74%, moderate), 15–18 (75% and more, high). The Shapiro−Wilk test was performed to check the normality of the data and demonstrate the nonnormality of the data (P value < 0.001). Moreover, the

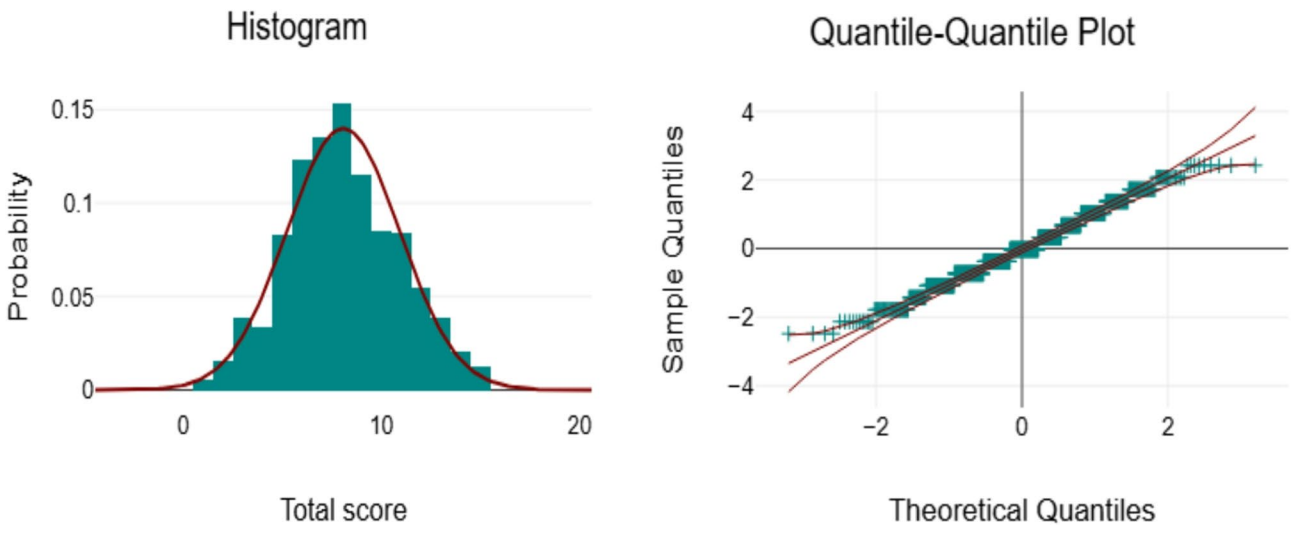

Fig. 1 Histogram and Q–Q plot showing the non-normal distribution of the data

Table 1 Gender and previous course distributions among the study groups

Demographic character's		Study groups		Total	*P* value
		Student	Dentists		
Gender	Male	245 (40.03%)	54 (52.43%)	299	0.013
	Female	367 (59.97%)	49 (47.57%)	416	
A previous course in radiation protection	Yes	590 (96.41%)	42 (40.78%)	632	< 0.001
	No	22 (4.59%)	61 (59.22%)	83	
Total		612	103	715	

histogram analysis and Q−Q plot shown in Fig. 1 indicate a non-normal distribution of the data; for this reason, the nonparametric test was used, whereas the Mann–Whitney U test and Kruskal−Wallis test with post hoc Dunn–Bonferroni correction for pairwise group comparisons were used to assess the relationships between the mean scores among the study groups and the demographic characteristics of each group, with the p value considered significant if < 0.01 and 0.05.

Results

Table 1 presents the demographic data of the study participants. Most of the dental students were female, accounting for 59.97% of the group, whereas more than half of the dentists were male, accounting for 52.43%. Additionally, a significant portion of the dental students (96.41%) reported having previously completed courses related to radiation protection. In contrast, only 40.78% of the dentists had attended such courses. Among the dental students, approximately 33.01% are in their fourth academic year, and 25.65% are in their fifth year. On the other hand, most dentists had less than four years of experience, accounting for 39.81%, as illustrated in Fig. 2.

Table 2 shows a comparison of radiation knowledge between students and dentists. When questioned about background radiation sources, 53.9% of the students and 51.5% of the dentists provided correct responses, and understanding of As Low As Reasonably Achievable (ALARA) principles was greater among dentists (69.9%) than among students (51.0%). In response to the question about the similarities between the properties of ionizing radiation used in the diagnosis and natural background radiation, 49.0% of the students answered correctly, whereas only 26.2% of the dentists did. A significant difference was observed in knowledge of the relationship between radiation exposure and distance from the source, where 93.3% and 29.1% of the students and dentists correctly answered, respectively.

In terms of the average dose from periapical radiography compared with daily background radiation, 56.9% of the students and 50.5% of the dentists answered correctly. Nevertheless, 75.7% of the dentists believed that the radiation dose from a single periapical radiograph was safe and had no health impact, whereas 39.4% of the students did. Both groups demonstrated a moderate understanding of the risk−benefit balance associated with radiation exposure, with 64.4% of the students and 69.9% of the dentists providing correct responses. Awareness of cancer risk from periapical examinations was generally low, with only 17.0% of students and 5.8% of dentists correctly disagreeing with the claim that 1 in 1000 examinations results in cancer-induced death.

The majority (82.5%) of the students and 76.7% of the dentists correctly reported that children and fetuses are more sensitive to radiation. However, only 12.3% of the students and 49.5% of the dentists correctly denied the misconception that radiologic exams for pregnant women are entirely forbidden. Awareness of legal limits

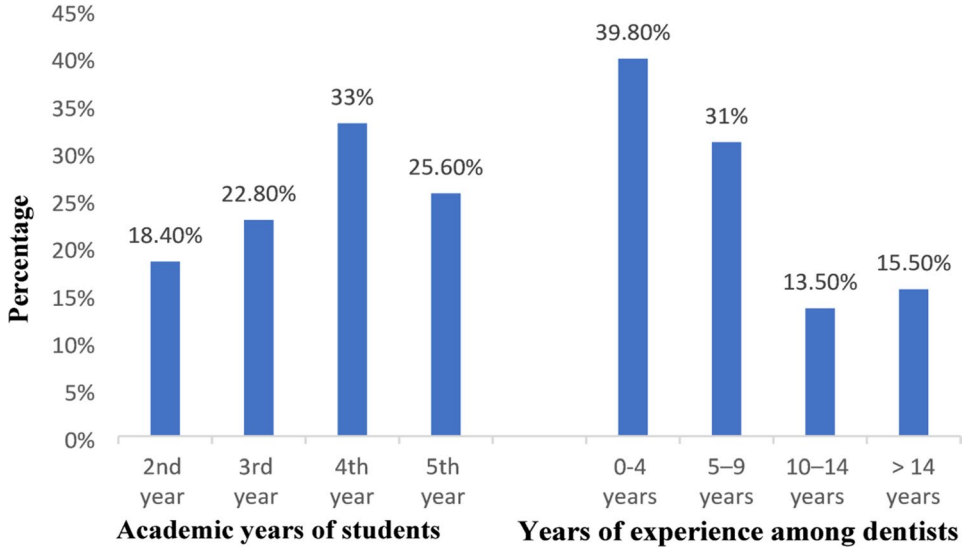

Fig. 2 Percentages of dental students participating in various academic years and the work experience levels of dentists based on their years of practice

Table 2 Frequency distribution of knowledge among both groups of study participants

Radiation Knowledge and Practices	Correct answer	Correct responses %		*P* value
		Students	Dentist	
Q1: Background radiation comes from (among others) radioactive isotopes in the Earth's crust, cosmic radiation emitted by the Sun, and radioactive elements contained in materials used for building construction	Yes	53.9	51.5	0.670
Q2: Do you understand ALARA principles (As Low as Reasonably Achievable)?	Yes	51.0	69.9	< 0.001
Q3: Ionizing radiation used in radiological diagnosis has similar properties to the natural background radiation	Yes	49.0	26.2	< 0.001
Q4: There is a relation between radiation exposure and distance from the source of radiation?	Yes	93.3	29.1	< 0.001
Q5: The average dose from periapical radiography is lower or comparable with the daily background radiation dose (Natural Radiation dose)	Yes	56.9	50.5	0.239
Q6: Radiation dose associated with one periapical radiograph is safe and has no impact on health	False	39.4	75.7	< 0.001
Q7: The risk involved with radiation should be lower than the benefits from diagnostic information, every radiation exposure brings the possibility of occurrence of harmful effects, e.g. leukemia	Yes	64.4	69.9	0.315
Q8: Statistically, 1 in 1000 people, who have undergone 1 periapical examination, will die owing to cancer induced by radiation	No	17.0	5.8	0.003
Q9: Children and fetuses are more sensitive to radiation	Yes	82.5	76.7	0.169
Q10: Performing radiologic examinations for pregnant women is forbidden	No	12.3	49.5	< 0.001
Q11: The number of radiographs prescribed to patients in 1 year is not limited by law	Yes	66.2	20.4	< 0.001
Q12: A patient must have a prescription form to perform periapical radiography	No	18.1	53.4	< 0.001
Q13: A patient must have a prescription form to perform CBCT	Yes	75.5	13.6	< 0.001
Q14: A patient must have a prescription form to perform a Panoramic X-ray	Yes	69.1	13.6	< 0.001
Q15: In all X-ray devices, there are radioactive materials that emit X-rays	No	10.0	13.6	0.296
Q16: The organ is least sensitive to radiation	Muscle and brain	26.5	35.9	< 0.001

Mean score of knowledge = 7.51 ± 2.67 (low level)

*Score of knowledge: Mean score = 1 to 8 (less than 50%, low), 9–14 (50–74%, moderate): 15–18 (75% and more, high)

on the number of radiographs was greater among students (66.2%) than among dentists (20.4%). In contrast, more than half of the dentists (53.4%) correctly mentioned that a prescription form was not needed for periapical radiography, which was related to a lower percentage of the students (18.1%).

For CBCT and panoramic X-rays, students demonstrated better knowledge, with 75.5% and 69.1% correctly identifying the need for prescription forms, respectively, compared with only 13.6% of dentists in both cases. When we questioned whether all X-ray devices included radioactive materials, 10.0% of the students and 13.6% of the dentists answered correctly, and regarding the

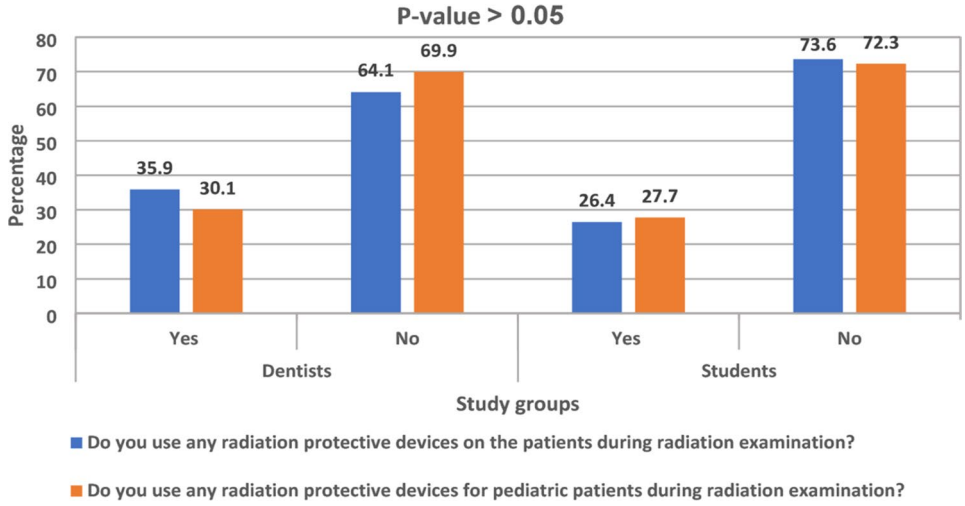

Fig. 3 Shows the percentage of radiation protection methods utilized during patient imaging with various devices, based on responses from both groups. Two categories were evaluated: whether dental students or dentists employed radiation protection devices during general examinations, and whether these devices were used for pediatric patients

Table 3 Comparison of mean knowledge and practices among both study groups

Domains	Groups	Mean (median)	Mean Rank	U	Z	*P* value	*r*
Knowledge	Student	7.67 (8)	371.59	23198.5	-4.32	< 0.001	0.16
	Dentists	6.6 (6)	277.23				
Practice	Student	0.54 (0)	353.45	28735.5	-1.61	0.152	0.06
	Dentists	0.66 (1)	385.01				
Total	Student	8.21 (8)	368.44	25,130	-3.31	0.001	0.12
	Dentists	7.26 (7)	295.98				

organ least sensitive to radiation, 26.5% of the students and 35.9% of the dentists correctly mentioned muscle as the least sensitive organ to radiation from the mentioned choices. The overall average knowledge score was 7.51 ± 2.67/16, representing a generally low level of knowledge among both groups.

The study assessed the use of radiation protection devices among participants engaged in general and pediatric radiography. The findings revealed that a significant number of participants did not use these protective devices. Specifically, 73.6% of the students indicated that they had not utilized radiation protection during general examinations, whereas 72.3% reported the same lack of protection for pediatric radiography. Additionally, 64.1% of the dentist participants did not employ protective measures in these settings, as shown in Fig. 3.

Despite the low level of knowledge and practice of radiation protection among both study groups, the results revealed significant differences in the mean rank of knowledge, with a higher rank among the students than among the dentists (371.59 versus 277.23, p value < 0.001), with an effect size (r) of 0.16; moreover, insignificant differences between them in the mean rank of practice, with dentists demonstrating higher ranks than the students did (385.01 versus 353.45, p value of 0.156), with an effect size (r) of 0.06. For the total scores of both knowledge and practice, significant differences in average score were noted, with students demonstrating higher scores and mean ranks than dentists did (the mean rank for students was 368.44 and for dentists was 295.98, p value 0.001), and the effect size (r) was 0.12. There were significant differences between those who had taken previous courses in radiation protection and those who had not taken previous courses in radiation protection in terms of the overall mean scores of knowledge and practice (p value 0.001, $r = 0.13$), as shown in Table 3 and Fig. 4.

There are significant differences in the mean ranks of knowledge and practices among students at different academic levels. Students at higher levels (4th and 5th years) have higher mean ranks than do those at lower academic levels (2nd and 3rd years). The mean ranks were 345.59 and 356.82 for the higher levels, whereas they were 260.64 and 230.68 for the lower levels. The results are statistically significant, with a p value of less than 0.001 and a chi-square value of 56.6 (Table 4a). Post hoc Dunn–Bonferroni correction revealed that the pairwise group comparisons of second year-fourth year, second year-fifth year, third year-fourth year and third year-fifth year had adjusted p values less than 0.05, which supported that the groups were significantly different in pairs (Table 4b).

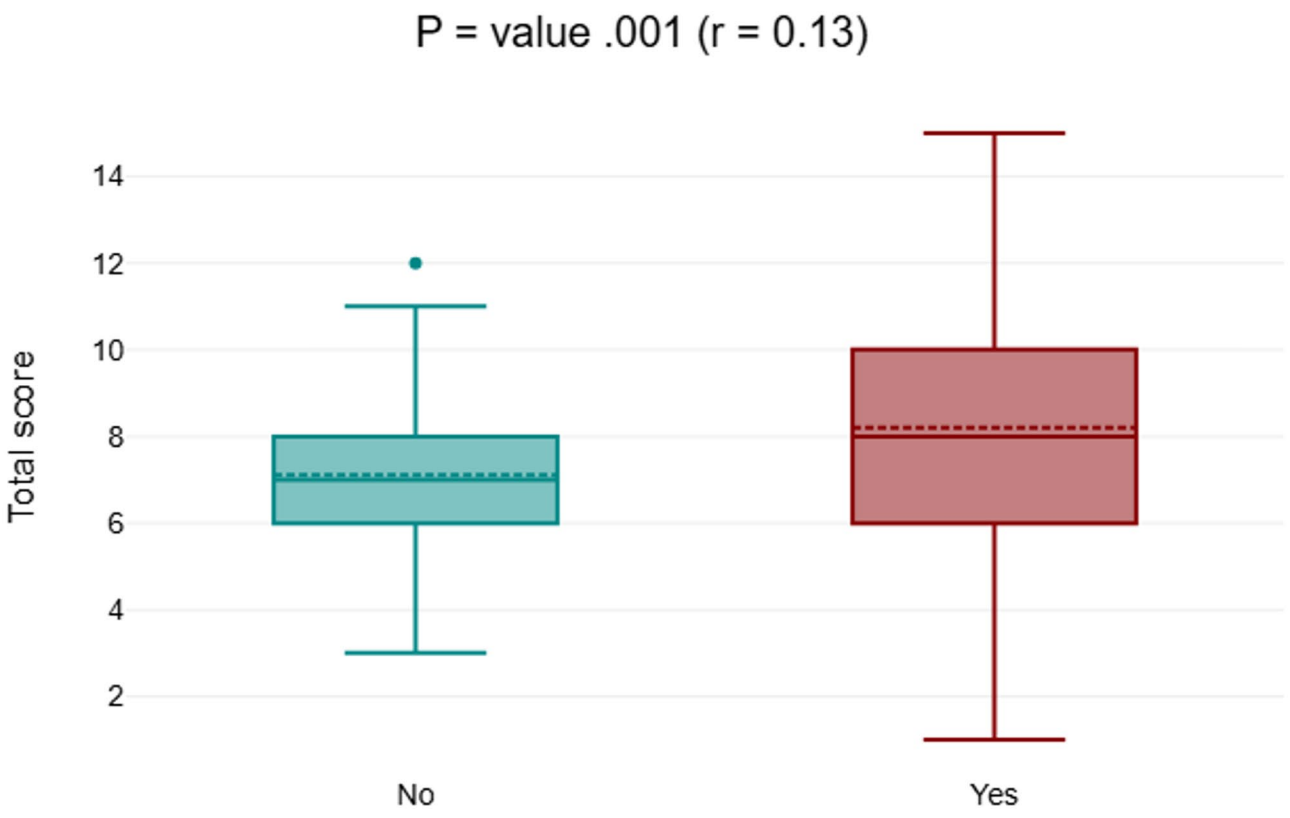

Fig. 4 Compare mean score of knowledge and practice with the taken of previous course in radiation protection (dot lines in the boxes, 7.26 and 8.21 for those were not taken course and taken previous radiation protection course respectively, furthermore it displays the lower, middle (Median) and upper quartile (25th, 50th and 75th percentile), it were 6-7-8 for not taken course, 6-8-10 for taken course respectively, with significant variation among them between those taken compare to non-taken previous course

Table 4a comparison of mean knowledge and practices among the different academic years of the students

Academic years	*N*	Mean (Median)	Mean Rank	Chi^2	*P* value
Second year	113	7.3 (8)	260.64	56.6	< 0.001
Third year	140	7.03 (7)	230.68		
Fourth-year	202	8.92 (9)	345.59		
Fifth year	157	9.01 (9)	356.82		
Total	612	8.21 (8)			

Table 4b Dunn-Bonferroni correction for pairwise group comparisons

	Test Statistic	Std. Error	Std. Test Statistic	*p*	Adj. *p*
Second year - third year	21.27	22.26	0.96	0.339	1
Second year - fourth year	-85.63	20.67	-4.14	< 0.001	< 0.001
Second year - Fifth year	-97.75	21.71	-4.5	< 0.001	< 0.001
Third year - fourth year	-106.9	19.35	-5.52	< 0.001	< 0.001
Third year - Fifth year	-119.02	20.46	-5.82	< 0.001	< 0.001
Fourth year - Fifth year	-12.12	18.72	-0.65	0.518	1

Adj. p: Values adjusted with Bonferroni correction

In contrast, the differences in the mean scores of knowledge and practice among dentists with varying years of experience were not significant. Dentists with more than 14 years of experience and those with 5–9 years of experience had higher mean ranks than did the other groups did, with a p value of 0.851 (Table 5, and Fig. 5).

Comparison of the mean scores of knowledge and practice among dentists with different years of experience.

Table 6 presents a summary of the correlation results between knowledge and practical scores among all the

Table 5 Comparison of mean knowledge and practice among dentists with different years of experience

Years of experiences	*n*	Median	Mean Rank	Chi2	*P* value
0–4	41	7	51.3	0.79	0.851
5–9	32	8	52.16		
10–14	14	7	47.82		
> 14	16	8	57.13		
Total	103	7			

Table 6 Correlations between knowledge and practical scores

Correlation		Practice
knowledge	Pearson Correlation	0.139**
	Sig. (2-tailed)	0.000
	N	715

**. Correlation is significant at the 0.01 level (2-tailed)

study respondents. The findings revealed a significant yet weak positive correlation between knowledge and practice, with a correlation coefficient of r (713) = 0.139 and a p value < 0.001.

Additionally, there were no significant differences in knowledge and practice scores between genders, as indicated by a p-value > 0.05. Refer to Fig. 6 for further details.

Discussion

This study assessed the knowledge and practice of radiation safety among a group of dental students and dentists. Most of the students mentioned that they had taken a previous course on radiation protection, indicating significant education. However, when their knowledge and awareness of some radiation protection concepts were assessed, the results demonstrated a low level of knowledge in some categories, such as knowledge of background radiation and ALARA principles (53.9% and 51%, respectively). Although both ALARA (As Low As Reasonably Achievable) and ALADA (As Low As Diagnostically Acceptable) are applied in radiologic protection, this study uses ALARA consistent with traditional dental imaging protocols and ICRP standards. Compared with other studies, Ageeli et al. and Mahabob et al. reported higher levels of awareness of the ALARA principle, with 90% and 70.7%, respectively. In contrast, Arnout et al. and Srivastava et al. reported that only 40% and 37.4% of dental undergraduate students, respectively, understood the ALARA principle, which is lower than

Fig. 5 Compare mean score of knowledge and practice among dentist with different year of experiences (dot lines in the boxes, 7.27 for 0–4 years, 7.19 5–9 years, 7.07 10–14 and 7.56 for more than 14 years), furthermore it display the lower, middle and upper quartiles (Q1, Q2 (median), Q3), (25th, 50th and 75th percentile), it were 6-7-8 for 0–4 years, 6-8-8 for 5–9 years, 6-7-8.5 for 10–14 years and 7-8-8 for more than 14 years of experiences, with insignificant variation among these values in different group of years of experiences

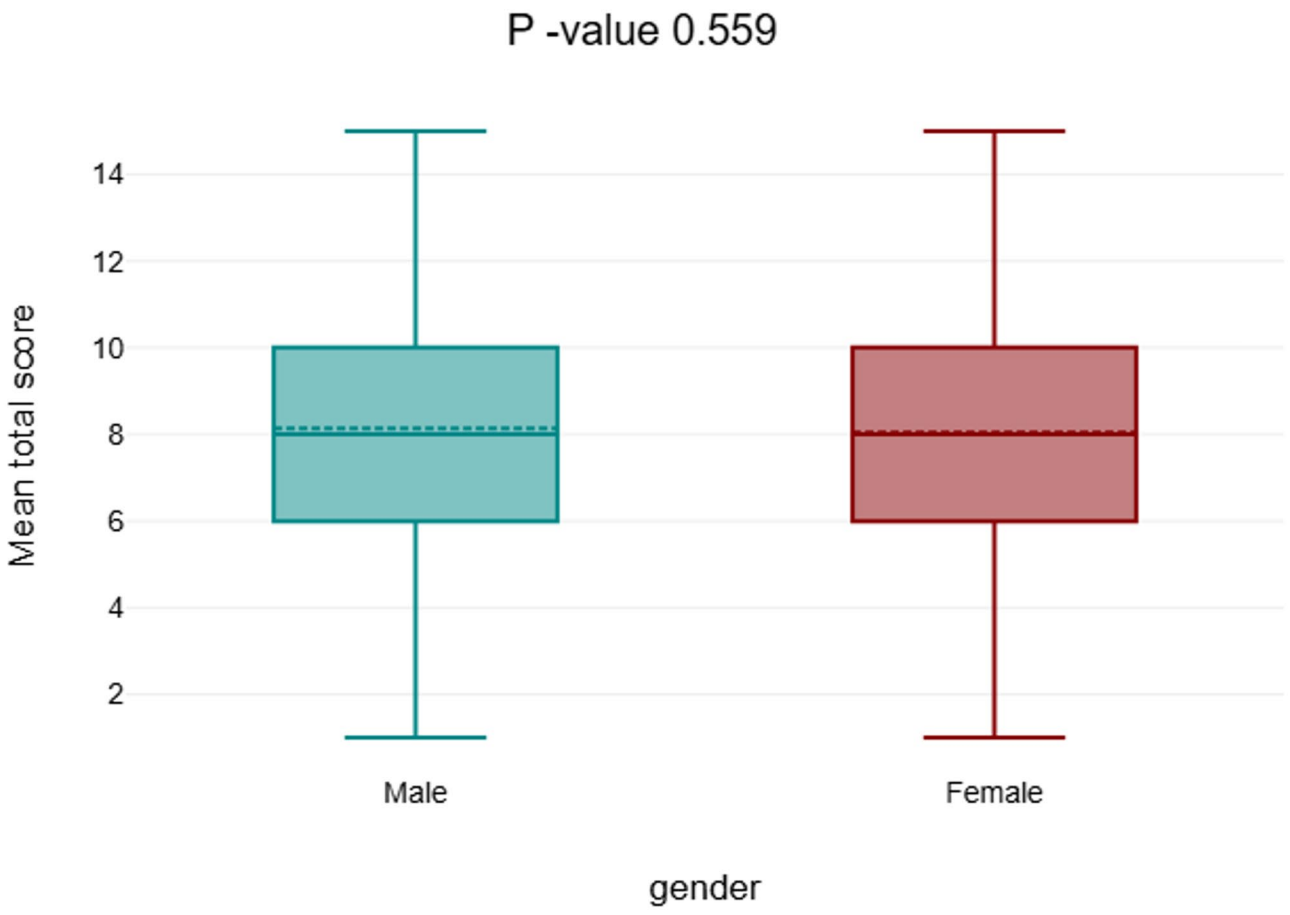

Fig. 6 Comparison of the total mean scores of knowledge and practice for both genders (dot lines in the boxes, 8.17 for male, 8.04 for female), furthermore it displays the lower, middle and upper quartiles (Q1, Q2 and, Q3), (25th, 50th and 75th percentile), it was 6-8-10 for male and, 6-8-10 for female, with insignificant variation among these values in different group

the percentages indicated in this study [10, 14–16]. These findings demonstrate the variation in the understanding of ALARA principles among undergraduate dental students.

Fewer than half of the dental students indicated that the ionizing radiation used in radiological diagnosis has properties similar to those of natural background radiation. This suggests that although students receive relevant training in radiation protection, their understanding of radiation safety and protection concepts requires improvement.

The distance from the radiation source is crucial for minimizing scattered radiation. Therefore, the operator of a dental X-ray machine should stand at least 6 feet away from the patient and at an angle between 90° and 135° relative to the central ray of the X-ray beam. This practice is essential for reducing the radiation dose to dentists. This survey emphasized that most dental students recognize the relationship between radiation exposure and distance from the source. In addition, the majority acknowledged that the risks of radiation should be outweighed by the benefits of diagnostic information. In a previous survey, 78.4% of participants were aware of the correct position and distance guidelines. Additionally, Rela noted that 77% of participants understood the position−distance rule [10, 17].

Only 39.4% of the students believed that the radiation dose from a single periapical radiograph was safe, which is incorrect. This suggests a potential gap in the understanding of the safety implications of radiological procedures. In contrast, most students accurately indicated that children and fetuses are more sensitive to radiation, which suggests that understanding radiation effects is related to a person's age. This finding aligns with a previous study by Zakirulla et al., who reported that 83% of participants recognized that children are more vulnerable to radiation than adults are [18]. Conversely, fewer individuals are aware that not all radiographic equipment produces radioactivity, and only 12.3% of the students accurately rejected the misconception that radiologic exams are completely prohibited for pregnant women.

Lead has been recognized as the most effective material for shielding against diagnostic X-rays. It is essential to protect the lens of the eyes and the thyroid, as they are

sensitive structures to radiation. Therefore, implementing a radiation protection strategy is crucial to reduce the radiation dose to these structures. According to a previous study, a properly fitted lead apron can reduce the effective dose by 75–90% [16]. When dental students were asked about their use of radiation-protective devices during examinations, only 26.4% reported using them. This raises concerns about the practical application of their knowledge in clinical settings. This study corroborates previous findings showing low rates of protection tool use among dental students, with only 32.8% and 33% reporting usage [14, 16]. In contrast, Enabulele, Igbinedion, and Rabhat et al. reported higher percentages of lead apron usage, at 46% and 66%, respectively [19, 20]. Some participants justified their nonuse of radiation protective devices by citing patient pressure in certain service centers, whereas other dental students complained that certain centers lacked these tools, especially for children. These complaints could be one of the factors contributing to the nonuse of protective devices for patients. Recent studies have indicated that wearing lead aprons and thyroid collars is not necessary for protecting patients from radiation exposure during dental procedures. These guidelines apply to all patients, regardless of age or health status, including pregnancy. Evidence shows that using modern digital X-ray equipment and limiting the beam size to a specific area of interest helps minimize radiation exposure to other parts of the body [21]. While lead aprons and thyroid collars can obstruct the primary X-ray beam and prevent dentists from obtaining the desired images, thyroid protection should be used if the thyroid gland is within or close to the primary beam. For cone beam computed tomography (CBCT) examinations, particularly in pediatric patients, the use of lead glasses and thyroid collars, along with reducing the field of view (FOV), can help decrease the radiation dose to organs outside the FOV [24].

The results revealed that some students are not aware of the legal requirements for radiological procedures. While 66.2% correctly believed that there is no legal limit on the number of radiographs prescribed to patients in a year, most acknowledged the necessity of a prescription for dental panoramic radiography and CBCT. However, only a small percentage (18.1%) mentioned that a request is not needed for periapical radiography. In comparison, Furmaniak et al. reported that only 23.29% correctly identified that one periapical radiation dose is unsafe, whereas 49.32% disagreed with the notion that 1 in 1000 patients who undergo such an exam may die from radiation-induced cancer. They also reported that 45.21% accurately disagreed that radiologic exams for pregnant women are prohibited, 34.25% recognized that there is no legal limit on the number of radiographs prescribed annually, and 79.45% understood that a prescription is not required for periapical radiography [13]. These findings highlight the need for better education on legal and ethical standards in dental radiology. Thus, medical professionals involved in the dental field are crucial for fully understanding the safe use of ionizing radiation. Consequently, these professionals must possess the necessary training, education, and expertise [22].

Compared with those at lower levels, students at higher academic levels have significantly greater mean ranks in knowledge and practice. This aligns with the findings of Ageeli et al., who reported a link between higher-year students and increased knowledge of radiation safety, which was attributed to earlier completion of radiation protection modules. In contrast, they reported that first-year students have less exposure to these educational resources, resulting in lower awareness of radiation protection principles [15].

A study of dentists' knowledge of and practices related to radiation protection revealed that 40.78% had taken courses in this area, highlighting a training gap. Over half (51.5%) correctly identified that background radiation comes from various sources, such as radioactive isotopes and cosmic radiation. Additionally, the majority of dentists (69.9%) were aware of the ALARA principles. However, Elmorabit et al. reported different findings, indicating that only 35% of dentists were aware of these principles [23]. In comparison, a study conducted in Egypt reported that 62.4% of dentists were familiar with the ALARA principles, which is lower than the percentage in our study [24]. Conversely, a study in Nigeria reported a higher level of knowledge among dentists, with 76.8% demonstrating awareness of the ALARA principles [25]. Compared with other studies by Yurt et al., Ahmed et al., and Arnout reported that only 53% of Turkish dentists, 37.1% of Saudi dentists, and 33.3% of Egyptian dentists were aware of the ALARA concept [14, 18, 24, 26, 27].

The results revealed that only 26.2% of dentists recognized that the ionizing radiation used in radiological diagnoses has properties similar to those of natural background radiation. Furthermore, only 29.1% accurately understood the relationship between radiation exposure and distance from the source. Additionally, 75.7% believed that the radiation dose from a periapical radiograph was unsafe and detrimental to health. Worryingly, many dentists exhibit low awareness of legal requirements regarding radiography. A few percent of dentists believe that the number of periapical radiographs performed annually is unrestricted by law, whereas almost half of them believe that a prescription is not required for periapical radiography. Only 35.9% of the respondents reported using protective tools during radiologic examinations, and the usage rate for pediatric patients was even lower at 30.1%. This is consistent with findings by

Hussein et al., who noted that only 38% of dentists frequently use lead aprons [24]. Dentists have varying opinions about the necessity of radiation protection. Some justify their decision not to use it by citing the low radiation doses involved, particularly in periapical imaging. They believe that the radiation used in dental imaging is harmless. This confirms the need to conduct educational courses on the harms of using radiation, especially when radiation is used in children's imaging.

Compared with adults, children are at greater risk of developing cancer from the same dosage. A longer life expectancy means that they have more time for any adverse effects of radiation to manifest [28]. Most dentists correctly noted that children are more vulnerable to radiation risk than adults are. However, this finding contrasts with the observations of Elmorabit et al., who reported that relatively few participants recognized that, for the same external exposure, the radiation dose and the risk of cancer induction are greater in children than in adults [23].

Despite the low level of knowledge and practice of radiation protection observed among both study groups, the results revealed significant differences in the mean rank of knowledge, with a higher rank among the students than among the dentists; moreover, there were insignificant differences between them in the mean rank of practice, with dentists demonstrating higher ranks than the students did. For the total score of both knowledge and practice, substantial differences were noted among both groups in average scores, with students demonstrating higher scores and mean ranks than dentists did. There were significant differences in the overall mean scores of knowledge and practice between those who had taken previous courses and those who had not. While knowledge scores differed significantly, practice scores were low across both groups with no statistically significant difference, highlighting a potential disconnect between theoretical understanding and clinical behavior. Several factors could explain the differences in scores between the two groups. One possible reason is the unequal sample sizes; fewer dentists than dental students participated. Additionally, variations in the educational backgrounds of the dentists may also have contributed to this discrepancy. For example, some dentists graduated from foreign institutions, which might influence whether they completed radiation protection courses at their universities. In contrast, Mahabob et al. reported that dental students in the eastern province of Saudi Arabia have strong fundamental knowledge and awareness of radiation and the importance of protection, although it is not uniformly distributed among them [10]. Another study mentioned inadequate radiation knowledge among dentists and dental students, with insignificant differences between them. They reported that dentists with previous radiation protection training were more aware than those with no training [20].

A previous review highlighted a lack of knowledge regarding radiation risk management among dental professionals. It was expected that experienced dentists would have a better understanding of dental radiation protection than newly graduated students did, and this was confirmed. Dentists with over 10 years of experience demonstrated awareness of the ALARA principle, the use of lead aprons, and the correct application of appropriate techniques [29]. Another study conducted in Saudi Arabia suggested that dentists, radiographers, and students are well versed in dental radiography and safety, with higher education levels indicating increased awareness and a favorable attitude. The safety and awareness of dental radiography exposure vary by group, emphasizing the importance of ongoing education and standardized training to increase the understanding and application of radiation hazards [30].

The findings of the study highlight a basic understanding of radiation principles among dental professionals; however, the identified gaps in knowledge underscore the urgent need for enhanced radiation safety education. This education should connect theoretical concepts with practical applications while also increasing awareness of the legal and ethical standards related to radiological procedures in dentistry. Continuous professional development and updated training programs could greatly enhance radiation safety practices among dental professionals and students. These results highlight the urgent need for increased education on radiation safety and protection, which must be enforced by stakeholders to improve theoretical knowledge combined with practical training on how to apply radiation protection for dental X-ray imaging applications.

This study has several limitations. The data were collected through an online questionnaire, which introduces various factors that may affect the validity and reliability of the results. A prevalent challenge is response bias, especially with fixed-choice questions. Additionally, there may have been misunderstandings regarding some of the inquiries. Another limitation is the unequal sample sizes, with significantly fewer dentists than dental students participating. This disparity might lead to biased comparisons and restrict the generalizability of the findings, ultimately diminishing the statistical power needed to detect meaningful differences.

Conclusion

This study revealed a significant gap in knowledge and practice regarding radiation protection and safety among Palestinian dentists and dental students. While students had moderate awareness of radiation risks, their understanding of safe radiation doses for periapical

radiographs was low. Despite some awareness of safety protocols, few participants used protective lead aprons during radiography. Additionally, many participants were unaware of legal requirements related to dental radiology, such as radiograph limitations and prescription necessities, especially among dentists. The results demonstrated that, despite the students having less experience, the students had greater knowledge than the dentists did, possibly because of the inadequate sampling of the dentist group related to the students, which could have skewed the results.

Abbreviations

CBCT	Cone beam computed tomography
ICRP	International Commission on Radiological Protection
ALARA	As low as reasonably achievable

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Author contributions
M. Aljamal conceived the idea. M. Aljamal and Tala Batakat collected the data, and M. Aljamal and M. Abuzaid wrote the introduction of the paper. M. Aljamal, Zuhal Hamd, and M. Abuzaid gathered related literature and helped write related works. M. Aljamal and Zuhal Hamd carried out the results and analysis. Zuhal Hamd and Awadia Gareeballah wrote the discussion. All the authors read, modified, and approved the final version of the manuscript.

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Data availability
The data and supportive information of this study can be obtained from the corresponding authors upon reasonable request.

Declarations

Ethics approval and consent to participate
All methods used in this study were conducted in accordance with the Declaration of Helsinki and approved by the Arab American University review board (Ethics Committee (2023–0270)). Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

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The authors declare no competing interests.

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