RESEARCH ARTICLE

Korean dentists' perceptions and attitudes regarding radiation safety and protection

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Objectives: To investigate dentists' perceptions and attitudes regarding radiation safety in dental practices in Korea.

Methods: 207 dentists participated in this study. An anonymous survey was conducted regarding the following areas: years of practice, characteristics of the radiography equipment, knowledge of diagnostic reference levels, prescription of dental radiographs, use of radiation protection procedures and participation in the radiation safety program. Data were evaluated according to frequency distribution; the χ test; and Fisher's exact test, which was used to investigate statistical significances ($p < 0.05$) between those with less than 10 years of experience in practice vs those with 10 years of experience or more.

Results: Approximately 83% of the dentists who responded to our survey participated in the radiation safety program, but only 58% were satisfied with it. There were statistically significant differences in the installation of X-ray units, learning pathway of diagnostic reference levels, prescription of dental radiography for new adult patients, use of personnel radiation monitoring systems and participation in the radiation safety program between those with less than 10 years of experience in practice vs those with 10 years of experience or more ($p < 0.05$).

Conclusions: Dentists with less than 10 years of experience were less attentive to radiation protection procedures. Therefore, taking both the duration of experience of dentists and the installed X-ray equipment into consideration, continuous and efficient education for both dental workers and patients regarding radiation safety and protection is recommended.

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Introduction

Recently, there have been increasing concerns over the use and stochastic effects of ionizing radiation in dental radiography.¹ Although the risk of primary cancers from radiation exposure during dental radiography is considered negligible, the risks related to cumulative doses should be assessed.² In addition, previous reports have shown that radiation exposures from CBCT are

significantly higher than from conventional dental radiographs.^{3,4}

Therefore, special attention should be paid to justification and optimization to minimize unnecessary radiation exposure in dental practices. Many steps can be taken to reduce patient exposure to radiation. The American Dental Association (ADA), US Food and Drug Administration (FDA) and the European Commission (EC) have recommended radiography guidelines for patient selection and limiting radiation exposure.^{5,6} The Korean FDA published a special report on the safety of dental radiography.⁷ Moreover, Korean

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dentists who own clinics are legally required to arrange for inspections of their dental radiography machines every 3 years and undergo approved radiation safety programs only once for their practices. Approved radiation safety programs in the Republic of Korea do not focus solely on radiation protection in dental practices; the program is mainly for doctors and radiologists. This may result in dentists not maintaining radiation safety protection in their clinics. In addition, the diagnostic reference levels (DRLs) for dental radiography and the average annual effective dose for dentists in the Republic of Korea are higher than those recommended in other countries.^{8,9} Finally, there is a dearth of published data regarding radiation safety in Korean dental clinics.^{9,10}

We aimed to investigate the significance differences between the radiation safety procedures followed by dentists with less than 10 years of experience in practice *vs* those with 10 or more years of experience. We would then suggest improvements to the radiation safety program to reduce the radiation exposure of dental patients in the Republic of Korea.

Methods and materials

This study included 400 randomly selected dentists who were registered with the Korean Dental Association. Their dental clinics were located in Seoul Special Metropolitan city, Daejeon Metropolitan city, Daegu Metropolitan city, Gwangju Metropolitan city, Gyeonggi Province, Gyeongsang Province and Jeolla Province in the Republic of Korea. *A priori* sample size of this study was calculated using G*power program (v. 3.1.9.2, Department of Experimental Psychology, Heinrich-Heine-University, Dusseldorf, Germany)¹¹ with the following condition: effect size 0.15; numbers of predictors 13; Type I alpha risk of 0.05; and a power of 95%. As a sample of 189 respondents was required, we sent out the survey to 400 dentists considering the response rate of 50%. In addition, all the measurements in the χ analysis showed over 85% power. A total of 207 dentists (51.8%) responded to this survey in 2016. With five exceptions, all dentists included in the survey were working in private clinics. Their practices were in both urban (89.4%) and rural (10.6%) areas. We conducted an anonymous questionnaire survey comprising 13 questions within 6 categories (Figure 1). The questionnaire was distributed to each

of the participating dentists and included the following categories: (i) years of practice and educational background; (ii) characteristics of the radiography equipment used; (iii) knowledge of DRLs; (iv) prescription of dental radiography for new patients; (v) use of radiation protection procedures; and (vi) participation in the approved radiation safety program. Participants were enrolled via either direct face-to-face interview (27.5%) or fax/email survey (72.5%). Due to the nature of this study, it was granted an exemption in writing by the Institutional Review Board of Chonnam National University Dental Hospital.

Statistical analyses were performed using the statistical software package SPSS 12.0 (SPSS Inc., Chicago, IL). The data were evaluated according to frequency distribution, and the χ test and Fisher's exact test, and odds ratio were used to investigate the significant differences between dentists with less than 10 years of experience in practice *vs* those with more experience.

Results

Years of practice and educational background

The 207 respondents were classified into 4 groups according to their years in practice and educational background (Table 1). Among the specialist dentists ($n = 97$, trained via a residency program), 18 were oral and maxillofacial surgeons, 17 were pedodontists, 16 were periodontists, 13 were orthodontists, 10 were prosthodontists, 7 were endodontists, 7 were oral and maxillofacial radiologists, 7 were advanced general dentists and 2 were specialists in oral medicine.

Radiography equipment

Table 2 shows the distribution of installed X-ray equipment according to duration of the dentist's experience. Korean dentists with less than 10 years of experience preferred to install handheld portable digital radiography devices in their practices. In intraoral radiography, the mean distance between the focal spot and skin was 22 cm.

Of the 207 respondents, 200 (97%) used panoramic radiography (2, analogue; 198, digital radiography) and 131 (63%) used CBCT. A statistically significant difference was found in the installation of X-ray units (*i.e.* intraoral radiography, cephalometric radiography

Table 1 The proportion of responders according to their years of dentistry practice and educational background

	Practiced dentistry for <10 years ($n = 62$); number (%) of dentists	Practiced dentistry for ≥ 10 years ($n = 145$); number (%) of dentists	Total ($N = 207$)
General dentists	43 (69%)	67 (46%)	110 (53%)
Specialist dentists	19 (31%)	78 (54%)	97 (47%)
Total	62 (100%)	145 (100%)	207 (100%)

n, number.

Table 2 Number of installed X-ray machines according to years of dentistry practice

<i>X-ray units</i>	<i>Practiced dentistry for <10 years</i>	<i>Practiced dentistry for ≥10 years</i>	<i>Total</i>	<i>OR</i>	<i>95% CI</i>	<i>p-value</i>
	<i>Number of X-ray machines installed</i>	<i>Number of X-ray machines installed</i>				
Intraoral radiograph						0.000 ^a
Digital (fixed X-ray units)	19 (31%)	78 (55%)	97 (47%)	(Reference)		
Digital (portable X-ray units)	19 (31%)	12 (8%)	31 (15%)	6.5	(2.697, 15.665) ^a	
Film (fixed X-ray units)	0 (0 %)	20 (14%)	20 (10%)	0.021 ⁺	(0.000, 10.460) ⁺	
Film (fixed), Digital (portable)	2 (3%)	2 (1%)	4 (2%)	4.105	(0.543, 31.043)	
Digital (fixed & portable)	21 (34%)	31 (21%)	52 (25%)	2.781	(1.317, 5.871) ^a	
Do not use	1 (1%)	2 (1%)	3 (1%)	2.053	(0.177, 23.841)	
Total	62 (100%)	145 (100%)	207 (100%)			
Panoramic radiograph						0.371
Digital	61 (98%)	137 (94%)	198 (96%)	(Reference)	(0.000, 64.816) ⁺	
analogue	0 (0%)	2 (1%)	2 (1%)	0.112 ⁺		
Do not use	1 (2%)	6 (4%)	7 (3%)	0.374	(0.044, 3.176)	
Total	62 (100%)	145 (100%)	207 (100%)			
Cephalometric radiograph						0.027 ^a
Digital	53 (85%)	101 (70%)	154 (74%)	(Reference)	(0.000, 55.081) ⁺	
analogue	0 (0%)	2 (1%)	2 (1%)	0.095 ⁺		
Do not use	9 (15%)	42 (29%)	51 (25%)	0.408	(0.185, 0.902) ^a	
Total	62 (100%)	145 (100%)	207 (100%)			
CBCT						0.02 ^a
Use	49 (79%)	82 (57%)	131 (63%)	(Reference)		
Do not use	13 (21%)	63 (43%)	76 (37%)	0.345	(0.173, 0.691) ^a	
Total	62 (100%)	145 (100%)	207 (100%)			

CI, confidence interval; OR, odds ratio.

^a*p* < 0.05; after replacing each zero by 0.1⁺.

and CBCT) between those who had been in practice for less than 10 years *vs* the more experienced dentists (Pearson's χ test, *p* < 0.05).

Knowledge of DRLs

DRLs are normally established at the third quartile value of the patient dose distribution observed for a

particular type of radiographic examination.¹² Of the 207 participants, 127 (61%) reported that they knew the definition of DRLs while 80 (39%) reported otherwise (Table 3). There was no statistically significant difference in knowledge of DRLs between those who had been in practice for less than 10 years *vs* the more experienced dentists (Pearson's χ test, *p* = 0.990). However, there

Table 3 Knowledge of DRLs according to time spent in dentistry practice

	<i>Practiced dentistry for <10 years</i>	<i>Practiced dentistry for ≥10 years</i>	<i>Total</i>	<i>OR</i>	<i>95% CI</i>	<i>p-value</i>
	<i>Number (%) of dentists</i>	<i>Number (%) of dentists</i>				
Knowledge of DRLs						0.99
Knowledge	38 (61%)	89 (61%)	127 (61%)	(Reference)		
No	24 (39%)	56 (39%)	80 (39%)	1.004	(0.55, 1.85)	
Total	62 (100%)	145 (100%)	207 (100%)			
DRL learning pathway						0.000 ^a
Approved radiation protection program	20 (53%)	74 (83%)	94 (74%)	(Reference)		
Dental literature	5 (13%)	11 (12%)	16 (13%)	1.682	(0.52, 5.40)	
School education	9 (24%)	4 (4%)	13 (10%)	8.325	(2.32, 29.86) ^a	
Radiation safety officer	4 (11%)	0 (0%)	4 (3%)	148	(0.27, 80143.16)	
Total	38 (100%)	89 (100%)	127 (100%)			

CI, confidence interval; DRL, diagnostic reference level; OR, odds ratio.

^a*p* < 0.05.

Table 4 Proportion of dental radiography modalities utilized for new patients

Modality utilized	Practiced dentistry for <10 years (n = 62)	Practiced dentistry for ≥10 years (n = 145)	Total (n = 207)	OR	95% CI	p-value
	Number (%) of dentists	Number (%) of dentists	Number (%) of dentists			
For new adult patients						0.032 ^a
Periapical radiography	12 (19%)	54 (37%)	66 (32%)	(Reference)		
Panoramic radiography	45 (73%)	76 (52%)	121 (58%)	2.664	(1.29, 5.51) ^a	
Both	5 (8%)	13 (9%)	18 (9%)	1.731	(0.52, 5.78)	
No radiography	0 (0%)	2 (1%)	2 (1%)	0.225 ⁺	(0.00, 132.96) ⁺	
Total	62 (100%)	145 (100%)	207 (100%)			
For new paediatric patients						0.514
Periapical radiography	35 (56%)	97 (67%)	132 (64%)	(Reference)		
Panoramic radiography	20 (32%)	34 (23%)	54 (26%)	1.630	(0.83, 3.20)	
Both	2 (1%)	4 (3%)	6 (3%)	1.386	(0.24, 7.90)	
No radiography	5 (2%)	10 (7%)	15 (7%)	1.386	(0.44, 4.34)	
Total	62 (100%)	145 (100%)	207 (100%)			

CI, confidence interval; OR, odds ratio.

^a*p* < 0.05; after replacing each zero by 0.1⁺.

was a statistically significant difference in the learning pathway of DRLs between those in practice for less than 10 years *vs* those with more experience (Fisher's exact test, *p* = 0.000, *p* < 0.05).

Prescription of dental radiography for new patients

Most of the participants utilized pre-determined radiographic examination to evaluate new patients. Table 4 shows the proportions regarding prescription of dental radiography for new patients according to the duration of the dentist's experience. Of the 207 respondents, 121 (58%) preferred to perform panoramic radiography to evaluate a new adult patient, while 132 (64%) usually utilized periapical radiography for evaluating a new paediatric patient. There was a statistically significant difference in the utilization of dental radiography for new adult patients between those who had been in practice for less than 10 years *vs* the more experienced dentists (Fisher's exact test, *p* = 0.032, *p* < 0.05). However, there was no statistically significant difference in the utilization of dental radiography for new paediatric patients between those who had been in practice for less than 10 years *vs* the more experienced dentists (Fisher's exact test, *p* = 0.514).

Use of radiation protection procedures & participation in the approved radiation safety program

Of the 207 participants, 40 (19%) used a rectangular collimator in their practice and 115 (56%) did not; 47 (23%) did not know the definition of a collimator (Table 5). There was no statistically significant difference in the use of a collimator between those who had been in practice for less than 10 years *vs* the more experienced dentists (Pearson's chi-squared χ test, *p* = 0.321). However, there was a statistically significant difference in the use of personnel radiation monitoring between

those who had been in practice for less than 10 years *vs* the more experienced dentists (Pearson's χ test, *p* = 0.000, *p* < 0.05).

All respondents' dental clinics were well equipped with lead aprons or thyroid collars.

Of the 207 respondents, 171 (83%) had participated in the approved radiation safety program (Table 5). There was a statistically significant difference in participation in the radiation safety program between those who had been in practice for less than 10 years and the more experienced dentists (Pearson's χ test, *p* = 0.001, *p* < 0.05). Among respondents, 121 (58%) were satisfied that the radiation safety program had helped them manage their radiography equipment and explain the radiation risk to patients. The participating dentists also suggested that the radiation safety and protection program should include information on the acceptable levels of radiation to which dental patients are subjected (56%), educational material on radiation risks and radiation safety for patients and employees (43%), information on thermoluminescent dosimeter (TLD) badge values used for personnel radiation monitoring (16%) and training content for employees regarding the operation and maintenance of radiographic equipment (10%).

Discussion

According to the United Nations Scientific Committee on the Effects of Atomic Radiation, Global Survey of Medical Radiation Usage and Exposures, the annual frequency of dental radiographic examinations in healthcare Level I countries is 275 per 1000 population.¹³ The number of dental radiographic examinations administered to paediatric and adolescent individuals in the Republic of Korea has increased steadily.⁸ Considering this increased usage of dental radiography,

Table 5 Dentists' attitudes toward the use of a collimator, personnel radiation monitoring system and inclusion in the radiation safety program

	<i>Practiced dentistry for <10 years</i>	<i>Practiced dentistry for ≥10 years</i>	<i>Total</i>	<i>OR</i>	<i>95% CI</i>	<i>p-value</i>
	<i>Number (%) of dentists</i>	<i>Number (%) of dentists</i>	<i>Number (%) of dentists</i>			
Collimator						0.321
Use	16 (26%)	24 (17%)	40 (19%)	(Reference)		
No use	32 (52%)	83 (57%)	115 (56%)	0.578	(0.27, 1.23)	
No knowledge of collimator	13 (21%)	34 (23%)	47 (23%)	0.574	(0.23, 1.41)	
No answer	1 (2%)	4 (3%)	5 (2%)	0.375	(0.04, 3.67)	
Total	62 (100%)	145 (100%)	207 (100%)			
Personnel radiation monitoring system						0.000 ^a
Use	22 (35%)	96 (66%)	118 (57%)	(Reference)		
No use	40 (65%)	49 (34%)	89 (43%)	3.562	(1.91, 6.65) ^a	
Total	62 (100%)	145 (100%)	207 (100%)			
Radiation safety program						0.001 ^a
Attended	42 (68%)	129 (89%)	171 (83%)	(Reference)		
Unattended	20 (32%)	16 (11%)	36 (17%)	3.839	(1.82, 8.08) ^a	
Total	62 (100%)	145 (100%)	207 (100%)			

CI, confidence interval; OR, odds ratio.

^a*p* < 0.05.

dentists and their staffs have a responsibility to ensure patient safety from the effects of radiation exposure during all dental radiography procedures. This study demonstrated that the majority of dentists (96%) were using digital panoramic radiography machines, with 131 of 207 (63%) using CBCT. This indicated that a large number of dentists are now using digital imaging devices in Korea; by comparison, previous studies in Turkey¹⁴ in 2011 reported that 67% of dentists used digital radiography, and 30% of dentists had referred their patients for CBCT.¹⁴ In the United Kingdom, 38.5% of dentists used digital panoramic radiography in 2013,¹⁵ along with 25% of Flemish dentists in 2010¹⁶ and 12% of Belgian dentists in 2005.¹⁷ It was reported that 58% of dentists in New Zealand used digital radiography systems in 2013.¹⁸

The present study found that the use of handheld portable dental X-ray devices, digital cephalometric X-ray machines and CBCT was greater among those who had been in practice for less than 10 years than among more experienced dentists (Table 2). One of the reasons for this may be related to greater familiarity with CBCT among younger dentists. Instruction on the use of CBCT has been included in the oral and maxillofacial radiology curriculum in every dental school since 2008 in the Republic of Korea.

In this study, most of the CBCT machines in use were supplied by one of three manufacturers (Vatech, HDXWILL and PointNix). The International Commission on Radiological Protection has published guidelines and recommendations on radiological protection issues regarding the use of CBCT.¹⁹ When using CBCT for dental and maxillofacial imaging, care should be taken to use the smallest possible field of view, as well as protective shielding. It is also important for radiation

workers to monitor the radiation doses administered.¹⁹ However, our findings indicate that dentists in practice for less than 10 years were significantly less likely to monitor their occupational radiation exposures.

The ADA suggests that the appropriate focal source-to-skin distance applied in intraoral radiography should be between 20 and 40 cm.²⁰ In this study, we found that the distances applied were within this range, except for handheld portable radiography devices, where they were generally under 20 cm. Another recent study reported that occupational dose monitoring is highly recommended when aiming to secure continuous, low-radiation exposure using handheld X-ray devices.²¹ Furthermore, handheld portable dental X-ray devices are not used routinely in dental practices in Europe;²² however, this study showed that Korean dentists with less than 10 years of experience preferred to install handheld portable radiography devices in their practices (Table 4), but they were significantly less likely to monitor their occupational radiation exposures and attend the radiation safety program. Such attitudes may lead to decreased awareness of radiation protection procedures.

Recognition of the harmful effects of radiation exposure and concerns regarding minimizing patient exposure have prompted the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements to establish DRLs for medical and dental diagnostic imaging.²³ The national DRLs were established, based on a domestic survey, at the 75th percentile of the dose distribution observed for a specific type of radiographic examination.²⁴ Dentists with less than 10 years of experience gained awareness of the concept of DRLs through the variable pathways involving school education and radiation safety officers (Table 5). The Korean FDA has

Questionnaire

This survey is to investigate the radiation safety management. Your response will be used as research data, and to protect your private information, the name of your dental clinic and your background will not be presented in the research paper. Thank you for your cooperation!

*Put a check mark (V) or fill in the blanks ().

1. Write down the number of years you have worked as a dentist ()
2. Did you complete an internship and residency program? If yes, please write down the name of your specialty.
1) Yes (): Specialty () 2) No ()
3. Please write characteristics of the installed X-ray equipment in working dental practices
:
4. Have you heard of diagnostic reference levels (DRLs) or reference doses, which are reported in the field of dentistry in order to optimize the medical radiation exposure level?
1) Yes 2) No
5. If you are familiar with the diagnostic reference levels (DRLs), how did you learn about them?
1) At an approved radiation protection program 2) Other places ()
6. Which radiography do you prescribe when a new adult patient comes to your dental clinic?
1) I usually prescribe periapical radiography focusing on the area of the patient's chief complaint.
2) I usually prescribe panoramic radiography.
3) I do not usually prescribe any radiography evaluations.
4) I usually prescribe panoramic radiography, as well as periapical radiography focusing on the area of the patient's chief complaint.
7. Which radiography do you prescribe when a new child patient comes to your dental clinic?
1) I usually prescribe periapical radiography focusing on the area of the patient's chief complaint.
2) I usually prescribe panoramic radiography.
3) I do not usually prescribe any radiography evaluations.
4) I usually prescribe panoramic radiography, as well as periapical radiography focusing on the area of the patient's chief complaint.
8. Do you utilize a rectangular collimator during intraoral radiographic examinations?
1) Yes 2) No 3) I do not know what a collimator is.
9. Is there a lead apron or thyroid collar in your working dental clinic?
1) Yes 2) No
10. You are working at a dental clinic with radiographic equipment. Have you monitored the amount of radiation you are exposed to? (by using a personal dosimeter or thermoluminescent dosimeter—or TLD—badge)
1) Yes 2) No
** If yes, how long have you monitored the amount of radiation? ()
11. Have you attended in the approved radiation safety program?
1) Yes 2) No
12. Does the radiation safety training help you manage the radiographic equipment or explain to patients about radiation?
1) Yes 2) No
13. What subject matter do you think that the radiation safety program training should cover?

Figure 1 Survey questionnaire.

stated that the DRL applied to intraoral radiography obtained using the dose area product is 87.4 mGy cm².²⁵ The recently established DRLs for paediatric panoramic radiography and cephalometric radiography in the Republic of Korea are 95.9 and 121.3 mGy cm², respectively;⁸ these values are higher than those recommended in other countries.^{24,26}

Furthermore, 80 of the 207 respondents (39%) in this study were unaware of the concept of DRLs. These findings demonstrate the need for the provision of continuous education and appropriate assistance to dentists regarding reduction of radiation exposure in dental clinics.

The ADA and EC have published radiographic selection criteria that satisfy the principle of justification.^{5,6}

Individualized radiographic examinations consisting of posterior bitewings with panoramic examination, or posterior bitewings and selected periapical imaging, are recommended for new patients.^{5,6}

In this study, while 73% of dentists with less than 10 years of experience were significantly more likely to perform panoramic radiography to evaluate new adult patients, only 52% of dentists in practice for 10 years or more performed panoramic radiography to evaluate new adult patients (Table 4). All dentists preferred to perform periapical radiography to evaluate new paediatric patients. In a previous study, 36.8% of Korean general dentists preferred to order radiographs routinely,¹⁰ and 44% of Iranian dentists preferred to perform periapical radiography on new patients.²⁷ However, selected periapical radiography of new adult patients will improve diagnostic performance,²⁸ and the EC recommends that panoramic radiography for a new adult dentate patient may be indicated in an orthodontic assessment and certain oral surgical procedures.⁶ Therefore, it is recommended that radiographic selection criteria be developed in the Republic of Korea.

Compared with a circular collimator, a rectangular collimator can reduce radiation exposure by about 60%;²⁹ therefore, film-positioning and sensor-positioning devices with rectangular collimators are recommended. The present study showed that 20% of the respondents used rectangular collimators, which was lower than the usage reported in the United Kingdom (42%),¹⁵ the Republic of Ireland (44%),¹⁵ and Sweden (29%),³⁰ but higher than that reported in previous studies in the Republic of Korea (14.8%)¹⁰ and Turkey (5.5%).³¹ However, 22% of respondents in the present study were unaware of collimators, thereby indicating the need for education regarding the benefits of using the rectangular collimator.

Routine personnel radiation monitoring among dentists is considered desirable but not mandatory in the Republic of Korea. The ADA recommends that monitoring be performed when workers are exposed to an annual radiation dose greater than 1 mSv.⁵ Moreover, pregnant dental workers operating radiography machines in the USA should wear personnel monitoring devices, irrespective of the expected exposure levels.⁵ In this study, 118 of the 207 dentists (57%) were using personnel monitoring systems, and dentists with 10 or more years of experience preferred to monitor their occupational radiation exposure (Table 5).

The use of lead aprons or thyroid collar shielding in panoramic radiography is controversial;^{32,33} however, a recent study showed that thyroid shielding is helpful in reducing radiation exposure when performing upper anterior tooth radiography.³⁴ The ADA recommends that protective thyroid collars be used whenever possible.⁵ All respondents' dental clinics were well equipped with lead aprons or thyroid collars.

Korean dentists who own their clinics are legally required to arrange for inspections of their dental

radiography machines every 3 years; thus, all radiographic equipment included in this study had been regularly checked. However, only 39% of Iranian dentists²⁷ and 16.7% of Turkish dentists³¹ performed regular check ups of their X-ray machines. This lower rate of regular checking of dental X-ray machines may be related to the fact that current regulations did not apply to general dental practice in the Islamic Republic of Iran²⁷ and that the regulations put in place by the Atomic Energy Commission in Turkey took effect when dentists first opened their clinics.³¹

Korean dentists who own their clinic are legally required, as a one-time measure, to undergo an approved radiation safety program. Most of the respondents (82%) in the present study had participated in the radiation safety program, but only 58% were satisfied with it. The participating dentists also suggested that the radiation safety and protection program should include information on the levels of radiation exposure to which dental patients are subjected; educational material on radiation risks and radiation safety for both patients and employees; information on TLD badge values used for personnel radiation monitoring; and training content for employees regarding the operation and maintenance of radiography equipment.

In conclusion, dentists with less than 10 years of experience in practice were significantly more likely to use CBCT, digital cephalometric radiography and handheld portable X-ray devices. Dentists with less than 10 years of experience were significantly more likely to perform panoramic radiography to evaluate new adult patients. However, they were significantly less likely to monitor their occupational radiation exposure and less likely to attend the radiation safety program. These results indicated that dentists with less than 10 years of experience are less attentive to radiation protection procedures.

Privately practicing dentists may not have enough information on radiation safety training, and without conscious efforts, radiation safety management for both patients and employees could be neglected. Therefore, taking both the duration of experience of dentists and the installed X-ray equipment into consideration, continuous and efficient education for both dental workers and patients regarding radiation safety and protection is recommended. Future research is required to evaluate quality assurance regimens and imaging quality.

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References

1. Scarfe WC. Radiation risk in low-dose maxillofacial radiography. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2012; **114**: 277–80. doi: <https://doi.org/10.1016/j.oooo.2012.07.001>
2. Looe HK, Pfaffenberger A, Chofor N, Eenboom F, Sering M, Rühmann A, et al. Radiation exposure to children in intraoral dental radiology. *Radiat Prot Dosimetry* 2006; **121**: 461–5. doi: <https://doi.org/10.1093/rpd/nci071>
3. Li G. Patient radiation dose and protection from cone-beam computed tomography. *Imaging Sci Dent* 2013; **43**: 63–9. doi: <https://doi.org/10.5624/isd.2013.43.2.63>
4. Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. *Br J Radiol* 2009; **82**: 35–40. doi: <https://doi.org/10.1259/bjr/31419627>
5. American Dental Association. Dental radiographic examinations: recommendations for patient selection and limiting radiation exposure. 2012. Available from: <http://www.fda.gov/downloads/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/MedicalX-Rays/UCM329746.pdf> [cited 2016 Aug 9]
6. European Commission (EC). Radiation Protection 136. In: *European guidelines on radiation protection in dental radiology*. Luxembourg; 2004.
7. Hunjin Oh HO, Lee G, Lee C, Lee B, Jeong S, Kim B. The safe use of dental X-ray. 2015. Available from: <http://www.imagegreen.org/info2/images/xx.pdf> [cited 2016 August 16]
8. Kim YH, Yang BE, Yoon SJ, Kang BC, Lee JS. Diagnostic reference levels for panoramic and lateral cephalometric radiography of Korean children. *Health Phys* 2014; **107**: 111–6. doi: <https://doi.org/10.1097/HP.0000000000000071>
9. Kim YJ, Cha ES, Lee WJ. Occupational radiation procedures and doses in South Korean dentists. *Community Dent Oral Epidemiol* 2016; **44**: 476–84. doi: <https://doi.org/10.1111/cdoe.12237>
10. Lee BD, Ludlow JB. Attitude of the Korean dentists towards radiation safety and selection criteria. *Imaging Sci Dent* 2013; **43**: 179–84. doi: <https://doi.org/10.5624/isd.2013.43.3.179>
11. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods* 2007; **39**: 175–91. doi: <https://doi.org/10.3758/BF03193146>
12. Harding K, Thomson WH. Radiological protection and safety in medicine - ICRP 73. *Eur J Nucl Med* 1997; **24**: 1207–9.
13. United Nations Scientific Committee on Effects of Atomic Radiation. Sources and effects of ionizing radiation. Vol I annex A 1: medical radiation exposures. 2008. Available from: http://www.unscear.org/docs/publications/2008/UNSCEAR_2008_Report_Vol.I.pdf [cited 2016 Sep 6]
14. Dölekoglu S, Fisekcioglu E, Iguy M, Iguy D. The usage of digital radiography and cone beam computed tomography among Turkish dentists. *Dentomaxillofac Radiol* 2011; **40**: 379–84. doi: <https://doi.org/10.1259/dmfr/27837552>
15. HJ R. Trends in dental radiography equipment and patient dose in the UK and Republic of Ireland. 2013. Available from: https://www.phe-protectionservices.org.uk/cms/assets/gfx/content/resource_3320cs36ed197b3f.pdf [cited 2017 May 23]
16. Aps JK. Flemish general dental practitioners' knowledge of dental radiology. *Dentomaxillofac Radiol* 2010; **39**: 113–8. doi: <https://doi.org/10.1259/dmfr/52763613>
17. Gijbels F, Debaveye D, Vanderstappen M, Jacobs R. Digital radiographic equipment in the Belgian dental office. *Radiat Prot Dosimetry* 2005; **117**: 309–12. doi: <https://doi.org/10.1093/rpd/nci761>
18. Ting NA, Broadbent JM, Duncan WJ. Dental radiography in New Zealand: digital versus film. *N Z Dent J* 2013; **109**: 107–14.
19. Rehani MM, Gupta R, Bartling S, Sharp GC, Pauwels R, Berris T, et al. Radiological protection in cone beam computed tomography (CBCT). ICRP publication 129. *Ann ICRP* 2015; **44**: 9–127. doi: <https://doi.org/10.1177/0146645315575485>
20. American Dental Association Council on Scientific Affairs. The use of dental radiographs: update and recommendations. *J Am Dent Assoc* 2006; **137**: 1304–12.
21. Makdissi J, Pawar RR, Johnson B, Chong BS. The effects of device position on the operator's radiation dose when using a handheld portable X-ray device. *Dentomaxillofac Radiol* 2016; **45**: 20150245. doi: <https://doi.org/10.1259/dmfr.20150245>
22. Berkhout WE, Suomalainen A, Brüllmann D, Jacobs R, Horner K, Stamatakis HC. Justification and good practice in using handheld portable dental X-ray equipment: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR). *Dentomaxillofac Radiol* 2015; **44**: 20140343. doi: <https://doi.org/10.1259/dmfr.20140343>
23. National Council on Radiation Protection and Measurements (NCRP). Report No: 172. In: *Reference levels and achievable doses in medical and dental imaging: recommendations for the United States*; 2012.
24. Holroyd JR. National reference doses for dental cephalometric radiography. *Br J Radiol* 2011; **84**: 1121–4. doi: <https://doi.org/10.1259/bjr/26420990>
25. Kim EK, Han WJ, Choi JW, Jung YH, Yoon SJ, Lee JS. Diagnostic reference levels in intraoral dental radiography in Korea. *Imaging Sci Dent* 2012; **42**: 237–42. doi: <https://doi.org/10.5624/isd.2012.42.4.237>
26. Poppe B, Looe HK, Pfaffenberger A, Chofor N, Eenboom F, Sering M, et al. Dose-area product measurements in panoramic dental radiology. *Radiat Prot Dosimetry* 2007; **123**: 131–4. doi: <https://doi.org/10.1093/rpd/nci090>
27. Shahab B, Kavosi A, Nazarinia H, Mehrizadeh S, Mohammadpour M, Emami M. Compliance of Iranian dentists with safety standards of oral radiology. *Dentomaxillofac Radiol* 2012; **41**: 159–64. doi: <https://doi.org/10.1259/dmfr/29207955>
28. Bohay RN. The sensitivity, specificity, and reliability of radiographic periapical diagnosis of posterior teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; **89**: 639–42. doi: <https://doi.org/10.1067/moe.2000.105908>
29. National Council on Radiation Protection and Measurements(NCRP). Report No: 145. In: *radiation protection in dentistry*. Bethesda: National Council on Radiation Protection and Measurement; 2003.
30. Svenson B, Söderfeldt B, Gröndahl HG. Attitudes of Swedish dentists to the choice of dental X-ray film and collimator for oral radiology. *Dentomaxillofac Radiol* 1996; **25**: 157–61. doi: <https://doi.org/10.1259/dmfr.25.3.9084265>
31. Ilgüy D, Ilgüy M, Dinçer S, Bayirli G. Survey of dental radiological practice in Turkey. *Dentomaxillofac Radiol* 2005; **34**: 222–7. doi: <https://doi.org/10.1259/dmfr/22885703>
32. Rottke D, Grosseckettler L, Sawada K, Poxleitner P, Schulze D. Influence of lead apron shielding on absorbed doses from panoramic radiography. *Dentomaxillofac Radiol* 2013; **42**: 20130302. doi: <https://doi.org/10.1259/dmfr.20130302>
33. Han GS, Cheng JG, Li G, Ma XC. Shielding effect of thyroid collar for digital panoramic radiography. *Dentomaxillofac Radiol* 2013; **42**: 20130265. doi: <https://doi.org/10.1259/dmfr.20130265>
34. Hoogveen RC, Hazenoot B, Sanderink GC, Berkhout WE. The value of thyroid shielding in intraoral radiography. *Dentomaxillofac Radiol* 2016; **45**: 20150407. doi: <https://doi.org/10.1259/dmfr.20150407>