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A Comparative Assessment of Radiation Doses to Eye Lens during Paralleling Versus Bisecting-Angle Periapical Radiography of Maxillary Teeth

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ABSTRACT

Background and Objective: Periapical radiography is extensively utilized in dental practice, resulting in considerable radiation exposure to the eyes. However, relevant studies remain limited. This study aims to compare the absorbed dose to the eye lens between the bisecting-angle and paralleling techniques in maxillary periapical radiography.

Methods: In this cross-sectional study, a total of 32 periapical radiographs were acquired from the maxilla—16 utilizing the paralleling technique (PA-Tech) and 16 using the bisecting-angle technique (BI-Tech). Radiographic exposures were performed on right and left sides across four regions: central and lateral incisors, canine, premolars, and molars. To measure the radiation dose delivered to the eye, thermoluminescent dosimeters (TLDs) were placed at the eye lens level of two dental phantoms. After the radiographic procedures, the TLDs were carefully read, and the measured dose values were statistically compared between the two techniques.

Findings: The mean absorbed dose to the eye lens on the irradiated side was greater for the paralleling technique (0.560±0.324 mGy) than for the bisecting-angle technique (0.434±0.386 mGy). On the non-irradiated side, a similar pattern was observed, with the paralleling technique yielding a higher mean dose (0.038±0.022 mGy) compared to the bisecting-angle technique (0.031±0.011 mGy). Nevertheless, these differences did not reach statistical significance on either side. When comparing exposed versus non-exposed sides in each technique, the absorbed dose to the eye lens was found to be significantly greater on the exposed side for both techniques ($p<0.001$).

Conclusion: The present findings suggest that the bisecting-angle technique may be preferred over the paralleling technique for periapical radiography of the central incisor and canine regions, as it is associated with a lower radiation dose to the patient's eyes.

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Introduction

Periapical radiography is the most frequently prescribed imaging modality in everyday dental practice (1). While this technique provides invaluable diagnostic information for the assessment of periapical pathology and root anatomy, it is not without its risks, as it exposes certain critical radiosensitive organs—most notably the lens of the eye—to potentially harmful ionizing radiation. The high volume of periapical radiographs performed in routine clinical settings underscores the importance of minimizing patient radiation exposure, particularly to vulnerable tissues. The lens of the eye, being a particularly radiosensitive structure, is at risk of receiving unnecessary scattered radiation during maxillofacial radiographic procedures (2).

Cataract formation (opacification of the eye lens) is a well-recognized complication of ocular exposure to ionizing radiation (3). Recent statements from the ICRP have emphasized that the radiosensitivity of the lens is greater than previously estimated, and emerging data suggest that even low-dose exposure in diagnostic radiology may pose a risk to ocular health. Moreover, given the uncertainty surrounding the threshold dose, a precautionary approach—maintaining exposure at the optimal minimum—is warranted (4). The majority of existing research has concentrated on panoramic radiography and cone-beam computed tomography (CBCT) (5-10), leaving a notable gap in the literature regarding periapical radiography. The few studies that do exist are limited in number and have reported inconsistent results, and none have systematically compared the paralleling and bisecting-angle techniques (11-13). It is important to recognize that technical differences between these two imaging methods may lead to differences in the radiation dose absorbed by the lens (3). Given the serious consequences of ocular radiation exposure and the scarcity of conclusive evidence, the present study was designed to compare the radiation dose to the lens between paralleling and bisecting-angle periapical radiography of the maxillary teeth.

Methods

This cross-sectional study was approved by the Ethics Committee of Isfahan University of Medical Sciences (IR.MUI.REC.1396.3.932). Thermoluminescent dosimeters (TLD700; Bicron NE Solon, USA) were positioned at the eye lens level within two dental radiographic phantoms (a total of 32 TLDs for each radiographic technique). A total of 32 periapical radiographs were acquired—16 using the paralleling technique and 16 using the bisecting-angle technique—from the right and left maxillary quadrants, encompassing four regions: central and lateral incisors, canine, premolars, and molars. Exposures were performed using size 2 intraoral films (Agfa-Gevaert NV, Mortsel, Belgium) and an intraoral X-ray unit (Planmeca, Helsinki, Finland) operating at 63 kVp and 8 mA, with exposure times of 0.2 seconds for the paralleling technique and 0.15 seconds for the bisecting-angle technique. A Rinn film holder (Rinn Corporation, IL, USA) was employed for the paralleling technique. The focus-to-object distance was standardized at 8 cm. After irradiation, the TLDs were read using a NE SOLARO 2A TLD reader. The heating protocol consisted of a preheat phase at 135°C for 10 seconds, a readout phase at 240°C for 20 seconds, and an annealing phase at 240°C for 10 minutes. The reader output was reported as corrected counts, calculated as follows:

Corrected count= (Raw count − Background current count) × Internal light factor (as determined by the manufacturer).

Subsequently, the corrected counts were converted into dose values using the following formula:

Dose absorbed by each TLD= Individual calibration factor × [Reading of each TLD − Background reading of each TLD] × Group calibration factor.

A total of 20 TLDs were utilized in the present investigation. These were subjected to two distinct calibration protocols: individual calibration and group calibration. In the individual calibration procedure, each TLD was exposed individually to the intraoral X-ray unit, with the tube potential set at 63 kVp, the tube current at 8 mA, and an exposure duration of 0.2 seconds. Following exposure, each TLD was read using the TLD reader to establish its individual response factor. For the group calibration, the 20 TLDs were allocated into five groups, each containing four TLDs. The first group was designated as the control group and received no additional radiation. The remaining four groups (groups 2 through 5) were exposed to escalating doses ranging from 5 to 20 cGy. After exposure, the TLD reader was used to measure the absorbed dose for each group.

The total radiation dose recorded by the TLDs was calculated independently for the paralleling and bisecting-angle techniques, and the values were compared between the two groups. For the paralleling technique, the mean TLD dose on the exposed side was determined for both the right and left sides of the two phantoms and compared with the corresponding mean values for the bisecting-angle technique (a total of four radiographs per dental site). The same procedure was repeated for the non-exposed side, with mean doses calculated per dental region and compared between the two techniques. Statistical analysis was performed using SPSS version 26, with the Wilcoxon and Mann-Whitney tests employed for group comparisons. A p-value of less than 0.05 was considered to indicate statistical significance.

Results

A total of 32 periapical radiographs were evaluated, comprising 16 obtained with the bisecting-angle technique and 16 with the paralleling technique. On the exposed (dosimetry) side, the bisecting-angle technique yielded the highest mean absorbed dose to the crystalline lens in the molar region, which was significantly greater than the doses recorded for other teeth ($p<0.05$). For the paralleling technique, however, no statistically significant differences were observed between premolars, molars, and canines. The overall mean absorbed dose to the lens on the exposed side was found to be higher with the paralleling technique (0.560±0.324 mGy) compared with the bisecting-angle technique (0.434±0.386 mGy). Nevertheless, this difference was not statistically significant (Table 1).

Table 1. Absorbed dose to the crystalline lens on the exposed (dosimetry) side for the bisecting-angle and paralleling techniques (mGy)

Technique	Tooth type	N	Mean±SD	95% Confidence Interval	
				Lower bound	Upper bound
Bisecting technique	Molar	4	0.860±0.070	0.749	0.971
	Premolar	4	0.731±0.173	0.456	1.006
	Canine	4	0.103±0.026	0.060	0.145
	Incisor	4	0.043±0.018	0.014	0.072
	Total	16	0.434±0.386		
Paralleling technique	Molar	4	0.698±0.177	0.417	0.980
	Premolar	4	0.755±0.136	0.538	0.972
	Canine	4	0.736±0.119	0.546	0.926
	Incisor	4	0.053±0.009	0.037	0.068
	Total	16	0.560±0.324		

On the non-irradiated side, the bisecting-angle technique yielded relatively uniform absorbed doses to the eye lens across all tooth groups. In contrast, the paralleling technique resulted in a significantly higher dose in the premolar region compared to the molar, canine, and incisor regions ($p<0.05$). The overall mean absorbed dose to the lens on the non-exposed side was greater with the paralleling technique (0.038±0.022 mGy) than with the bisecting-angle technique (0.031±0.011 mGy); however, this difference did not reach statistical significance. When comparing the exposed and non-exposed sides within each technique, the absorbed dose on the exposed side was found to be significantly higher than on the non-exposed side for both techniques ($p<0.001$) (Table 2).

Table 2. Absorbed dose to the eye lens on the non-exposed (non-dosimetry) side for the bisecting-angle and paralleling techniques (mGy)

Technique	Tooth type	N	Mean±SD	95% Confidence Interval	
				Lower bound	Upper bound
Bisecting technique	Molar	4	0.024±0.004	0.018	0.030
	Premolar	4	0.035±0.013	0.013	0.056
	Canine	4	0.031±0.014	0.008	0.053
	Incisor	4	0.023±0.006	0.014	0.032
	Total	16	0.031±0.011		
Parallel technique	Molar	4	0.026±0.011	0.008	0.042
	Premolar	4	0.073±0.005	0.065	0.080
	Canine	4	0.029±0.010	0.013	0.046
	Incisor	4	0.034±0.009	0.018	0.048
	Total	16	0.038±0.022		

Discussion

Our findings revealed that the mean absorbed dose to the eye lens was 0.560±0.324 mGy for the paralleling technique and 0.434±0.386 mGy for the bisecting-angle technique. Notably, the dose associated with the paralleling technique marginally exceeded the recommended threshold of 0.5 mGy (14). Considerable variation exists in the literature regarding lens dose in periapical radiography. Granlund et al., utilizing TLDs on a head-and-neck phantom, reported a lens dose of 4 μSv, with the highest value observed in the molar region (11). Kanzaki et al. reported mean lens doses of 0.11±0.09 mGy and 0.08±0.04 mGy for maxillary incisors and molars, respectively (13). Jibiri et al. reported the entrance skin dose to the eye ranging from 0.0742 to 0.3989 mGy (12). Eren et al. reported a lens dose of 2.08 mGy for a full-mouth periapical series, which was 1.047 mGy when using a digital sensor, with no significant difference between the two modalities (15). Nevertheless, these values differ from those obtained in the present study. Technological advancements in sensor speed and quality, along with improvements in X-ray unit design, have substantially reduced patient radiation doses over time. A study from 1994 reported a lens dose of 4.43 mGy for a full-mouth intraoral series (16), whereas this decreased to 2.08 mGy in a 2015 study (15). This reduction has been attributed to the use of a long open-ended cylinder, which increases the source-to-object distance and reduces image blurring, as well as to the introduction of faster films requiring lower exposure (3). Discrepancies between recent studies may also be explained by differences in the specific X-ray equipment used and the radiographic technique employed (bisecting-angle vs. paralleling). Most previous investigations have evaluated lens dose using only a single technique; the present study is the first to compare the two techniques directly. Although the overall lens dose did not differ significantly between the two techniques, the paralleling technique yielded higher doses in the incisor and canine regions on both the exposed and non-exposed sides. This finding may be explained by the lower vertical angulation used in the paralleling technique, which directs the primary beam toward the eye, thereby increasing the dose. Additionally, in the canine region, the paralleling technique often necessitates a more distal projection due to the positioning of the film holder (17).

It is essential to recognize that efforts to minimize the absorbed dose to the eye lens should be prioritized, particularly among patients who already have cataracts or who are considered to be at increased risk for cataract development. In light of the results obtained from the current investigation, we recommend the use of the bisecting-angle periapical technique when performing radiography of the central incisor and canine regions in such vulnerable populations. It must be acknowledged, however, that the present study employed a phantom model, which represents a methodological limitation and may limit the generalizability of the results. To address these limitations, future studies should be conducted with larger sample sizes and should also assess the absorbed dose to other radiosensitive organs, such as the thyroid gland.

Conflict of Interest: The authors declare that they have no conflicts of interest relevant to the content of this article.

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References

1.Aps JKM, Lim LZ, Tong HJ, Kalia B, Chou AM. Diagnostic efficacy of and indications for intraoral radiographs in pediatric dentistry: a systematic review. Eur Arch Paediatr Dent. 2020;21(4):429-62.

2.Khafaji M, Albadawi GH. Assessment of Scattered Dose to the Eye in Dentistry: A Systematic Review. Cureus. 2023;15(8):e43113.

3.White SC, Pharoah MJ. Oral radiology-E-Book: Principles and interpretation, 7th ed. Elsevier Health Sciences; 2014. p. 120-3.

4.Prins R, Dauer LT, Colosi DC, Quinn B, Kleiman NJ, Bohle GC, et al. Significant reduction in dental cone beam computed tomography (CBCT) eye dose through the use of leaded glasses. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;112(4):502-7.

5.Eftekhari Moghadam A, Mardani M, Hasanzadeh H, Rafati M. Assessment of absorbed dose in critical organs in OPG: a phantom study. Arch Adv Biosci. 2015;6(1):44-9.

6.Reza A, Hassan J, Adibi A. Evaluation of radiation exposure of eyes, parotid and thyroid gland during panoramic radiography. Afr J Intern Med. 2018;6(7):488-94.

7.Naserpour F, Hassanpour N, Panahi F, Karami V, Gholami M. An estimate of radiation dose to the lens of the eyes, parotid gland, and thyroid gland in dental panoramic radiography. Iran J Med Phys. 2019;16:425-9.

8.Ahmadi A, Negarestani A, Sina S, Sarshough S. Measurement of entrance skin dose and the dose received by different organs in panoramic dental imaging. J Biomed Phys Eng. 2020;10(5):569-74.

9.Sohaimi N, Maarof K. an Assessment on the Radiation Dose Received By the Eyes and Thyroid Using Panaromic View (Opg): a Phantom Study. Int J Allied Health Sci. 2020;4(2):1128-39.

10.Schindler F, Müller-Winter D, Karle H, Schulze R. Measurement of radiation dose and analysis of dose distribution in the thyroid and eye lens during digital panoramic tomography. Dentomaxillofac Radiol. 2025;54(7):605-12.

11.Granlund C, Thilander-Klang A, Ylhan B, Lofthag-Hansen S, Ekestubbe A. Absorbed organ and effective doses from digital intra-oral and panoramic radiography applying the ICRP 103 recommendations for effective dose estimations. Br J Radiol. 2016;89(1066):20151052.

12.Jibiri NN, Adeleye B, Kolude B. Radiation dose to the thyroid, eyes and parotid glands of patients undergoing intra-oral radiographic procedures in a teaching hospital in Ibadan, Oyo state Nigeria. Int J Radiat Res. 2017;15(1):101-6.

13.Kanzaki T, Takahashi Y, Yarita K. Absorbed dose to the eye lens during dental radiography. Oral Radiol. 2016;33(1):246-50.

14.Sánchez RM, Vañó E, Fernández JM, Rosati S, López-Ibor L. Radiation Doses in Patient Eye Lenses during Interventional Neuroradiology Procedures. AJNR Am J Neuroradiol. 2016;37(3):402-7.

15.Eren H, Gorgun S. Evaluation of Effective Dose with Two-dimensional and Three-dimensional Dental Imaging Devices. J Contemp Dent. 2015;5(2):80-5.

16.Freeman JP, Brand JW. Radiation doses of commonly used dental radiographic surveys. Oral Surg Oral Med Oral Pathol. 1994;77(3):285-9.

17.Farman AG, Kolsom SA. Intraoral Radiographic Techniques. American Dental Assisstants Association; 2014. Available from: https://cdeworld.com/courses/21129-intraoral-radiographic-techniques