RESEARCH ARTICLE

Oblique lateral radiographs and bitewings; estimation of organ doses in head and neck region with Monte Carlo calculations

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Objectives: When bitewing radiographs are not possible (e.g. patients with special needs), oblique lateral radiographs may offer an alternative. The aims of this study were to assess the impact of horizontal projection angulation, focus-to-skin distance, exposure time and age of the patient on the equivalent radiation dose of several organs in the head and neck region by means of personal computer X-ray Monte Carlo (PCXMC) calculations and to assess the dose obtained from conventional bitewing radiographs.

Methods: PCXMC v. 2.0 software (STUK[®], Helsinki, Finland) was used to estimate the equivalent radiation doses and the total effective dose. Three exposure times, five age categories, two focus-to-skin distances and eight horizontal geometric angulations were assumed. The organs involved were the thyroid gland, oesophagus, salivary glands, bone marrow, oral mucosa, skull, cervical spine and skin. A similar calculation was also performed for bitewings taken with a rectangular collimator.

Results and conclusion: Bitewings taken with rectangular collimation decrease the radiation burden of the patient to 50%, compared with circular collimation. In the oblique lateral radiographs, focus-to-skin distance, patient's age and beam collimation had a significant impact on the equivalent doses measured in this study. Exposure time had a significant impact on the equivalent doses of the salivary glands, oral mucosa, skull and skin. Horizontal angulations had a significant impact on the equivalent doses of the thyroid gland, bone marrow, oral mucosa, skull and cervical spine. The total effective radiation dose was significantly influenced by all parameters investigated in this study.

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Introduction

Bitewing radiography is an ideal method to investigate interproximal dental decay. The technique is ideal because one aims the X-rays perpendicular through the interproximal contacts at an image receptor that has been placed inside the patient's mouth behind and parallel to the teeth. Ideally, this should be performed with the so-called long-cone technique and a rectangular collimator. The rectangular collimator will decrease

the irradiated surface and hence cause less scattered radiation within the patient's tissues, subsequently resulting in better image quality, and should also result in a lower radiation burden for the patient.^{1–5} Periapical radiographs are supposed to be taken in the same way. However, small children, medically and/or mentally compromised, and older patients do not always cope well with this technique and therefore alternatives can be used, such as the oblique lateral radiograph. These are performed with the patient or a caregiver holding a cassette with either an analogue film or a photostimulable

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phosphor storage plate against the side of the face while the X-ray machine is positioned from the opposite side perpendicular to it through the radiographic keyhole that occurs between the posterior border of the ramus of the mandible and the cervical spine when the patient's head is turned to the side under investigation. Ideally, for caries diagnosis, the central X-ray beam should be aimed along the occlusal plane. One uses a circular collimator, which enables a view of the maxillary and mandibular teeth. Figure 1 illustrates the type of radiographic image that is obtained. One can opt for either imaging one side per image receptor or both sides to be imaged on the same receptor, as shown in Figure 1.

Practitioners working with patients with special needs will acknowledge that the majority of patients might not be able to stand or sit still long enough in a panoramic machine and/or might not be able to handle intraoral radiographs and as a consequence the oblique lateral technique might prove to be a good alternative with sufficient diagnostic yield. Practice will enable the radiographer to aim perpendicularly at the image receptor and obtain good diagnostic images that will add valuable information to the clinical examination that was performed earlier.

As this technique uses a circular collimator, which is positioned from an oblique horizontal angle, the irradiated surface is much larger than when a bitewing is taken at a 90° angle to the midsagittal plane of the skull with a rectangular collimator. Consequently, one can question the impact of such action with regard to the absorbed radiation dose to the tissues in the head and neck region, especially in children whose tissues are more susceptible to the effects of ionizing radiation and where the risks for developing a fatal cancer as a result of being exposed to ionizing radiation are so much higher than those for adults.^{3,6-9}

The first aim of the current report was to investigate the absorbed radiation doses by the tissues in the head and neck region from oblique lateral radiographs taken from different horizontal angles using personal computer

X-ray Monte Carlo (PCXMC 2.0[®]; STUK[®], Helsinki, Finland) calculations.

The second aim was to investigate with the same software what the difference in absorbed radiation dose by those tissues could be between bitewings taken with circular vs rectangular collimation.

Methods and material

The PCXMC 2.0 is a computer program that simulates patient's equivalent organ doses and the total effective dose from medical and dental X-ray examinations.¹⁰⁻¹³ The program uses a modification of the 1987 mathematical hermaphrodite phantom models of Cristy and Eckerman and implements the most recent 2007 tissue weighting factors for its calculations.¹²⁻¹⁷ The software PCXMC 2.0 has been shown to provide accurate assessments of absorbed radiation doses. Comparison of the estimated doses with thermoluminescent dosimetry, ion chamber dosimetry and pin silicon photodiode dosimetry has shown that the PCXMC software can come as close to 0.003 mSv and between 2.1% and 5.2% to what was measured physically. The latter came from medical diagnostic investigations and not dental.^{18,19} The latter illustrates the ability of the software to assess radiation doses accurately enough to be used as a guidance. The PCXMC 2.0 software was used to calculate the equivalent radiation doses for different tissues in the head and neck region and to calculate the total effective radiation dose. This software takes into account the voltage (65 kV), the current in milliamperes (7 mA), the exposure time (14, 16 and 20 ms), the beam filtering (1.5 mm Al), photons involved (10^6), focus-to-skin distance (24 and 40 cm), horizontal (110°, 120°, 130°, 140°, 150°, 160°, 170° and 180° relative to the midsagittal plane of the skull) and vertical angulation (90°) of the X-ray beam, surface covered by the X-ray beam (a rectangle of 3.5 cm by 4.5 cm and a rectangle of 6 cm by 6 cm) and the age of the patient in

Figure 1 An example of two oblique lateral radiographs taken on one cassette with a phosphor storage plate.

Figure 2 Illustration of the cropped personal computer X-ray Monte Carlo phantoms of 1-, 5-, 10- and 15-year olds and an adult, and the position of the X-ray beam for a focus-to-skin distance of 24 cm.

incremental steps (1-, 5-, 10- and 15-year-old persons and an adult). **Figure 2** shows the layout of the phantoms and the X-ray beam that can be visualized. Special attention was paid to the x , y and z coordinates to position the X-ray beam to the phantom's head for the different age categories correctly and similarly. The position needed to be adjusted for each age selection, as the mathematical phantom changed in shape and size. This was performed by changing the coordinates a 10th of a degree each at a time instead of dragging the collimated beam with the computer mouse and by verification of the drawing, provided by the software. The latter was not considered accurate enough, as it could not be reproduced by the investigator (JKMA).

The following tissues were considered important and relevant in the head and neck region: skin, cervical spine, skull, bone marrow, salivary glands, thyroid gland, oral mucosa and oesophagus. The total effective dose was also calculated. The generated data were imported into Excel[®] (Microsoft[®], Redmond, WA) and Stata v. 12.1 (StataCorp, College Station, TX) for analysis.

Data analysis

Although estimates of the mean values of energy deposition in the various organs of the phantom are used for calculating the doses in these organs, the analysis treats each dose as an individual observation.

Descriptive statistics (means and standard deviations) were calculated for the radiation dose stratified by groups

of interest. One-way ANOVA and two-sample t -tests with unequal variances were used to test the difference in the mean radiation dose within organ sites by all settings, by age and by collimator type. The level of significance was set at 0.05.

Results

Focus-to-skin distance

Equivalent radiation dose was significantly associated with the focus-to-skin distance (24 cm vs 40 cm) for every organ site. In particular, the equivalent dose was significantly lower when the distance was 40 cm than that of 24 cm in every organ site. In addition, the total effective radiation dose was also significantly associated with the focus-to-skin distance, with the effective dose decreasing as the distance increased (**Table 1**). Both of the above were calculated, irrespective of the exposure time.

Exposure time

The impact of the exposure time (0.14, 0.16 and 0.20 s) on the equivalent radiation dose by the relevant tissues appeared to be limited. The doses were significantly associated with only exposure time in the salivary glands, oral mucosa, skull and skin. In all these organ sites, it appears that the equivalent radiation dose increased as the exposure time increased. In addition, the total effective radiation dose was also significantly associated with the

Table 1 Association between the equivalent radiation dose (μGy) and focus-to-skin distance by organ sites, irrespective of the exposure time

Organ site	Focus-to-skin distance		p-value ^a
	24 cm (n = 120), mean (SD)	40 cm (n = 120), mean (SD)	
Thyroid gland (equivalent dose in μGy)	0.03295 (0.04729)	0.00968 (0.01396)	<0.001
Oesophagus (equivalent dose in μGy)	0.00086 (0.00099)	0.00034 (0.00049)	<0.001
Salivary glands (equivalent dose in μGy)	0.26878 (0.09784)	0.09796 (0.03615)	<0.001
Bone marrow (equivalent dose in μGy)	0.00536 (0.00449)	0.00196 (0.00162)	<0.001
Oral mucosa (equivalent dose in μGy)	0.11821 (0.05993)	0.04477 (0.02339)	<0.001
Skull (equivalent dose in μGy)	0.09360 (0.05050)	0.03327 (0.01484)	<0.001
Cervical spine (equivalent dose in μGy)	0.07307 (0.09034)	0.02541 (0.03230)	<0.001
Skin (equivalent dose in μGy)	0.01341 (0.00871)	0.00493 (0.00322)	<0.001
Entire body (effective dose in μSv)	0.00711 (0.00471)	0.00260 (0.00172)	<0.001

SD, standard deviation.

^aCalculated by comparing the mean radiation dose across focus-to-skin distance using two-sample t -tests.

Table 2 Association between the equivalent radiation dose (μGy) and exposure setting by organ sites, irrespective of the focus-to-skin distance

Organ site	Exposure setting (65 kV, 7 mA)			p-value ^a
	0.14 s (n = 80), mean (SD)	0.16 s (n = 80), mean (SD)	0.20 s (n = 80), mean (SD)	
Thyroid gland (equivalent dose in μGy)	0.0195 (0.0354)	0.0197 (0.0331)	0.0247 (0.0413)	0.606
Oesophagus (equivalent dose in μGy)	0.0005 (0.0007)	0.0006 (0.0009)	0.0007 (0.0009)	0.274
Salivary glands (equivalent dose in μGy)	0.1540 (0.0913)	0.1760 (0.1044)	0.2201 (0.1305)	<0.001
Bone marrow (equivalent dose in μGy)	0.0031 (0.0031)	0.0035 (0.0036)	0.0044 (0.0045)	0.080
Oral mucosa (equivalent dose in μGy)	0.0685 (0.0477)	0.0782 (0.0545)	0.0978 (0.0681)	0.005
Skull (equivalent dose in μGy)	0.0520 (0.0342)	0.0641 (0.0559)	0.0742 (0.0489)	0.013
Cervical spine (equivalent dose in μGy)	0.0414 (0.0596)	0.0473 (0.0681)	0.0591 (0.0851)	0.283
Skin (equivalent dose in μGy)	0.0077 (0.0064)	0.0088 (0.0073)	0.0110 (0.0092)	0.024
Entire body (effective dose in μSv)	0.0041 (0.0035)	0.0046 (0.0040)	0.0059 (0.0049)	0.018

SD, standard deviation.

^aCalculated by comparing the mean radiation dose across exposure setting using ANOVA.

exposure time, with the effective dose increasing as the exposure time increased (Table 2). These calculations did not take into account the focus-to-skin distance.

Horizontal projection angle

Not taking into account the focus-to-skin distance and the exposure time, the equivalent radiation dose was significantly associated with the horizontal projection angle in the following organ sites: thyroid gland, bone marrow, oral mucosa, the skull and the cervical spine. In all these organ sites, it appears that the equivalent radiation dose increased as the angulation increased. In addition, the total effective radiation dosage was also significantly associated with the horizontal projection angle, with the effective dose slightly increasing as the angulation increased (Table 3).

Age categories

When not taking into consideration the focus-to-skin distance, the exposure time or the horizontal X-ray beam angulation, the equivalent radiation dose was significantly associated with the age category for every organ site. In particular, the equivalent dose decreased as the age increased in every organ site. The total effective radiation dose was also significantly associated with the age, with the total effective dose decreasing as the age increased (Table 4).

Collimator type

When considering bitewings, there is a significant association between the equivalent radiation dose and collimator type (rectangular vs circular X-ray beam collimation) for every organ site except for the cervical spine. In all these organ sites, the doses were significantly lower when the rectangular collimator was used. The total effective dose for bitewings taken with a circular collimator is twice as high as the total effective dose when a rectangular collimator is used (Table 5).

Discussion

The use of PCXMC 2.0 software to assess the absorbed radiation dose offers an interesting alternative to what is usually performed with the help of dosimeters on

anthropomorphic phantoms. However, some restrictions should be emphasized, such as the fact that the software does not take into account the use of an intraoral image detector, which scatters the radiation within the skull. Besides this fact, the accurate positioning of the X-ray tube in different phantom sizes is not easy and obviously prone to errors. The authors have tried to position the primary radiation beam as good as possible in the same position for every phantom size, based on the coordinates and the visual drawing the software provided when a change was made. Secondly, the software cannot collimate the radiation beam to a circle, which translates into a difference also in the absorbed radiation dose, compared with the real situation. As it was the authors' opinion that it is always better to overestimate the risk, the rectangular collimation was chosen at 6 cm by 6 cm. The latter resulted in a 22% larger surface being irradiated. However, as the focus-to-skin distance in reality also varies from case to case, especially with the lateral oblique radiographs, this was considered reasonable and clinically relevant.

All the above cause the results to be interpreted with care and the figures mentioned in the tables not to be interpreted as absolute and exact figures. Nevertheless, the results are valuable as they showed what can happen to the equivalent doses when certain exposure parameters are changed, as is the case in a real clinical situation.

It should be emphasized that this study had no intention of assessing the image quality of oblique lateral radiographs with regard to the different horizontal angulations or exposure settings. It is even questionable if an oblique lateral radiograph taken at a horizontal X-ray beam angulation of 120° still yields diagnostic information. This study aimed only to assess the equivalent radiation doses from different projection angles, as they may occur in the clinical situation, irrespective of the diagnostic quality of the image. The latter is also the reason why the focus-to-skin distance was considered. Many clinicians will have to acknowledge that the ideal situation, as described in textbooks, is often not achievable in the clinic when working with children and patients with special needs. Nevertheless, it is clinically relevant and important to evaluate the

Table 3 Association between the equivalent radiation dose (μGy) and horizontal projection angle by organ sites, irrespective of the focus-to-skin distance and the exposure time

Organ site	Horizontal projection angle (degrees)										p-value ^a
	110 (n = 30), mean (SD)	120 (n = 30), mean (SD)	130 (n = 30), mean (SD)	140 (n = 30), mean (SD)	150 (n = 30), mean (SD)	160 (n = 30), mean (SD)	170 (n = 30), mean (SD)	180 (n = 30), mean (SD)			
Thyroid gland (equivalent dose in μGy)	0.0115 (0.0362)	0.0084 (0.0131)	0.0127 (0.0205)	0.0184 (0.0289)	0.0230 (0.0329)	0.0281 (0.0399)	0.0325 (0.0463)	0.0360 (0.0527)			0.020
Oesophagus (equivalent dose in μGy)	0.0004 (0.0005)	0.0004 (0.0006)	0.0004 (0.0005)	0.0005 (0.0006)	0.0006 (0.0008)	0.0008 (0.0011)	0.0008 (0.0010)	0.0009 (0.0011)			0.091
Salivary glands (equivalent dose in μGy)	0.1351 (0.0850)	0.1553 (0.0967)	0.1714 (0.1048)	0.1840 (0.1111)	0.1954 (0.1174)	0.2044 (0.1216)	0.2102 (0.1246)	0.2113 (0.1245)			0.080
Bone marrow (equivalent dose in μGy)	0.0021 (0.0021)	0.0023 (0.0023)	0.0028 (0.0027)	0.0034 (0.0032)	0.0041 (0.0039)	0.0048 (0.0046)	0.0049 (0.0047)	0.0050 (0.0048)			0.004
Oral mucosa (equivalent dose in μGy)	0.0479 (0.0329)	0.0546 (0.0374)	0.0660 (0.0439)	0.0807 (0.0522)	0.0970 (0.0608)	0.1046 (0.0689)	0.1028 (0.0676)	0.0984 (0.0654)			<0.001
Skull (equivalent dose in μGy)	0.0358 (0.0217)	0.0405 (0.0246)	0.0615 (0.0733)	0.0601 (0.0357)	0.0727 (0.0427)	0.0813 (0.0496)	0.0789 (0.0486)	0.0767 (0.0482)			<0.001
Cervical spine (equivalent dose in μGy)	0.0152 (0.0170)	0.0162 (0.0176)	0.0187 (0.0198)	0.0232 (0.0240)	0.0367 (0.0457)	0.0601 (0.0693)	0.0945 (0.0925)	0.1295 (0.1113)			<0.001
Skin (equivalent dose in μGy)	0.0075 (0.0064)	0.0083 (0.0070)	0.0092 (0.0076)	0.0101 (0.0082)	0.0106 (0.0091)	0.0096 (0.0086)	0.0090 (0.0080)	0.0091 (0.0079)			0.861
Entire body (effective dose in μSv)	0.0030 (0.0023)	0.0033 (0.0025)	0.0039 (0.0031)	0.0047 (0.0038)	0.0054 (0.0043)	0.0060 (0.0049)	0.0063 (0.0052)	0.0063 (0.0053)			0.002

SD, standard deviation.

^aCalculated by comparing the mean radiation dose across horizontal projection angle using ANOVA.

absorbed radiation dose in certain tissues in the head and neck region under such conditions.^{14,20,21}

The exposure time did not have a uniform impact on the radiation dose by the different tissues in the head and neck region. The dose to the thyroid gland did not seem to be significantly affected at all by the exposure time. However, the latter does not mean that the thyroid gland is not sensitive to ionizing radiation, because it is proven and described in numerous studies that it is.^{6–9} The salivary glands, however, also included in the list of radiosensitive organs, seemed to be more susceptible to changes in exposure time.^{6–9} This is probably because the thyroid gland is not in the field of view, while the salivary glands are. Moreover, since the software cannot take into account the presence of an intraoral image detector, the scattered radiation estimate is different as both parotid salivary glands are supposed to be within the primary radiation beam in this mathematical model. Therefore, the thyroid gland's equivalent dose is purely from scattered radiation, while that of the salivary glands is from the primary radiation beam.

It was interesting to observe that not all tissues involved in this study are susceptible to changes in horizontal projection angulation. The absorbed radiation doses by the salivary glands, skin and oesophagus were not significantly affected by the horizontal angulation settings, while the thyroid gland was. The latter is valuable clinically relevant information, as under everyday conditions this will occur.

With respect to the patient's age, it can be appreciated that the younger the patient's age, the higher the effect of the radiation dose will be. The latter is understandable as the age of the patient is related to the susceptibility of the tissues to ionizing radiation effects.^{6–9,14,20,21} Moreover, the relative irradiated surface in young patients is considerably larger than that in older patients. This should always be taken into account by clinicians when working with paediatric patients. The total effective dose in an adult patient was five times less than the dose in a 1-year-old. The thyroid gland in a 1-year-old patient absorbed a dose 14 times higher than that of an adult person. The latter can be explained by the fact that the thyroid gland's vertical position in the neck changes over time and by the fact that younger individuals are more susceptible to the effects of ionizing radiation. The latter is definitely a message for clinicians to use thyroid gland shielding by means of a thyroid gland collar.

Salivary glands are always within the primary radiation beam and cannot be shielded adequately without interfering with the diagnostic quality of the image. Nevertheless, the results show that clinical actions, such as focus-to-skin distance, exposure time and collimation, significantly influence the equivalent dose to the salivary glands. From a clinician standpoint, this is interesting because collimation and focus-to-skin distance should be easily controllable without conflicting with the image quality.

When traditional bitewings are possible and oblique lateral radiographs are not indicated, the present study

Table 4 Association between the equivalent radiation dose (μGy) and age categories by organ sites, irrespective of focus-to-skin distance, exposure time or horizontal X-ray beam angulation

Organ site	Age categories (years)					p-value ^a
	1 (n = 48), mean (SD)	5 (n = 48), mean (SD)	10 (n = 48), mean (SD)	15 (n = 48), mean (SD)	Adult (n = 48), mean (SD)	
Thyroid gland (equivalent dose in μGy)	0.071279 (0.057042)	0.015160 (0.013976)	0.011622 (0.010095)	0.003909 (0.002692)	0.004605 (0.003254)	<0.001
Oesophagus (equivalent dose in μGy)	0.001723 (0.001047)	0.000728 (0.000632)	0.000336 (0.000208)	0.000109 (0.000064)	0.000085 (0.000050)	<0.001
Salivary glands (equivalent dose in μGy)	0.255131 (0.132333)	0.223706 (0.116173)	0.190520 (0.100145)	0.141570 (0.075092)	0.105937 (0.056894)	<0.001
Bone marrow (equivalent dose in μGy)	0.008454 (0.005085)	0.004406 (0.002685)	0.002535 (0.001541)	0.001733 (0.001037)	0.001168 (0.000708)	<0.001
Oral mucosa (equivalent dose in μGy)	0.135643 (0.074570)	0.090048 (0.051687)	0.080388 (0.045678)	0.061679 (0.035416)	0.039688 (0.023129)	<0.001
Skull (equivalent dose in μGy)	0.089416 (0.052226)	0.076290 (0.045806)	0.057645 (0.033996)	0.048547 (0.027859)	0.045266 (0.058711)	<0.001
Cervical spine (equivalent dose in μGy)	0.121469 (0.116144)	0.043894 (0.052153)	0.035404 (0.041596)	0.025022 (0.027456)	0.020397 (0.022543)	<0.001
Skin (equivalent dose in μGy)	0.019352 (0.009828)	0.010735 (0.005463)	0.007094 (0.003658)	0.004725 (0.002419)	0.003952 (0.002009)	<0.001
Entire body (effective dose in μSv)	0.009622 (0.005894)	0.005302 (0.003086)	0.004195 (0.002445)	0.002858 (0.001616)	0.002313 (0.001500)	<0.001

SD, standard deviation.

^aCalculated by comparing the mean radiation dosage across age categories using ANOVA.

has clearly shown the efficiency of the use of a rectangular collimator to reduce the patient's effective radiation dose to 50%. For the thyroid gland, the difference is almost a factor of 7 when a rectangular collimation is used instead of a circular collimator. The reduction in dose to the other organs is substantial and should convince every clinician to use rectangular collimation for intraoral radiography. This is also supported by the literature.^{22–25} Rectangular collimation is one of the most effective ways to reduce radiation exposure to the patient, with the exception of using fast image receptors, extended focus-to-detector distance and leaded thyroid gland collars. Not only will the radiation dose be reduced, the image quality will be increased because of reduced backscatter.^{22–25}

The 5-year increments in the PCXMC software are not a limitation when estimating the radiation burden in a 7- or 3-year-old patient for instance. It is the authors' opinion that for reasons of safety it is better to interpret the obtained data from a 5- and a 1-year-old, respectively, in

this example. It is our opinion that it is better to overestimate the risk than to underestimate it, because until it is proven that low-dose ionizing radiation is harmless to biological tissues, one should act as if they are harmful.^{6,8,9}

In conclusion, bitewings taken with rectangular collimation decrease the radiation burden of the patient to 50%, compared with circular collimation. Oblique lateral radiographs can offer a great alternative to bitewings when they are difficult to obtain (*e.g.* for patients with special needs). Focus-to-skin distance, patient's age and beam collimation had a significant impact on the equivalent doses measured in this study. Exposure time had a significant impact on the equivalent doses of the salivary glands, the oral mucosa, the skull and the skin. Horizontal angulations had a significant impact on the equivalent doses of the thyroid gland, the bone marrow, the oral mucosa, the skull and the cervical spine. The total effective radiation dose was significantly influenced by all parameters

Table 5 Association between the equivalent radiation dose (μGy) and collimator type by organ sites for bitewing radiographs

Organ site	Collimator type		p-value ^a
	Rectangular (n = 30), mean (SD)	Circular (n = 30), mean (SD)	
Thyroid gland (equivalent dose in μGy)	0.0058 (0.0063)	0.0360 (0.0527)	0.004
Oesophagus (equivalent dose in μGy)	0.0003 (0.0004)	0.0009 (0.0011)	0.018
Salivary glands (equivalent dose in μGy)	0.1374 (0.0863)	0.2113 (0.1245)	0.010
Bone marrow (equivalent dose in μGy)	0.0022 (0.0020)	0.0050 (0.0048)	0.006
Oral mucosa (equivalent dose in μGy)	0.0680 (0.0485)	0.0984 (0.0654)	0.046
Skull (equivalent dose in μGy)	0.0376 (0.0206)	0.0767 (0.0482)	<0.001
Cervical spine (equivalent dose in μGy)	0.0763 (0.1452)	0.1295 (0.1113)	0.117
Skin (equivalent dose in μGy)	0.0030 (0.0026)	0.0091 (0.0079)	<0.001
Entire body (effective dose in μSv)	0.0031 (0.0022)	0.0063 (0.0053)	0.004

SD, standard deviation.

^aCalculated by comparing the mean radiation dosage by collimator type using a two-sample *t*-test.

investigated in this study. Although there are some limitations for estimating the equivalent doses from intraoral radiographs with the use of the PCXMC 2.0 software, the results are still useful and indicative for clinicians.

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