Volume 18, No 4 | International Journal of Radiation Research, October 2020

Estimating and comparing the radiation cancer risk from cone-beam computed tomography and panoramic radiography in pediatric and adult patients

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[DOR: 20.1001.1.23223243.2020.18.4.31.1]
[DOI: 10.52547/ijrr.18.4.885]

► *Original article*

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Revised: June 2020
Accepted: July 2020

Int. J. Radiat. Res., October 2020; 18(4): 885-893

DOI: 10.18869/acadpub.ijrr.18.4.885

ABSTRACT

Background: This study aimed to estimate and compare the absorbed dose, lifetime cancer risk and mortalities due to cone-beam computed tomography (CBCT) and panoramic examinations on patients. ***Materials and Methods:*** The exposure factors were applied to 332 patients in two age groups (6-10, and >18-year-old). The dose-area product (DAP) values were measured for CBCT and panoramic radiographies. Organ absorbed doses and effective doses were calculated based on the collected parameters applying PCXMC software. The risk of exposure-induced death (REID) and cancer risks were estimated by BEIR VII phase 2 model at different age groups and genders for the two dental radiography modalities. ***Results:*** Salivary glands was the largest contribution of the organ absorbed dose and effective dose in both CBCT and panoramic radiographies. The mean (±SD) REID values (per ten million) in CBCT were obtained at 35.6±5.2 for females and 29.01±1.8 for males, in the pediatric group, and were 31.1±2.2 for females and 25.71±2.02 for males in the adult group for all cancers. In addition, these values for panoramic radiography were 10.2±1.2 and 6.61±1.2 for women and men, respectively, in the pediatric group, and were 5.3±1.06 and 3.01±1.12 in the adult group. The mean REID values were higher significantly in CBCT compared to panoramic, and also in the pediatric than adult groups ($p<0.05$). ***Conclusion:*** CBCT had a significantly higher level of radiation risks compared to panoramic radiography. Therefore, clinicians should request CBCT examinations by considering their determents and benefits.

Keywords: *Cone-beam computed tomography, panoramic radiography, effective dose, cancer risk, dose-area product.*

INTRODUCTION

In recent years, cone-beam computed tomography (CBCT) devices have increased in dentistry departments to optimize the diagnoses and treatments [1]. As compared with traditional radiographs such as panoramic, CBCT supports a wide range of applicability including 3D image quality and has accurate diagnosis of skeletal asymmetry, easier location of impacted teeth, improved surgical planning, and increased detection of pathologies placing [2-4]. Its benefits have been widely reported, however, CBCT scans have poor soft-tissue contrast and artifacts, and also expose the patient to biologic risks of ionizing radiation [5-7].

The amount of patient exposure dose in diagnostic dental CBCT examination remains an important issue. Several studies have demonstrated that CBCT's have higher radiation

dose compared to intra-oral or extra-oral conventional methods of X-ray. For instance, Grünheid *et al.* [8] have indicated that CBCT delivers a higher effective dose to the patient than a typical panoramic radiograph by 3.22–6.24 times. In another study, Li *et al.* [7] reported that the effective dose for panoramic radiographs was about 22 µSv and for CBCT examination ranged from 61-134 µSv. Nevertheless, all are considered low doses compared to all natural environmental radiation received for life.

Although radiation doses to the patients undergoing the panoramic radiographs and CBCT scans are usually low, the number of examinations has been increased [9-11]. Therefore, dentists' awareness of the risk of cancer from these tests is important for making the appropriate decisions.

Several studies have reported radiation doses from dental radiographies. For example, in a study, Aps *et al.* [12] expressed the thyroid gland's radiation dose from radiographies taken in dento-alveolar trauma cases in pediatric patients using PCXMC (personal computer X-ray Monte Carlo calculations) software. In another study, Souza *et al.* [13] obtained the absorbed dose of the thyroid gland during intra-oral dental examinations using male and female phantoms. Also, they estimated the lifetime cancer incidence attributable to dental examinations for adults in both genders.

The effective dose is a suitable dose index to assess the patient radiation risk from ionization radiation, however, it does not express its value in terms of gender and age, while these criteria will account in REID (risk of exposure-induced cancer death) values [14].

Following our investigation, the previous studies have reported the REID values for children or/and adults in panoramic radiography [10, 15, 16], or only for CBCT [15, 17]. In the present study, we obtained the dose-area product (DAP), organ doses, effective dose, cancer risk and REID values for two different patient groups in CBCT and panoramic radiographies. Briefly, the distigushing feature of the present study was to (a) calculate organ doses and effective doses resulting from the CBCT and panoramic radiographies, and (b) estimate REID values and cancer risk for the patients in pediatric and adults performed in both male and female groups.

MATERIALS AND METHODS

Data collection

In this study, 332 patients have participated in two different age groups. The study was done following National Research Ethics Board approval with the registration number of "IR.SSU.MEDICINE.REC.1398.118" at "15.04.1398". The patients' groups were set as 6-10 and over 18 years old. Three CBCT and 7 digital panoramic machines were assessed in the radiology departments. The information and technical specifications of the studied systems were summarized in table 1. Exposure factors for CBCT and panoramic methods, including tube-current exposure-time product (mAs) and tube voltage (kVp) were determined for the two

Table 1. Information and technical specifications of the equipment evaluated.

Equipment	Model	Manufacture- country	Year of manufacture	Total filtration mm (Al)	kVp max	Type
Panoramic	PM2002CC	Planmeca-Finland	2010	2.5	80	DR
	Promax 3D	Planmeca-Finland	2018	2.5	84	DR
	Promax 3D	Planmeca-Finland	2018	2.5	84	DR
	Promax 3D	Planmeca-Finland	2019	2.5	84	DR
	Ray Scan α-SC	Toshiba-Japan	2014	2.6	100	DR
	Soredex	Soredex-Finland	2011	2.7	85	DR
	Promax XC	Planmeca-Finland	2012	2.5	80	DR
CBCT	Promax 3D	Finland	2009	2.5	84	DR
	CANON	France	2019	2.5	80	DR
	HDX WILL DENTRI α	Korea	2017	2.5	90	DR

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age groups. Patients' anatomical data including weight, height, age, and body mass index (BMI, kg/m^2) were measured.

DAP values were measured by a DAP-meter (Diamentor M4-KDK, PTW, Freiburg, Germany) consisting of a large area ionization chamber mounted directly in front of the exit portion of the X-ray tube. The measurements of DAP were performed in the absence of the patients, while the exposure factors related to the patients were applied for every dental radiography at different X-ray machines [16].

PCXMC simulation

The Monte Carlo code named PCXMC 2.0 Ration (STUK, Helsinki, Finland) was used to calculate the organ doses and effective doses in medical X-ray examinations. For CBCT, the patient data (age, gender, height, and weight of the simulation), beam parameters, and irradiation geometry were defined and modeled for all teeth in all age groups. The parameters for the PCXMC software include 360-degree rotation, the coordinate of the location, focus-skin distance, the size of the radiation field, number of photon beams, and maximum energy. This software can work with arbitrarily high photon numbers. Indeed, the number of histories was set to one hundred thousand for all examinations to achieve less than 0.1% statistical uncertainty in the simulation results.

The geometry of projections in panoramic radiography could not be completely simulated all at once in PCXMC software, therefore, it was simulated by splitting the scan into eighteen sections of the left to the right ear. The parameters for the PCXMC including the size of the radiation field, the coordinates of the location and beam angle on the patient, focus-reference point distance, the number of simulated photons, and maximum energy were defined for each section.

Calculation of organ doses and effective doses

The effective dose is calculated by the equation: $E=\Sigma W_T H_T$, where W_T is the tissue weighting factor representing the relative contribution of that organ or tissue to the overall risk, and H_T is equivalent dose [14, 18]. Therefore, to achieve the effective dose and cancer risk from radiology tests, it is necessary to obtain organs' absorbed doses. The organ doses and effective doses were calculated by the PCXMC for panoramic and CBCT dental radiographies. For each dental radiography, the measured DAP, kVp, and total filtration were entered into the program to calculate the organ doses. The effective doses were calculated in 29 organs and tissues based on weighting factors of ICRP-103 [18] and ICRP-60 dosimetry recommendations [14].

Calculation of induced cancer risks and mortalities

The lifetime attributable risk of cancer incidence and mortality from the exposure to ionizing radiation was estimated by BEIR VII phase 2 model [19] and PCXMC software. The BEIR VII model was developed to provide an estimate of cancer risk for an exposed individual. These models require expressing the dependence of risk not only on radiation dose but also on sex and age at exposure.

In PCXMC software, lifetime cancer risk mortalities are expressed in terms of REID. In addition, the cancer risks were estimated for the brain, thyroid, all solids, and all cancers for both genders and machines.

Statistical analysis

The statistically significant results of cancer risk and REID among the age groups, genders, and systems were assessed by one-way ANOVA and Man-Whitney test by SPSS version 19 (SPSS Inc., Chicago, Illinois, US). The level of statistical significance was set at $p<0.05$.

RESULTS

Data measurement

Table 2 represents the patient demographic data in both groups including the average age, weight, height, and BMI examined in this study. The exposure parameters data (kVp and mAs), and DAP values (mGy.cm^2) for panoramic radiography and CBCT are shown in tables 3 and 4, respectively.

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Table 2. The mean (± SD) values of patient demographic data.

	CBCT		Panoramic	
	Pediatric	Adult	Pediatric	Adult
Number of patient	30	101	60	141
Age (year)	9.3 ± 1.26	37.8 ± 12.17	9.17 ± 1.66	37.95 ± 10.2
Weight (kg)	35.0 ± 14.0	69.0 ± 14.0	39.0 ± 16.0	70.0 ± 19.0
Height (cm)	136.0 ± 7.0	175.0 ± 0.0	139.0 ± 12.0	170.0 ± 9.0
BMI (kg/m^2)	19.0 ± 7.0	22.0 ± 4.0	20.0 ± 5.0	24.0 ± 6.0

Table 3. The mean (±SD) values of kVp, mAs, and DAP (mGy.cm^2) for two age groups in panoramic radiography.

Device	Age groups					
	6-10 year-old			> 18-year-old		
	kVp	mAs	DAP	kVp	mAs	DAP
1	65.4 ± 0.96	100.8 ± 12.0	71.99 ± 13.0	66.1±1.0	108.0 ± 5.7	79.8 ± 5.3
2	63.8 ± 1.47	98.43 ± 23.4	77.7 ± 11.83	66.4±0.82	128.9 ± 14.0	103.3 ± 13.0
3	-	-	-	66.0±0.0	1.026 ± 0.0	99.7 ± 0.0
4	65.1 ± 1.79	106.1 ± 11	83.16 ± 14.0	69.1±1.16	142.4 ± 18.0	126.2 ± 20.0
5	68.6 ± 1.26	79.0 ± 0.0	50.89 ± 1.9	71.4 ± 1.23	133.0.2 ± 5.5	93.38 ± 7.0
6	57.0 ± 0.0	86.0 ± 0	27.0 ± 0.0	63.0 ± 0.0	110.0 ± 0.0	45.1± 0.0
7	60.0 ± 0.0	48.0 ± 0.0	21.6±0	66.0 ± 0.0	137.0 ± 0.0	91.0 ± 0
Total	63.31 ± 0.9	86.52 ± 15.4	55.4 ±13.5	66.85 ± 1.2	126.4 ± 6.17	91.22 ± 6.47

Table 4. The mean (±SD) values of kVp, mAs, and DAP (mGy.cm2) for two age groups in CBCT radiography.

Device	Age groups					
	6-10 year-old			> 18-year-old		
	kVp	mAs	DAP	kVp	mAs	DAP
1	80 ± 0	108 ± 0	663 ± 0	84 ± 0	147 ± 51.67	805.0 ± 14.42
2	-	-	-	80 ± 0	200 ± 0	595.5 ± 0
3	-	-	-	90 ± 0	113 ± 2.49	1430 ± 12.47
Total	80 ± 0	108 ± 0	663 ± 0	84.6 ± 0	153.3 ± 18.05	943.8 ± 8.96

Calculation of organ absorbed dose and effective dose

The mean values with standard deviation (±SD) of organ absorbed doses and effective doses from the two different devices are listed in table 5 in terms of μGy and μSv, respectively. The effective dose of CBCT is significantly higher than that of dental panoramic machine. Also in both pediatric and adult groups and systems, the absorbed doses for pediatric subject were significantly higher compared to the adults ($p<0.05$).

According to table 5, in CBCT, the largest contribution of the organ absorbed dose was from the salivary glands (1770 ± 8.53 μGy for the pediatric and 2950 ± 299.9 μGy for the adult groups), and the oral mucosa was in second place (908.41±11.9 μGy for the pediatric and 1470 ±119.5 μGy for the adult groups). For panoramic machine, the mean organ absorbed dose of salivary glands was 281.55 ±59.68 and 318.47±68.92 μGy for the pediatric and adult patients, respectively, which contribute the highest level. This number for oral mucosa as the second highest organ was 213.26±56.15 and 231.6±67.18 μGy for the pediatric and adult groups, in that order. Thyroid and extrathoracic regions received a higher dose than the other organs in both machines and groups which suggests that the organ absorbed doses are higher in the irradiated and its adjacent area.

The mean effective dose for panoramic radiography was 12.4±4.13 and 10.51±3.04 μSv in pediatric and adult groups, respectively. This number for CBCT was 17.3±5.17 and 9.41±2.94 μSv in pediatric and adult age groups, respectively. In almost all examinations, the effective dose decreased significantly with an increase in age (pediatric vs. adult) ($p<0.05$).

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[DOI: 10.52547/ijrr.18.4.885]

Table 5. The mean (±SD) values of organ absorbed dose and effective dose of panoramic and CBCT machines for pediatric and adult groups.

Organs	Absorbed dose (µGy) from panoramic		Absorbed dose (µGy) from CBCT	
	Pediatric	Adults	Pediatric	Adults
Salivary Glands	281.55 ± 59.68	318.47 ±68.92	1770 ± 8.53	2950.81 ± 299.34
Oral Mucosa	213.26 ± 56.15	231.6 ± 67.18	908.41 ± 11.9	1470.26 ± 119.55
Extrathoracic Region	43.56 ± 14.41	38.96 ± 11.32	134.38 ± 34.52	132.06 ± 38.40
Thyroid	79.13 ± 15.51	32.61 ± 10.09	133.5 ± 18.26	369.03 ± 31.96
Skeleton	54.61 ± 26.37	45.23 ± 12.99	110.2 ± 17.14	387.2 ± 31.3
Lymphatic Nodes	45.04 ± 18.88	44.97 ± 12.86	357.99 ± 34.48	423.9 ± 39.5
Brain	17.8 ± 9.09	14.79 ± 4.69	125.6 ± 24.56	139.7 ± 34.7
Skin	15.91 ± 7.64	14.13 ± 3.96	87.1 ± 17.70	121.1 ± 19.9
Red Bone Marrow	11.91 ± 5.91	1.43 ± 0.84	25.4 ± 4.26	9.66 ± 3.95
Muscle	9.76 ± 4.76	6.29 ± 1.8	12.3 ± 2.49	59.9 ± 5.44
Thymus	3.82 ± 1.92	0.469 ± 0.13	5.54 ± 1.05	9.96 ± 2.95
Lung	2.25 ± 1.15	1.07 ± 0.34	5.61 ± 1.78	11.65 ± 1.91
Osophagus	2.07 ± 1.12	0.802 ± 0.28	17.65 ± 4.43	9.19 ± 3.62
Heart	0.558 ± 0.30	0.141 ± 0.060	1.17 ± 0.25	2.07 ± 0.127
Pancreas	0.258 ± 0.16	0.0062 ± 0.0037	1.55 ± 1.02	0.043 ± 0.025
Liver	0.216 ±0.124	0.092 ± 0.03	0.25 ± 0.04	0.83 ± 0.02
Breast	0.17 ± 0.06	0.27 ± 0.11	0	1.94 ± 0.35
Adrenals	0.123 ± 0.0146	0	0.98 ± 0.10	0.25 ± 0.08
Spleen	0.095 ± 0.035	0.0021 ± 0.0013	0.31 ± 0.09	0.78 ± 0.67
Stomach	0.094 ± 0.058	0.0035 ± 0.0042	0.05 ± 0.003	0.1 ± 0.1
Gall Bladder	0.076 ± 0.049	0	0	0.12 ± 0.17
Kidneys	0.053 ±0.036	0.0015 ± 0.0035	0.35± 0.20	0.08 ± 0.00
Colon	0.0097 ± 0.0066	0.0003 ± 0.0007	0.044 ± 0.01	0.01 ± 0.01
Small Intestine	0.0047 ± 0.0033	0.0011 ± 0.0006	0.04 ± 0.002	0.06 ± 0.003
Effective dose (µSv)	***12.4 ± 4.13***	***10.51 ± 3.04***	***17.3 ± 5.17***	***9.41 ± 2.94***

Estimating the REID values

Figures 1-3 show the mean values of REID with regard to the panoramic and CBCT radiographies from male and female patients in the two groups (per ten million). Following the figures, the mean (±SD) REID values in CBCT are 35.6±5.2 and 29.01±1.8 for females and males, respectively, in the pediatric group, and are 31.1±2. 2 and 25.71±2.02 in the adult group for all cancers. These values for panoramic radiography are 10.2±1.2 and 6.61±1.2 for women and men, respectively, in the pediatric group, and are 5.3±1.06 and 3.01±1.12 in the adult group, for all cancers. There was a remarkable increase in REID risk in pediatrics compared to the adults ($p<0.05$), female versus male patients in panoramic radiography ($p<0.05$), and also CBCT compared to panoramic ($p<0.01$). All in all, REID values in pediatric, female, and CBCT were remarkably higher compared to the adult, male, and panoramic radiography.

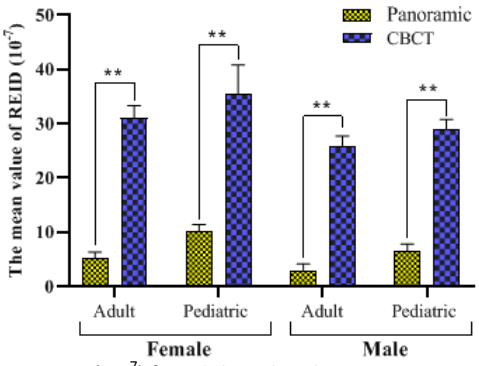


Figure 1. REID (10^{-7}) for adult and pediatric patients in both genders as function of examinations (CBCT and panoramic). Error bars indicate the standard deviation. **significant difference between the groups at $P < 0.01$.

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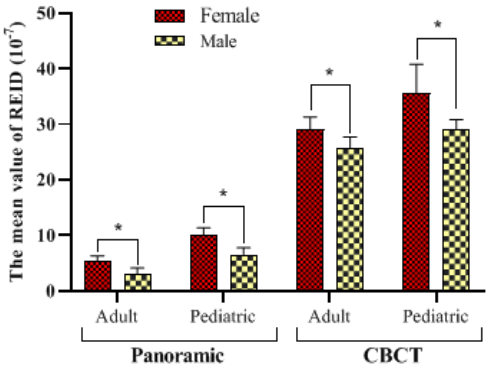


Figure 2. REID (10^{-7}) for adult and pediatric patients in both CBCT and panoramic examinations as function of genders (male and female). Error bars indicate the standard deviation. *significant difference between the groups at P < 0.05.

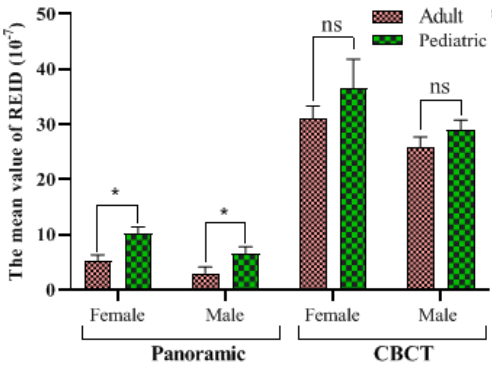


Figure 3. REID (10^{-7}) for male and female patients in both CBCT and panoramic examinations as function of ages (adult and pediatric). Error bars indicate the standard deviation. *significant difference between the groups at P < 0.05. nsno significant difference between the groups.

Estimating the cancer risks

Table 6 depicts the cancer risk values (per ten thousand) of the brain, thyroid, all solids, and all cancers for both genders in CBCT and panoramic examinations. The mean cancer risk value for the brain was 17.34±0.99 and 2.33±1.12 for CBCT and panoramic, respectively. Also, this number for thyroid was obtained at 0.77±0.21 and 0.34±0.17. For all solids and cancers, the mean value of cancer lifetime risk was 18.82±1.55 and 18.87±0.35 for CBCT, in that order, and it was 2.88±1.38 and 2.89±1.39 for panoramic radiographs. It is notable that for all four cancer risks there was a significant difference between CBCT and panoramic examinations. In table 7, more details of p-values have been demonstrated.

Table 6. The mean (±SD) of cancer risk values (per 10,000) for brain, thyroid, all solids, and all cancers for adult and pediatric patients due to panoramic radiography and CBCT.

Lifetime cancer incidence risk					
Organ / Modality		Brain	Thyroid	All solids	All cancer
CBCT	**Adults**	6.55 ± 1.63	0.46 ± 0.05	7.85 ± 2.73	7.92 ± 2.80
	Male	6.55 ± 1.63	0.16 ± 0.04	5.89 ± 2.05	5.91 ± 2.18
	Female	6.55 ± 1.63	0.75 ± 0.08	9.81 ± 3.41	9.88 ± 3.39
	Children	28.13 ± 0.35	1.08 ± 0.22	29.79 ± 2.37	29.82 ± 1.91
	Male	28.13 ± 0.35	0.33 ± 0.09	20.50 ± 2.25	21.25 ± 1.36
	Female	28.13 ± 0.35	1.82 ± 0.31	37.96 ± 2.48	38.47 ± 2.46
	All	17.34 ± 0.99	0.77 ± 0.21	18.82 ± 1.55	18.87 ± 0.35
	Male	17.34 ± 0.99	0.24 ± 0.07	13.19 ± 1.17	13.79 ± 1.77
	Female	17.34 ± 0.99	1.28 ± 0.34	28.88 ± 2.95	29.42 ± 2.92
Panoramic	**Adults**	0.69 ± 0.22	0.04 ± 0.01	0.83 ± 0.26	0.84 ± 0.26
	Male	0.69 ± 0.22	0.01 ± 0.00	0.62 ± 0.19	0.65 ± 0.20
	Female	0.69 ± 0.22	0.07 ± 0.02	1.04 ± 0.32	1.08 ± 0.31
	Children	3.98 ± 2.04	0.64 ± 0.33	4.93 ± 1.51	4.95 ± 2.52
	Male	3.98 ± 2.04	0.19 ± 0.1	3.40 ± 1.73	3.51 ± 1.79
	Female	3.98 ± 2.04	1.08 ± 0.56	6.45 ± 1.64	6.58 ± 3.25
	All	2.33 ± 1.12	0.34 ± 0.17	2.88 ± 1.38	2.89 ± 1.39
	Male	2.33 ± 1.12	0.1 ± 0.05	2.01 ± 0.96	2.08 ± 1.00
	Female	2.33 ± 1.12	0.57 ± 0.39	3.75 ± 1.83	3.95 ± 1.78

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Table 7. P-values for brain, thyroid, all solids, and cancers for both genders, ages, and radiography systems.

Modality		CBCT		Panoramic		
Comparisons / Organs		Male vs. female	Adult vs. children	Male vs. female	Adult vs. children	CBCT vs. panoramic
Brain	P-value	0.1	0.01	0.1	0.01	0.001
Thyroid		0.01	0.03	0.02	0.01	0.04
All solids		0.06	0.02	0.07	0.04	0.001
All cancers		0.06	0.02	0.06	0.03	0.001

DISCUSSION

In the present study, we aimed to calculate the input dose, organ dose, effective dose, cancer risk, and REID values in CBCT and panoramic radiographies in two different age groups for both male and female groups. Also, we intended to compare the absorbed doses and cancer risk values between each device, based on values assessed for adult and pediatric groups.

Results indicated that the DAP values increased with the rise in patient age in almost all examinations. The mean value of DAP for the adult patient undergoing panoramic radiography was 91.22 mGy.cm^2 which is in line with Poppe *et al.* [20], Hart *et al.* [21], and Chaparian *et al.* [16] studies, but it was lower than the results of Choi *et al.* [22] study. The mean DAP value for CBCT was 943 mGy.cm^2, which is higher considerably compared to the panoramic radiography. The results of our study were consistent with those of the other relevant studies [6, 23, 24]. The reason for some discrepancies with the other studies can be attributed to the use of different X-ray machines and setting parameters for each X-ray examination.

Our findings demonstrated that the effective dose decreased with an increase in age which is similar to the other studies results like Chaparian *et al.* [16] and Zenone *et al.* [25]. The reason can be due to the involvement of more organs in younger groups in the same field size used for older patients. As shown in table 5, the highest organ absorbed dose was found in the salivary glands and then oral mocusa in both CBCT and panoramic examinations. In general, the absorbed dose value is higher significantly in CBCT in comparison with panoramic because of the higher X-ray setting factors and the different geometry of CBCT [1, 10, 23, 26].

The REID values in the pediatric group were approximately double those in the adult almost in all cancers. Children have a larger proportion of dividing cells due to their growing periods, therefore, they are inherently more vulnerable to radiation. In addition, as mentioned in the above paragraph, the adjacent organs in children receive larger doses of scatter radiation than adults due to the smaller body size [15]. The results show a high degree of agreement with Jih -Kuei *et al.* [15] research. Horner *et al.* [27] investigated the REID value for adults during panoramic radiography and it was between 2 to 9 (per ten million) which is relatively consistent with the results of present study (3 to 5). The discrepancy between the studies can be possiblly because of different devices and radiation conditions. Another reason might be the use of different methods for obtaining the cancer risk so that the effective dose was simply multiplied by constant coefficients in some studies, while the risk estimation in our study was applied based on the BEIR VII model [19]. In general, the highest change in the REID values was found in female patients in the two types of dental X-ray and this can be related to the breast organ as a sensitive tissue [28].

The mean cancer risk value in CBCT was higher in panoramic examination considerably (table 7) which is related to the higher radiation parameters. In Pauwels *et al.* [29] study the cancer lifetime risk for CBCT was 0.0027 for adults and 0.0098 for pediatric patients per ten thousand which shows that it is 3.5 times higher for pediatric, approximately. According to the findings of the present study, the mean cancer risk value for children is almost 4 times higher

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in all mentioned cancers.

Regarding the higher radiation and cancer risk in CBCT, it should be justified in the examinations which provide new information compared to panoramic radiography [29, 30].

In the current work, we measured the absorbed dose and cancer-induced risks using only the DAP-meter. Furthermore, we did not investigate the relationship between radiation dose and field of view, which can provide various anatomic coverage areas of the radiosensitive organs during the radiographic examinations. Thus, for future research, it is suggested that other dosimetric tools such as thermoluminescent and radiochromic film in different dental radiography systems should be used at various fields of view and the results be compared with DAP-meter.

CONCLUSION

Following the explanations given in this study, the total REID and cancer risk values in pediatric, female, and CBCT are higher, therefore, it is notable that clinicians should request the dental examinations by considering their risks and benefits during treatment procedures.

ACKNOWLEDGEMENTS

This work was approved by Shahid Sadoughi University of Medical Sciences (Yazd, Iran). The authors would like to thank the radiography centers for their collaboration in this project.

***Conflicts of interest*: Declared none.**

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[DOR: 20.1001.1.23223243.2020.18.4.31.1]

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