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Review: Dosimetry in Dental Radiology

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Abstract

The aim of this study was to determine, by a systematic review, the radiation doses of different dental x-ray devices, their particular effects, and the cumulative results of various studies done with various dosimeters. Google scholar was searched from 2014 to 2021 using the following keywords: radiation dose, dosimeters in dentistry, types of dosimeters, Cone beam computed tomography (CBCT) radiation. The references of selected papers were also analyzed. Articles were chosen that fit the criterion for utilizing dosimeters in dentistry applications. This review was separated into four sections: (1) biological impacts of radiation, (2) dosimeter characteristics, (3) dosimeter kinds, and (4) the findings of numerous investigations employing various dosimeters. According to a recent assessment of dosimetry based on different investigations conducted with dosimeters, the effective dosage supplied has decreased since the introduction of radiography techniques. As a result, radiological method selection is critical in dental dosage administration.

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1. Introduction:

Diagnostic radiology exists because the benefits of the examination outweigh the hazards of radiation exposure. Dosimeters that measure absorbed doses for risk analysis are used to resolve information about the dosage provided by a diagnostic radiography examination. The most widely used dosimeters for such point dosimetry assessments are thermo-luminescent dosimeters (TLDs) [1] [2] [3]. To enhance in patient evaluation, a variety of intraoral and extraoral imaging techniques are now available. Bitewing, periapical, and panoramic radiography are examples of common two-dimensional (2D) modes. These modes are reasonable in light of the fact that they are effortlessly procured, modest, and give high-resolution images. Moreover, while all of these modalities can provide useful diagnostic information, none of them are without restrictions [4] [5]. Medical applications are the most common source of population exposure to radiation; among them, dental radiology is the most well-known radiological examination type used in industrialized countries, with intraoral radiography being one of the most often used X-ray exams in humans. Periapical radiography is one of the intraoral radiography methods[6]. Periapical radiographs (”peri” means ”around” and ”apical” means ”apex” or end of tooth root) provide pictures of the teeth’s shapes, positions, and mesiodistal extension [7]. The intraoral periapical method is a dental radiography technique that allows for the identification of a range of dental abnormalities such as caries, dental trauma, and periodontal diseases while exposing patients to relatively modest radiation doses [8]. Intraoral periapical radiography is applied to examine two to four teeth from crown to apex, as well as the periodontal area and adjacent bone tissue [6]. The standard difficulty with periapical radiography for detecting root resorption is that the 3-dimensional anatomy of the region being radiographed is compressed into a 2-dimensional picture, which is impacted by anatomic superposition and the angle of the X-ray spectrum [9] [10]. A panoramic radiograph, which is a routinely conducted examination by dentists and oral surgeons in everyday practice, is another essential diagnostic tool. All new grown-up patients are routinely screened using panoramic radiographs alone or in conjunction with bitewings radiographs [11]. Panoramic radiography allows for the creation of numerous anatomical lineaments at a reasonable cost and with a low radiation dosage. However, potential abuses of this approach include superimposition of anatomical features, inappropriate horizontal and vertical magnification, and a lack of cross-sectional information [12]. The panoramic radiograph is less

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staggering to the patient than a series of small separate intraoral radiographs, make it easy for the dentist to demonstrate the diagnosis and curative way to the patient and is a good imaging form in patients with trismus or trauma [13]. It also lower the necessity of taking unnecessary, several periapical and bitewing radiographs, and therefore minimize added exposure to radiation [14]. Cone beam computed tomography (CBCT) machines, which can scan vast anatomical dimensions in one rotation, have emerged as a result of advancements in 3D imaging technology. CBCT scanners with large flat plate sensors are commonly used in oral and maxillofacial diagnostics nowadays for head and neck applications. CBCTs are an alternative to multi-detector computed tomography (MDCT) scanners for 3D imaging, particularly when crisp pictures of high-contrast bone structures or teeth are needed. However, the amount of radiation delivered to a patient in both modalities is a source of concern; in many situations, dental CBCT scanners are replacing low-dose 2D panoramic modalities. MDCT methods, on the other hand, have been shown to provide the greatest doses in diagnostic imaging; as a result, their usage may be no longer acceptable if lower dosage modalities are available [15] [16]. Multiplanar, thin-sliced images free of superimposition are critical in CBCT [17]. The most essential thing to remember is that CBCT scans have a significantly higher radiation dosage and expense, therefore they should only be used in specific circumstances [18] [19]. According to dosimetric studies, the effective dosage of a dental CBCT scan is greater than that of panoramic radiographs, but still less than that of a dental multi-slice Computed tomography (MSCT) [19] [20] [21]. Dentists were among the first to identify the hazards of ionizing radiation exposure, since pioneers in radiographic imaging like as Edmund Kells had hand cancer [22]. Patient radiation doses from investigative radiology technique found to be the largest amount of population exposure for intended radiation [23]. Essentially, exposure may be reduced in one of two ways: by lowering the CT tube's radiation output or by using protective techniques during the intervention—a list. Controlling parameter setup, such as scan duration, tube current-time product, and tube voltage, might result in a reduced tube output. Wearing lead gear and, if feasible, increasing the distance between the radiologist and the radiation source are two ways to protect a radiologist. In most cases, the quantity of radiation is only monitored for the patient, and there are no regulated statistics on interventional radiologists' exposure [24]. Therefore, the attention is to gain high-quality radiographs with minimum radiation dose to the patient. The quality of the radiograph and its anatomical part depends basically on the properties of the imaging system. To reduce the risk of radiation exposure to patients, increased focus has been placed on optimizing imaging conditions. The dangers of X-ray radiation are based on radiobiology and epidemiological studies that use dosimeters to determine the radiation dosage. Radiation dosimetry has its origins in medical uses of ionizing radiation, dating back to the discovery of X-rays in 1895 [[11] - [25]]. The absorbed dose in organs can be projected using dosimeters placed in a phantom for in vitro or in vivo radiation dosimetry [26] [27]. In order to reduce the quantity of radiation dosage, it is critical to employ an intensifying screen (I.S) in the diagnosis sector of dentistry [28].

2. Dosimeter Properties:

Accuracy and precision, linearity, energy dependency, directional dependence, spatial resolution and physical size, readout convenience, and ease of use are some of the greatest features of a dosimeter [29].

Dosimetry Types Include:

1. Ionization chamber dosimetry schemes.
2. Film dosimetry.
3. Luminescence dosimetry.
4. Semiconductor dosimetry [24].

The current systematic study aims to answer two questions: 1) what radiation dosage does a person get during a dental imaging diagnosis? 2) Is it possible to reduce the radiation dose while maintaining image quality? Answering these questions requires knowledge of how a radiation dosage is computed. As a result, the following two elements make up this systematic review: 1) Dosimetry of radiation; 2) Biological consequences of radiation exposure received in dentistry using various radiological methods.

Ionizing Radiation Exposure Measurements:

Radiation dosage is measured through exposure, which is the simplest method. A number of radiation detection instruments can be used to measure the ionization produced by radiation [22]. The entrance surface dose (ESD) is a measurement of the X-ray beam dosage absorbed by the skin at the site of entry. The ESD may be estimated indirectly or directly based on parameters such as current, exposure duration, kilovoltage, filtering, and beam collimation. This can be done directly using thermoluminescent dosimeters (TLD) or ionization chambers. Thermoluminescent dosimetry (TLD-100) was utilized for dental dosimetry owing to the distinct properties of this type of dosimeter [6]. It is advised that these findings be shared with dentists in order to raise awareness about the need of having a quality assurance procedure and not using X-rays haphazardly [6]. In 2008, the thermopile and the densitometer optical density readings were compared. The densitometer could only measure the optical density of X–ray films, but the thermopile could measure the optical density of any transparent polymer [30]. Radiation dosage is expressed in a variety of quantities and units. The following values are used to approximate patient dosage, from minimum to maximum biological importance: absorbed dose, equivalent dose, and effective dose. Instead of dosage, the word ”kerma (K)” is frequently used [30]. The International Commission on Radiological Protection has given the quantities used for patient dose assessment [31] [32]. The International System of Units presently describes the measurement values of radiation quantities (SI units) [31].

Absorbed dose: For all kinds of ionizing radiation, the absorbed dose (D) is the most important physical dosage parameter. It is well-defined as the mean energy given by ionizing radiation to mass matter. Gray is the specific term for the SI unit of absorbed dosage, which is J/kg (Gy) [3] [24] [33] [34].

Equivalent dose: It's measured in terms of absorbed dosage multiplied by a multiplier that varies depending on the kind of radiation. For example, a 0.1 Gy absorbed dosage of alpha radiation is more hazardous than a 0.1 Gy received dose of beta or gamma radiation. The equivalent dose is used to expose the damage caused in biological systems by various kinds of radiation. The sievert, Sv, is the SI unit of dosage. The equivalent dosage rate is measured in microsieverts per second (mSv/s) or microsieverts per hour (mSv/h) [24] [35].

Effective dose: The tissue-weighted total of the equivalent dosages in all of the body's designated tissues and organs is the effective dosage, E, which is measured in sievert (Sv) [22] [31] [36].

3. Biological Effects of Radiation:

Ionizing radiation is the primary instrument in nuclear medicine, thus it is critical for users to understand its biological consequences and pathophysiological foundation. Ionizing radiation's biological effects are varied and inconsistent due to a variety of variables [37] [38]. Early or delayed effects, somatic or inherited effects, and stochastic or deterministic effects are categorized depending on their kind and time following exposure Figure 1 [31].

3.1 Deterministic Effects:

is the direct death of cell populations that needs a substantial dose over a short period of time and frequently only happens after a dose level (threshold) has been reached below which no clinical effects have been recorded. In the dosage range seen in traditional oral and maxillofacial radiography, deterministic effect thresholds are never achieved. They are, however, visible in dental patients who receive head and neck radiotherapy for cancer treatment. Radiation-induced oral mucositis is a good example of this [24] [31].

3.1.1 Deterministic effects include:

1. **Acute Radiation Effect:** is a non-critical effect that occurs when the radiation dosage must be large and the dose must be transported in a short period of time. These effects occur only after exposure or within 24 hours of it. These are easy to treat and manage. Symptoms include discomfort, vomiting, headaches, high temperatures, and skin and tissue fire.[39].
2. **Chronic Radiation Sickness:** develops after a month or year after receiving a high dose of radiation. These side effects are dangerous and difficult to cure, and they may lead to death. These impacts do not occur immediately and may have long-term consequences. Chronic consequences include cataracts, cancer, and genetic mutations [39].

3.2 Stochastic effects:

The second impact is permanent cell modification, which generally results from cellular DNA damage. Even at very low dose levels, stochastic effects can occur. Furthermore, given stochastic effects, there is a no-threshold or ”safe” dosage [31] [39]. Hereditary effects and carcinogenesis as a result of diagnostic imaging are both unpredictable.

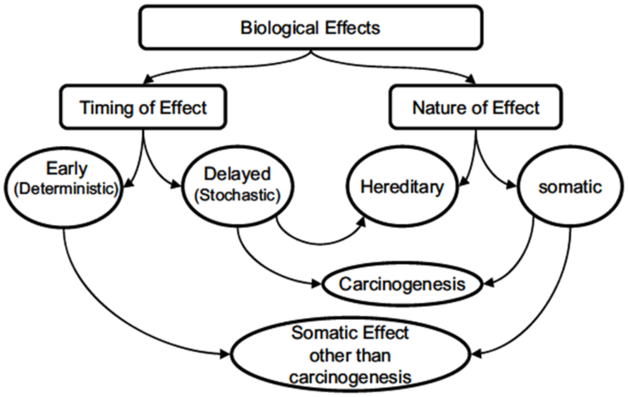

Figure 1. The biological effects of Ionizing radiation [40]

Despite the fact that the radiation produced by dental X-ray devices is much lower than that produced by routine clinical medical diagnostic X-ray tools and much lower than that used in radiation therapy, cumulative radiation effects may occur as a result of the late effect of low dose X-ray radiation in somatic cells [41]. The most significant difference between lumbar spine exams and intraoral testing is that the same quantity of radiation applied to one region of the body might be more hazardous than the same amount of radiation applied to another. This is because the tissue-weighting factor determines whether tissues or organs are more radiosensitive than others [42]. Many studies were conducted years ago to determine the level of radiation exposure and discovered a high incidence of cancer, abortion, fetal mutagenic alterations, cataracts, and a decrease in life span. Despite the fact that the preceding statement is indefinite and inapplicable to diagnostic dental radiography, the stochastic biological risks effect can still be used [43] [44]. Except for cancer, all fetal bio effects induced by radiation are deterministic (tissue effects), implying that they should have a dosage below which they do not occur. Due to a mix of animal research and observational human studies from radiologic events such as the atomic bomb blasts in Hiroshima and Nagasaki, it is difficult to identify the exact dosage limits [45].

4. Radiation Effects Mechanisms:

Ionizing radiation has two primary ways by which it affects biological targets: direct and indirect 2 [40] [46] [47] [48].

Direct Effect: The direct effect hypothesis, often known as the target theory, states that ionizing radiation works by hitting target atoms directly. Ionizing radiation, on the other hand, is the primary target, causing single- or double-stranded chromosomal breakage [40] , [47].

Indirect Effect: In describing cellular radiation damage, the direct mechanism theory was shown to be inadequate. According to the indirect approach, ionizing radiation exerts its impact through radiolysis of cellular water, resulting in the formation of free radicals [40] , [47] , [49]. Two kinds of free radicals are generated when X-rays interact with water. During cell irradiation, an overabundance of oxygen allows for the production of additional free radicals. Indirect action is thought to be responsible for around two-thirds of the biological damage caused by low linear energy transfer (LET) radiation. High LET causes biological harm largely by direct ionization [40].

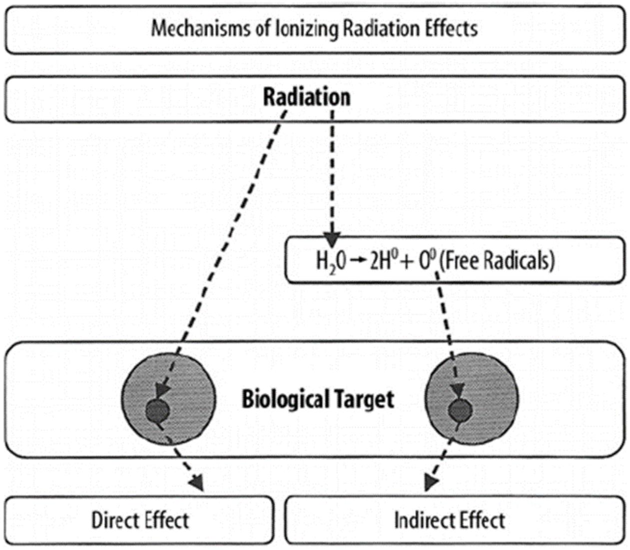

Figure 2. The mechanisms of ionizing radiation effects [40]

5. Results and Discussion:

Google scholar was searched from 2014 to 2021 using the following keywords: radiation dose, dosimeters in dentistry, types of dosimeters, CBCT radiation. The references of selected papers were also analyzed. To conduct a systematic review of dental dosimetry, the search was limited to papers written in English. A full-text reading of published publications that matched the criteria for employing dosimeters in dental applications was chosen. As mentioned, the literature was examined and categorized:

1. The results of various studies measured radiation dosage using different dosimeters.
2. Radiation dosage to patients from CBCT, Panoramic, and Intraoral devices.

Many studies have been carried out on dental radiographic dosimetry. Organ absorbed doses of the three different devices as the findings of this review article have been summarized in Table 1. From this table, it can be seen that the most of selected studies are focused on the radiation dose effect from CBCT and panoramic devices which are the most common used in dental radiology.

Table 1. Number and percentages of Proteus spp in different clinical samples.

Absorbed dose of dental devices (mGy)						
CBCT	Panoramic	Intraoral	Dosimeter used	Organ	Study number	Ref.
1.469	...	...	TLD-100 (LiF:Mg,Ti)		7	[50]
1.020	...	...	TLD chips	Brain	1	[51]
0.636	0.037	0.014	LiF TLD-100		2	[52]
0.012	...	...	calibrated Ion Chamber (IC)		3	[15]
36.31	...	...	(LiF: Mg, Cu, P) TLD		4	[53]
7.775	0.622	0.803	LiF TLD-100		2	[52]
...	1.028 - 2.428	0.452	TLD-100		8	[54]
5.737	....	....	TLD-100 (LiF:Mg,Ti)	Salivary glands	7	[50]
1.466	...	...	TLD chips		1	[51]
0.013	...	...	calibrated Ion Chamber (IC)		3	[15]
8.727	0.256	0.066	LiF TLD-100		[52]	
...	0.04 – 0.111	0.053	TLD-100		8	[54]
0.847	...	....	TLD-100 (LiF:Mg,Ti)	Thyroid	7	[50]
0.73	...	...	(LiF: Mg, Cu, P) TLD		4	[53]
0.08	...	...	TLD		5	[55]
0.043	...	...	(TLD) chips		1	[51]
0.010			calibrated Ion Chamber(IC)		3	[15]
0.08	...	...	TLD		5	[55]
0.01	...	...	calibrated Ion Chamber (IC)	Eye lens	3	[15]

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Absorbed dose of dental devices (mGy)						
CBCT	Panoramic	Intraoral	Dosimeter used	Organ	Study number	Ref.
0.057	0.016	0.011	LiF TLD-100	Lung	2	[52]
0.212	…	…	calibrated Ion Chamber (IC)		3	[15]
0.323	…	…	calibrated Ion Chamber (IC)	Esophagus	3	[15]
0.277	….	…	TLD-100 (LiF:Mg,Ti)		7	[50]
0.053	0.020	0.011	LiF TLD-100		2	[52]
0.004	…	…	TLD chips		1	[51]
0.035	0.018	0.011	LiF TLD-100	Breasts	2	[52]
0.085-0.089	0.00004-0.0006	…	Xi Survey detector (solid state detector)		6	[41]
0.009	0.015	0.011	LiF TLD-100	Liver	2	[52]
0.009	0.018	0.009	LiF TLD-100	Stomach	2	[52]
0.008	0.018	0.009	LiF TLD-100	Colon	2	[52]
0.008	0.016	0.009	LiF TLD-100	Bladder	2	[52]
0.011	0.016	0.009	LiF TLD-100	Testis	2	[52]
6.433	…	…	calibrated Ion Chamber(IC)	Bone surface	3	[15]
3.776	0.268	0.318	LiF TLD-100		2	[52]
0.008	…	…	TLD chips		1	[51]
…	0.045 – 0.162	0.035	TLD-100		8	[54]
33.68	…	…	(LiF: Mg, Cu, P) TLD	bone marrow	4	[53]
0.278	0.024	0.027	LiF TLD-100	2	[52]	

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Absorbed dose of dental devices (mGy)						
CBCT	Panoramic	Intraoral	Dosimeter used	Organ	Study number	Ref.
0.022	…	…	TLD chips		1	[51]
1.488	…	…	calibrated Ion Chamber (IC)		3	[15]
0.588	0.075	0.005	LiF TLD-100		2	[52]
0.218	…	…	TLD-100 (LiF:Mg,Ti)	Skin	7	[50]
0.064	…	…	TLD chips		1	[51]
2.971	…	…	TLD chips		1	[51]
0.95	…	…	TLD-100 (LiF:Mg,Ti)	Remainder	7	[50]
0.688	0.024	0.032	LiF TLD-100		2	[52]
0.03–3.43	…	…	Thermoluminescent dosimeters	Head and Neck	9	[56]
6.04–22.94	…	…	Thermoluminescent dosimeters	Chest	9	[56]
2.5–25.28	…	…	Thermoluminescent dosimeters	Pelvis	9	[56]

End of Table

Based on the studies mentioned above, it can be done a quick summary of each study and then made a comparison between the results of the various studies. In the study 1, Signorelli et al. [50] performed CBCT doses using a portrait mode (17 cm FOV). Thermoluminescent dosimeter (TLD) chips (3 × 1 ×1 mm) were implanted on selected locations in the head and neck area of an adult male tissue-equivalent phantom to quantify the absorbed radiation dose. The brain, eyes, skull, salivary glands, thyroid, and spine are among the key organs known to be susceptible to radiation. Qiang W et al. [51] determined effective dosage in 2. The head, neck, chest, and buttocks of the phantom are cut into 34 equal slabs, each 2.5 cm thick. TLDs were inserted into the holes of several phantom slabs containing representative tissue or organs. The dental panoramic machine also included a maxillofacial mode. In 3, Andreas Stratis et al. [15] in his comparative study to calculate the effective doses from CBCT and MDCT scanners on The SK 150 phantom, using Calibrated ion chamber (IC). This research used the biggest FOVs accessible in dental CBCT scanners. The findings indicated that dental CBCT delivers lower doses for orthognathic patients, whereas CBCT and MDCT give equivalent doses for temporal bone operations. In 4, Sima Nikneshan et al. [52] estimated average tissue absorbed dose and effective dose using TLD chips in a radiation analog dosimetry phantom in Comparative dosimetry of dental CBCT systems for important organs. The average absorbed dosage in both FOVs varied from 0.31 mGy to 81.42 mGy. The average absorbed dosage in wider FOV varied from 0.31 mGy to 47.84 mGy, whereas the average absorbed dose in small FOV ranged from 0.31 mGy to 115.00 mGy. In 5, Maria Rosangela et al. [53] carried out an experimental investigation to assess the absorbed dosage in the thyroid and eye lens when the patient wears individual protection. Imaging Sciences International's CBCT i-Cat Classical equipment was used in this study. The pulsed waveform, anthropomorphic phantoms, personal protective equipment (PPE), Monte Carlo Stimulations, and air kerma are all used in this device. Dose is absorbed and effective. In research 6, Anna Kelaranta et al. [41] used the Xi R/F MAM detector to calculate the upper estimate of radiation exposure to the fetus and breasts of an anthropomorphic female phantom in intraoral, panoramic, cephalometric, and CBCT dental modalities with and without lead shielding. The top estimates for foetal doses ranged from 0.009 mGy to 6.9 mGy, whereas breast doses ranged from 0.602 mGy to 75.4 mGy. The foetal doses with lead shielding ranged from 0.005 to 2.1 mGy, whereas the breast doses ranged from 0.002 mGy to 10.4 mGy. In 7, Pauwels et al. [54] used 148 thermoluminescent dosimeters implanted in an anthropomorphic phantom in the head and neck area down to the sternoclavicular joint level to calculate effective doses. On a dental CBCT equipment, dose measurements were obtained with a FOV of (17 cm×12cm) and complete rotation (360°). In study 8, Granlund et al. [55] utilized thermoluminescent dosimeter data on an anthropomorphic head and neck to compute the doses supplied during digital intra-oral and panoramic radiography using the ICRP publication 103 tissue weighting parameters to determine the absorbed dose to the organs. Lastly in recent study 9, the organ doses were measured using thermoluminescent dosimeters in an Alderson RANDO male phantom for the Elekta Synergy XVI kV CBCT system's head and neck, chest, and pelvic protocols. The organ doses for head and neck, chest, and pelvic scans were 0.03–3.43 mGy, 6.04–22.94 mGy, and 2.5–25.28 mGy, respectively [56]. The dangers of ionizing radiation exposure have been extensively documented in earlier research, and they are a public health concern, especially because of the cancer risks. One of the most common sources of ionizing radiation is medical imaging [57]. Comparing between all these studies it became clear that radiation doses delivered to patients depends not only on exposure parameters, but also on FOV in different dental devices. According to previous research, reducing the FOV size, especially for CBCT examinations to the actual region of interest, can result in significant dose reduction [24] , [54] , [54] , [50] , [51]. Although it is self-evident that using a wider FOV increases the dosage, the exact relationship between FOV and doses is complicated by interplaying variables. Based on existing evidence, it may be assumed that the dosage will be mostly determined by the FOV's height and location [54]. When examining the data in further depth, it's crucial to consider the relative positions of the various organs in relation to the FOV, as well as the type of dosimeter utilized in the study. Returning to table 1, the CBCT produces the maximum dosage, followed by the intraoral device and the dental panoramic machine. The as-low-as-reasonably-achievable (ALARA) approach should be used to picture selection criteria throughout any therapy phase. As a result, the type of CBCT used should be based on the demands of the patient. In 2019, researches shows that the absorbed doses using CBCT of brain, salivary glands, thyroid, lung, esophagus, breasts, liver, stomach, colon, bladder, testis, bone surface, bone marrow, skin and other organs are 0.636 mGy, 7.775 mGy, 8.727 mGy, 0.057 mGy, 0.053 mGy, 0.035 mGy, 0.009 mGy, 0.009 mGy, 0.008 mGy, 0.008 mGy, 0.011 mGy, 3.776 mGy, 0.278 mGy, 0.588 mGy and 0.688 mGy, respectively. It is very obvious that the area around head and neck including salivary glands and thyroid has received high radiation dose than others. However, testis is received high amount of radiation because it is sensitive for radiation [58].

Conclusion:

In dental radiology, a broad variety of X-ray equipment is utilized. As one of the dentist's major tasks and responsibilities is to reduce the ionizing danger of medical radiation, the findings of numerous studies using different dosimeters reveal that the CBCT dosage is significantly higher than that of other devices; hence, CBCT use should be limited to the patient's requirement. In CBCT, limiting the field of view, protecting the thyroid, and employing a lead apron are all recommended measures that must be used to reduce the exposure dosage. All the above-mentioned studies using various dosimeters concluded that with the use of specific system, the “ALARA” principle is being followed. Therefore, it is vital to educate both dentists and patients about the use of this evolutionary system and its negligible effect on the excellence of life.

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مراجعة: قياس الجرعات في أشعة الأسنان

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الخلاصة

الهدف من هذه الدراسة هو تحديد الجرعات الإشعاعية لأجهزة الأشعة السينية المختلفة ، من خلال مراجعة منهجية ، وتأثيراتها الخاصة ، والنتائج التراكمية للدراسات المختلفة التي أجريت باستخدام مقاييس جرعات مختلفة. تم البحث من خلال محرك البحث الباحث الاكاديمي من 2014 إلى 2021 باستخدام الكلمات الدالة الرئيسية التالية: جرعة الإشعاع ، مقاييس الجرعات في طب الأسنان ، أنواع مقاييس الجرعات ، إشعاع التصوير المقطعي المحوسب بالأشعة المخروطية *CBCT* . تم تحليل مراجع الأوراق البحثية المختارة. تم اختيار المقالات التي تناسب معيار استخدام مقاييس الجرعات في تطبيقات طب الأسنان. تم تقسيم هذه المراجعة إلى أربعة أقسام: (1) التأثيرات البيولوجية للإشعاع ، (2) خصائص مقياس الجرعات ، (3) أنواع مقاييس الجرعات ، (4) نتائج العديد من التحقيقات التي تستخدم مقاييس جرعات مختلفة. وفقًا لتقييم حديث لقياس الجرعات بناءً على تحقيقات مختلفة أجريت باستخدام مقاييس الجرعات ، فإن الجرعة الفعالة المتوفرة قد انخفضت منذ إدخال تقنيات التصوير الشعاعي. نتيجة لذلك ، يعد اختيار الطريقة الإشعاعية أمرًا بالغ الأهمية في إعطاء جرعات الأسنان.

الكلمات الدالة: الجرعة الممتصة؛ التصوير البانورامي؛ التصوير المقطعي المحوسب بالأشعة المخروطية؛ مقاييس الجرعات