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REVIEW ARTICLE

Rationalization of radiation dose

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ABSTRACT

Currently there is a great acceptance in medicine and dentistry that clinical practice should be "evidence-based" as much as possible. That is why multiple works have been published aimed at decreasing radiation doses in the different types of imaging modalities used in dentistry, since the greater effect of radiation, especially in children, forces us to take necessary measures to rationalize its use, especially with Cone Beam computed tomography (CBCT), the method that provides the highest doses in dentistry. This review was written using such an approach with the purpose of rationalizing the radiation dose in our patients. In order to formulate recommendations that contribute to the optimization of the use of ionizing radiation in dentistry, the SEDENTEXCT project team compiled and analyzed relevant publications in the literature, guidelines that have demonstrated their efficiency in the past, thus helping to see with different perspectives the dose received by patients, and with this, it is recommended taking into account this document so as to prescribe more adequately the complementary examinations that we use on a daily basis.

Keywords: Ionizing Radiation; Radiobiology; Radiation Dose-response Relationship

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1. Introduction

Since the introduction of imaging examinations, which use ionizing radiation, we should have a consensus on the risk of radiation dose to patients[1]. The risk to patients from a single radiograph is very low. However, the population risk is increased by the frequency with which radiographic exposures are performed and by the number of people subjected to these exposures. For this reason, all efforts to reduce the radiation dose should be directed in this direction, as well as to reduce the same dose depending on the device or type of image used as a diagnostic tool[2].

The recommendations in the SEDENTEXCT should be applied to all patients. Dentists should use complementary examinations with the use of ionizing radiation only after knowing the history and clinical examination of the patient[3], since every precaution should be taken to minimize radiation exposure, especially in children, breastfeeding women and pregnant women[4].

In addition, there is a lack of knowledge on the part of professionals and patients regarding the dose of radiation used in the acquisition of images and an excessive fear of the risks caused by exposure to X-rays[3]. The existing parameters for the rationalized use of radiation should be reviewed and updated from time to time in order to reduce radiation in the population[5].

2. Literature review

X-rays, as well as radio waves, microwaves and cosmic radiation, are a type of electromagnetic radiation, characterized by short wavelength, high energy and high penetrating power, capable of causing damage to exposed human tissue. Long-term exposure refers to the number of X-ray photons that the unit produces and the penetrating power they have on matter, factors determined by the configuration of the device (time, mA and kVp). Since the term dose is used to describe the amount of energy absorbed per unit mass in the region of interest, its unit of measurement is the sievert (Sv)[1].

As already mentioned, the dose is directly related to the radiation that arrives and is absorbed by the organs of the human body. Therefore, this exposure can give rise to two types of biological effects: deterministic effects and stochastic effects. Deterministic effects are those in which the severity of the response is proportional to the dose, causing a degree of cell death not compensated by repair. They are produced by high doses, where the severity of the damage increases with the dose applied. Examples include nuclear accidents and radiotherapies. Stochastic effects lead to cellular transformation and have no threshold dose, the damage can be caused by a minimum dose of radiation. They are caused by random changes in the deoxyribonucleic acid (DNA) of a single cell that continues to reproduce. When damage occurs in germ cells, genetic or hereditary effects may occur[6].

The doses received during radiographic examinations are low and the damage is reparable. However, we have to observe the organs that are irradiated in the performance of certain dental radiographic techniques. As an example, we can mention the realization of images of the mandible which exposes the region of the thyroid gland, and the realization of images of the maxilla where the crystalline lens of the eyes is irradiated. Therefore, it is of utmost importance the correct indication of examinations, in order to reduce the dose of ionizing radiation that the patient will receive, avoiding exposure to critical organs[7].

Periapical radiographic examination is indicated for single or groups of teeth, providing a detailed view of the anatomy and structures surrounding the tooth through a two-dimensional image. Based on SEDENTEXCT guidelines, performing a periapical radiograph using photostimulated phosphor plates or speed-F radiographic film with rectangular collimation exposes the patient to a dose of 1.5 μSv. In a complete examination (14 radiographs), with the same parameters, this number rises to 21 mSv. It is important to note that using a cylindrical collimator increases the dose by almost five times and the use of films with slower speeds increases it even more[1]. Another frequently requested examination is the panoramic radiograph, indicated for the general evaluation of the arches, monitoring dental development and growth. On average, a panoramic radiograph exposes the patient to a dose of 2.7 to 24.3 μSv. Lateral teleradiography is also known as lateral skull radiography and is another two-dimensional examination widely used by surgeons and orthodontists for the planning of orthognathic surgery and orthodontics. This method exposes the patient to a dose of approximately 6 μSv[3].

Unlike the two-dimensional examinations mentioned above, CBCT is a three-dimensional type of examination, which also exposes the patient to X-radiation. It has been applied in various dental specialties, and is mainly used in the evaluation of polytraumatized patients, orthognathic surgery planning, evaluation of dental implants, impacted teeth, to diagnose bone lesions, anatomical variations, fractures and radicular resorption. Depending on the parameters and devices used, it exposes the patient to approximately 48 to 652 μSv when using a field of view (FOV) of less than 10 cm and 68 to 1,073 μSv when using a FOV greater than 10 cm[3].

The FOV is another factor that interferes with the radiation dose produced by CBCT, taking into account that the smaller the FOV, the lower the amount of radiation involved in the process[8] (**Table 1**).

The use of CBCT in the evaluation of the dentomaxillofacial region has allowed the expansion in the field of diagnosis, enabling a better orientation of the operative and surgical procedures. Like other imaging tests that use ionizing radiation, CT also involves some risks for the patient and therefore it is essential to judge between the risks and benefits of this modality. Its indication should be made thinking about the benefits of the diagnosis over the possible harm that radiation exposure may cause, being essential the indication based on the history and clinical examination of each patient. The routine use of this modality on the basis of a generalized approach is unacceptable[2].

Table 1. Effective dose in the different imaging modalities

	Effective dose (μSv)	References
Intraoral radiography	<1.5	Ludlow *et al.*[1]
Panoramic Radiography	2.7–24.3	Ludlow *et al.*[1] Okano *et al.*[9] Garcia Silva *et al.*[10] Palomo *et al.*[11] Garcia Silva *et al.*[12]
Lateral Teleradiography	<6	Ludlow *et al.*[1]
CBCT (small FOV)	48–652	SEDENTEXCT 2012[3]
CBCT (large FOV)	68–1,073	SEDENTEXCT 2012[3]
Medical Tomography	280–1,410	Okano *et al.*[9] Garcia Silva *et al.*[12] Loubele *et al.*[13] Faccioli *et al.*[14] Suomalainen *et al.*[16]

There are some questions that the dentist should be aware of and use with discretion before indicating CBCT examination: Is the conventional radiography sufficient to provide the necessary information? Will the 3D image modify or add information to the diagnosis and treatment plan? From these answers, the practitioner will have the basis for a safe indication and will follow the CBCT indication rules specifying that the exam should only be done when conventional methods are not sufficient and/or when it brings additional information about each case[5].

With the aim of conveying scientifically based information on the clinical use of CBCT, a multidisciplinary group from the European Union, including physicists, radiologists and other dental specialists, created SEDENTEXCT. This material was prepared to reinforce the safe use of CBCT in clinical practice, at the same time, to develop evidence-based guidelines to justify, optimize and define the criteria for its indication for use in dentistry[3].

In general, this document presents guidelines for professionals working with this technology, whether they are technicians, physicians or dental surgeons. According to Keith Horner, project coordinator, the current guidelines in SEDENTEXCT are not rigid and should be subject to necessary changes according to current national legislation and local health service delivery. It is a guide for professional orientation and for optimizing the use of ionizing radiation in dental imaging[3].

This material can be accessed at http://www.sedentexct.eu, and presents a number of strategies that should be adopted to reduce the dose of ionizing radiation to which patients are subjected during a CT examination. Although the dose of CBCT for an exam is considered low compared to conventional or medical CT, it is increasing with its large-scale use. In addition, many patients are children, and therefore more susceptible to the harmful effects of radiation[3] (**Table 2**).

Table 2. Risk factors according to each age group

Age (years)	Multiplication factor for risk
<10	X 3
10–20	X 2
20–30	X 1.5
30–50	X 0.5
50–80	X 0.3
80 and over	Negligible risk

3. Discussion

With all the advancement of technology in the world, dental radiology has achieved a significant improvement in recent years. With the advent of CBCT, along with the improvement of equipment for intraoral and extraoral radiographs, there was an increase in the quality of examinations available, allowing for better diagnosis and much more accurate treatment planning for patients.

However, it should be noted that despite the improvement in quality, X-radiation is used for these images, and even at low intensity, it can cause damage to the DNA of human body cells. Although the doses and risks are small in oral radiology, some epidemiological studies have provided limited evidence of an increased risk of brain[16,17], salivary gland[17] and thyroid[18,19] tumors. Therefore, it is important for professionals to keep in mind that radiographic examinations are complementary examinations and that if they are requested randomly, without a thorough analysis, they expose the patient to unnecessary doses and risks, making them unjustifiable.

In order to protect human beings against undue effects caused by ionizing radiation, the International Commission on Nuclear Energy created three basic principles as guidelines. They are justification, optimization and individual dose limitation[20].

The rationale recommends that no practice should be authorized unless it produces sufficient benefit to the exposed individual or to society. The medical exposure must result in a real benefit to the health of the individual and/or society. The efficacy, benefits, and risks of alternative techniques available for the same purpose, but which do not involve or reduce exposure to ionizing radiation, should be analyzed[3].

Optimization implies that exposures should keep the radiation level as low as possible, following the ALARA principle (as low as reasonably achievable). Radiation protection is optimized when exposures use the lowest possible dose of radiation, without loss of image quality[3].

The individual dose limitation for each patient should not be exceeded by the limits established by the radiation protection standards in each country. This principle does not apply to limiting the dose in patients, but is intended for workers occupationally exposed to ionizing radiation and for the general public. It focuses on the individual, taking into account all exposures resulting from all practices to which the individual may be exposed[3].

Thus, following the guidelines of the International Commission on Nuclear Energy, before requesting any type of radiological examination, the professional should make a thorough clinical examination and a detailed anamnesis, and when possible, examine the previous radiographs that some patients may have. Only after these stages the professional should make the judgment to determine which is the exam that will bring more complementary information solving the case in question (justification), besides establishing the lowest possible dose of radiation, without which will cause the loss of image quality (optimization)[20].

Professionals should also be attentive to other important factors for the protection of patients. The correct execution of the technique by the professional, thus avoiding the repetition of the examination and the use of patient protection equipment, such as lead vest and thyroid collar, since they can avoid unnecessary exposure to the patient, thus minimizing the possible risks[20].

Finally, it is of utmost importance that the dental professional knows the main indications for requesting a CBCT, since, as mentioned in **Table 1**, scientific studies prove that this is an examination that has a higher radiation dose compared to the periapical, interproximal and panoramic techniques, which may have greater biological consequences.

CBCT has been the examination of choice in dentistry in cases where there is a need for evaluation in three dimensions, which is a valuable complement to two-dimensional images[21,22]. Its application has been highlighted in various clinical situations, such as periodontal evaluation[23], the study of the temporomandibular joint[24], periapical lesions[25], detection of internal and external root resorption[26], preoperative planning of implants[27] and diagnosis of root fractures[28-30].

The literature clearly demonstrated the negative influence of artifacts in the diagnosis of root fractures by CBCT, especially when there is the presence of intra-duct material of high physical density such as gutta-percha[29,31-34] and metal spike[29,32,35,36]. The presence of metal spikes and intraconduit gutta-percha channel significantly reduced the accuracy, sensitivity and specificity of CBCT in the diagnosis of root fractures[33,35]. This reduction in accuracy is justified by the appearance of artifacts in the form of hypodense (dark) lines that mimic fracture lines and also hyperdense (white) lines that make diagnosis difficult. Both can lead to an incorrect diagnosis and treatment plan, and in some cases even lead to the unnecessary extraction of the tooth[37].

A similar limitation applies when there is a need to evaluate the surfaces of titanium dental implants[38]. Research has been carried out in order to find better scanning protocols[39] and post-processing[40] to evaluate the peri-implant region, in order to reduce the artifacts generated. However, what is observed is that although CBCT provides accurate data related to bone morphology and orientation in the positioning of the implant in the alveolar ridge[41], the peri-implant region is compromised by the presence of artifacts resulting from the titanium screw[38,24], impairing or even preventing the diagnosis in this region. Therefore, it is evident that this type of imaging, as well as the others, has limitations and should be properly indicated.

There are devices on the market with different FOV sizes, therefore, some examinations can cover only the maxilla, mandible, maxilla and mandible together, or the entire craniofacial complex. The average size of the FOV for craniofacial complex analysis is around 14 cm[43,44], and the larger the size, the higher the radiation to the patient. For orthodontics and orthognathic surgery, the ideal FOV should cover the entire craniofacial complex[45], and it is there where it should be taken into account that the age range of patients who are treated in these specialties are children, who are more at risk of biological effects.

In summary, it is essential that the professional has the specific knowledge, performing a thorough anamnesis, to subsequently request, if necessary, the radiographic examination that provides the most complementary information for a correct diagnosis, exposing the patient to a dose of radiation as low as possible. Knowledge of the criteria and guidelines for the use of images is fundamental to allow the advancement of Peruvian dental radiology, since the new imaging techniques have proven to be an adequate alternative to improve the quality of diagnosis.

4. Conclusions

Although we have some damage from ionizing radiation, scientific research has shown that the risk associated with the use of intraoral, panoramic and CBCT radiographic techniques is less than the risk of background radiation (cosmic radiation, earth radiation, ultraviolet rays). Therefore, it is important to have a greater knowledge of the dentist surgeon in the indication of each exam so as not to expose patients to radiation unnecessarily. Also, a greater integration of the same with radiologists is suggested, in order to exchange knowledge and better inform their patients about the real risks of X-radiation.

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