ENGENHARIA NA PRÁTICA:
IMPORTÂNCIA TEÓRICA E TECNOLÓGICA

FRANCIELE BRAGA MACHADO TULLIO
(ORGANIZADORA)

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Ciências Exatas e da Terra e Engenharias

Engenharia na prática: importância teórica e tecnológica

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APRESENTAÇÃO

A obra “Engenharia na Prática: Importância Teórica e Tecnológica” contempla vinte e oito capítulos com pesquisas relacionadas a diversos temas da engenharia.

Os estudos refletem a teoria obtida em livros, normas, artigos na prática, verificando sua aplicabilidade.

O desenvolvimento de novos materiais e a utilização de novas tecnologias partem de estudos já realizados, o que garante desenvolvimento nas diversas áreas da engenharia, gerando novas alternativas.

O estudo sobre o comportamento de materiais permite o aperfeiçoamento de materiais já existentes e proporciona uma otimização na execução de novos projetos.

O uso de energia limpa também é um tema muito abordado, tendo em vista a necessidade de otimização de recursos naturais.

Esperamos que esta obra proporcione uma leitura agradável e contribua para a geração de novos estudos, contribuindo para o desenvolvimento tecnológico.

Franciele Braga Machado Tullio

SUMÁRIO

CAPÍTULO 10

EFEITOS DA RADIAÇÃO ELETROMAGNÉTICA IONIZANTE EM EQUIPAMENTOS ODONTOLÓGICOS

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RESUMO: O estudo dos níveis de radiação ionizante de alguns equipamentos odontológicos é oportuno, uma vez que estes ao serem utilizados apresentam riscos biológicos aos operadores, pacientes e a todos os envolvidos. Os equipamentos de Raios-X são fontes de radiação eletromagnética ionizante muito utilizados na odontologia. Três equipamentos de Raios-X pertencentes ao Núcleo de Odontologia de uma Universidade no interior do Estado de São Paulo foram analisados através de laudos técnicos emitidos para o controle de radiação do local. Os dados dos relatórios dos equipamentos foram analisados de modo a classificá-los em satisfatórios ou não quanto ao grau de segurança, por meio dos seguintes parâmetros: tempo de exposição, dose de entrada na pele e kerma no ar. Os

equipamentos de Raios-X estudados se enquadraram dentro das exigências dos valores referenciais da norma, exceto a divergência da dose de penetração na pele (ESD) de 0,13 mGy acima da norma para o equipamento RX3, e na medida do Kerma no ar 3.59 mGy para RX1, apresentando risco ao operador e paciente, principalmente em relação à exposição prolongada. O presente trabalho procurou avaliar e comparar os padrões internacionais de limites de dose com a legislação brasileira e ressaltar os princípios básicos de radioproteção, bem como dos mecanismos de ação danosos da radiação ionizante.
PALAVRAS-CHAVE: efeitos biológicos da radiação; biossegurança; equipamento odontológico; radioproteção.

EFFECTS OF IONIZING ELECTROMAGNETIC RADIATION IN DENTAL EQUIPMENT

ABSTRACT: The ionizing radiation assessment of dental equipment around the risk levels is timely, since its use involves risks of biological effects to the operators, patients and all those involved. X-ray equipment is a source of ionizing electromagnetic radiation (X-ray), widely used in dentistry. Three X-ray equipment from the Dental Nucleus of a local University at State of São Paulo were evaluated through technical reports issued by the radiation control company of the University's equipment. The comparison between the parameters obtained from the reports was analyzed to characterize the data evaluated as satisfactory or not for the safety level through the following parameters: exposure time, entrance skin dose (ESD) and air kerma. The results conformed to the requirements of the standard values reference, except for the divergence about the ESD (0.13 mGy) above the norm for the RX3 equipment and air kerma (3.59 mGy) for the RX1, thus presenting a risk to the operator, especially in relation to the effects of prolonged exposure. The present work sought to assess and compare the international standards about dose limits with Brazilian legislation and to highlight the basic principles of radiation protection, as well as the harmful ionizing radiation mechanisms of action.
KEYWORDS: biological effects of radiation; biosecurity; dental equipment; radiation protection.

1 I INTRODUCTION

Radiation is a form of energy emitted by a source, transmitted through vacuum, air or other material means that interacting with matter can produce several effects (Okuno 2013).

These radiations can be classified as of corpuscular (or particulate) origin - comprising natural radioactivity or radioisotopes such as α (alpha), β (beta), cathode rays and neutrons; and that of electromagnetic origin (Freitas 2000).

Electromagnetic radiation can be classified as ionizing and non-ionizing. According to Okuno and Yoshimura (2010), "a radiation is considered ionizing if it is capable of pulling an electron from an atom or a molecule to which it is electrically connected, otherwise it is considered non-ionizing."

Such radiations are present in X-ray equipment used in the acquisition of images of buccal structures, being the source of ionizing electromagnetic radiation, justifying the non-approach of corpuscular radiation in this article.

The use of radiation in the search for benefits can bring some biological damage to those involved, with the ionizing radiation being the most harmful. Examples of damage to humans include those of skin lesions, cancer, leukemia, cataracts and DNA or cellular modifications, and may even become hereditary (Freitas 2000). Therefore, it is necessary to meet several standards regulated by national and international bodies to obtain and operate equipment of this nature in order to minimize the damages.

X-ray equipment may lose calibration over time, resulting in undue changes in the level of radiation emitted, making the exposure environment unsafe because of 'invisible' risks that go unnoticed by both the operator and the patient. Three X-ray equipment belonging to the Dental Nucleus of a local University at State of São Paulo, Brazil, were evaluated through technical reports issued for the radiation control of the site.

2 I OBJECTIVES

The purpose of this study was to compare the data related to the dental X-ray equipment of a local University at State of São Paulo, Brazil, with the data contained in the national and international legislation, allowing characterizing the data evaluated as safe or unsafe. Still in the scope of this study, we compared Brazilian legislation on radiation dose limits with US and European legislation, as well as discussing the basic mechanisms that determine the biological effects of radiation exposure.

3 I X-RAYS IN DENTISTRY

Radiology is the medical specialty that uses the effects of artificial radiation for image acquisition and diagnosis of the human body for disease control and treatment, the main methods being known for radiography, ultrasonography, tomography and magnetic resonance imaging (Mello Junior 2016). Such methods are vastly employed in medicine and dentistry.

In dentistry, X-ray machines are characterized by simpler construction to make them portable or, at least, mobile. According to Alvares and Tavano (1998) these devices are "equipped with Auto Rectifier type tubes, which can operate with alternating current (AC) power" which allows their more compact design.

According to Brazil (1998), the use of radiation represents a major advance in medicine, requiring, however, that the practices that give rise to radiological exposures in health be carried out under optimized conditions of protection to the operator of the equipment and to the patient.

Another source of radiation used is radiotherapy, which consists of a "method capable of destroying tumor cells, employing ionizing radiation beam [...] with the least possible damage to the normal surrounding cells, at the expense of which the regeneration of the irradiated area will be carried out" (Brazil 1993).

4 | BRAZILIAN REGULATION OF RADIATION SAFETY AT WORK

Occupational safety and health consist of obligations, rights and duties to be complied by employers and employees, ensuring a safe and healthy work, preventing the occurrence of diseases and accidents at work. Such measures are provided by means of regulatory standards (Brazil 2015).

Regulatory Standard No. 15 (NR15) - Unhealthy Activities and Operations, addresses safety requirements for exposure to ionizing radiation (Annex 5) and non-ionizing radiation (Annex 7). In Annex 5, we can verify that the safety measures to be adopted are those contained in the CNEN Standard NN 3.01: “Basic Guidelines for Radiation Protection”, published in 1988 and with updates, or one that supersedes it (Brazil 2014). The CNEN NN 3.01 standard is developed by the National Nuclear Energy Council, a federal agency linked to the Ministry of Science and Technology and responsible for “establishing the basic requirements for the radiation protection of people in relation to exposure to ionizing radiation” (National Nuclear Energy Commission 2014).

Besides, the Regulatory Standard N° 32 (NR32) - Health and safety at work in health services does not exonerate the compliance with the provisions established in the specific regulations of CNEN and ANVISA, and also regulates aspects of the Radiation Protection Plan (PPR).

The Secretariat of Health Surveillance, an agency of the Ministry of Health, in its Ordinance 453 (1998), establishes the basic guidelines for radiological protection in medical and dental diagnostic radiology (Brazil 1998). This ordinance regulates the sector of medical and dental diagnostic radiology throughout the country.

5 | PRINCIPLES OF RADIATION PROTECTION

From the standpoint of the patients’ health, the professionals involved in the care, and members of general public, exposed to ionizing radiation, we must pay attention to the fact that this type of radiation, either if it is external, when the source is outside of the exposed organism, or internally, when the radioactive material is incorporated in the organism, generates cellular damage, and there is no safe dose. The doses received in radiation exposure are cumulative, some of the somatic damages (on the individual that receives the radiation) being reversible, but in the case of genetic damage, they are irreversible. Precisely because of these previously mentioned factors, the exposure of individuals to radiation should be reduced as much as possible (Soares 2002).

The basic guidelines for radiological protection in medical and dental diagnostic radiology are present in Ministry of Health Ordinance 453 (1998), as well as in specific legislation of the National Nuclear Energy Commission - CNEN - NN 3.01.

These principles are: justification, optimization, individual doses limitation and prevention of accidents: a) Justification: exposure to radiation should bring real benefits to the individual or to society, in exchange for the probability of occurrence and severity of the effects of their exposure, either for the individual himself or for his descendants, and their efficacy, benefits and risks should also be weighed against that of alternative techniques; b) Optimization: Studies show that there is no dose threshold for stochastic effects, so there is always a carcinogenic risk involved depending on the radio sensitivity of the exposed tissue. There is still the possibility of changes in gametes when gonadal (testicles and ovaries) exposure to radiation. To mitigate these hazards, the principle of optimization works with the planning of facilities and practices in order to reduce exposure to ionizing radiation. In this context the principle of keeping such exposure As Low As Reasonably Achievable (ALARA) applies; c) Individual Doses Limitation: it establishes the primary limits of individual annual doses of workers and of members of the public. These limits in the scope of medical and dental radiological practices are present in the abovementioned legal regulation. The CNEN-NN-3.01 standard was based on the recommendations of the International Commission on Radiological Protection (ICRP), initially in its publication n. 26 and later in publication n. 60, in 1991; and d) Accident Prevention: it aims to minimize the probability of occurrence of accidents in the design and operation of equipment and facilities. It should be noted that this last principle is only present in the Ministry of Health Ordinance.

The annual effective dose of 20 mSv/year in a period of 5 consecutive years shall be used as annual limits for occupationally exposed individuals, not exceeding 50 mSv in a single year. For members of the public, this limit is 1 mSv/year, and CNEN may authorize, in special circumstances, an effective dose of up to 5 mSv/year, but not exceeding 1 mSv/year in a 5-year period. The equivalent dose limits for the lens, skin and extremities (hands and feet) in occupationally exposed individuals are 20 mSv/year for the first, and 500 mSv/year for the last two, being for the lens, this value (20 mSv) shall be the result of the arithmetic mean of 5 consecutive years and shall not exceed 50 mSv in any year. For individuals in the public, the equivalent dose limits for the lens and skin are, respectively, 15 mSv/year and 50 mSv/year, with no threshold reference for the extremities. In the case of occupationally exposed pregnant women, in order to ensure embryonic/fetal health, it is established that their activities should be controlled to ensure that the dose at the surface of the abdomen does not exceed 2 mSv throughout the remainder of the pregnancy, making it unlikely that, from pregnancy notification, the embryo/fetus receives an effective dose greater than 1 mSv.

When it comes to minors under 18 years of age, the Ministry of Health Ordinance defines that they cannot work with diagnostic x-rays, except in training, however, for students aged between 16 and 18 years, in traineeship, the effective annual dose should not be greater than 6 mSv and the annual equivalent dose limit should be 50 mSv for the lens and 150 mSv for the extremities. Although it is not expressly provided by law, the radiation exposure to students over 18 year of age who, in the context of academic studies, work with radiation, it is understood that the same professional exposure rules are applied.

For protection against ionizing radiation we must consider: 1) Distance from the Source: since the exposure is inversely proportional to the square of the distance, that is, by doubling the distance, we reduce the exposure by its fourth part;

2) Shielding: through the insertion of radiation absorber between the source and the person; and 3) Exposure Time: limiting exposure to the shortest possible time. Air kerma is a radiation measure used to express the radiation concentration delivered to a space point, such as the entrance surface of a patient's body. The quantification terminology originated from the acronym KERMA for Kinetic Energy released per unit of air mass. The measurement of the Kinetic Energy is the amount of radiation energy in the unit of joules (J), deposited in or absorbed in a unit mass (kg) of air. Therefore, Air kerma is expressed in the units of J/kg which is also the radiation unit, the gray (G).

According to the table 1 below, we verify the references of the levels of entrance skin dose (ESD), with unit in mGy (miligray), according to the previously mentioned Ordinance of the Ministry of Health, elaborated for typical adult patient (weight between 60 and 75 kg and height between 1.60 and 1.75 m).

EXAM		**DEP (mGy)***
Lumbar spine	AP	10
	LAT	30
	LSJ	40
Abdomen, urography and cholecystogram	AP	10
Pelvis	AP	10
Thorax	PA	0.4
	LAT	1.5
Thoracic spine	AP	7
	LAT	20
Dental	Periapical	3.5**
	AP	5
Skull	AP	5
	LAT	3
Mammography***	CC using grid	10
	CC not using grid	4

TABLE 1. Diagnostic radiology by radiography reference levels for typical adult patient.

Source: adapted from Ordinance 453/1998 (Brazilian Ministry of Health).

Observations: PA: posteroanterior projection; AP: anteroposterior projection; LAT: lateral projection; CC: craniocaudal projection; LSJ: lumbosacral junction.

(*) ESD, entrance skin dose. These values are representative for medium sensitivity image receiver, with relative speed of 200. For faster screen-film combination (400-600), these values should be reduced by a factor of 2 to 3.

(**) for group E film.

(***) determined in a 4.5 cm compressed breast for screen-film system and a unit with anode and molybdenum filtration.

With the update of the ICRP-60 for the ICRP-103, in 2007, Brazil is relatively outdated compared to the one recommended by the world radiation protection community. Among the main differences between the Brazilian standard CNEN-3.01 (2014) and the last edition of the ICRP (2007) are the change in the radiation and tissue weighting values, the introduction of the concepts of planned and emergency exposures and of existing exposures (not included in the scope of this study), and recommendations for the development of a project of radiation protection of the environment. Despite these changes, the fundamental principles of radiation protection were maintained (Pereira et al. 2015).

In the most recent ICRP publication no. 118 (2012), some changes in dose limits were established for tissue reactions, previously said deterministic effects, when compared to what was previously established by the same organ.

When it comes to radiation induced cataracts, a threshold of 5 Gy for acute exposures and a dose greater than 8 Gy for highly fractionated doses as well as for prolonged exposures when considered cataract with visual impairment was established in ICRP publication 103, these values remaining unchanged from the recommendations of 1990 (ICRP 1991). Regarding cataract detection, lower dose limits were valid since the 1984 ICRP publication, being 0.5-2 Gy for acute exposures and 5 Gy for highly fractionated doses or prolonged exposures. The new publication considers a threshold dose value of about 0.5 Gy for both acute and chronic exposure for the presence of cataracts.

As for circulatory diseases, it has been recognized as important late effects of exposure to radiation, both for mortality and morbidity. A threshold dose of approximately 0.5 Gy has been proposed for acute and fractional/prolonged exposures, as they should lead to a low percentage of developing circulatory diseases in exposed individuals, one to a few percentage points. Although the risk estimate at this dose level is uncertain.

The threshold dose values for chronic exposure have great difficulty to be well defined, because it requires the evaluation of the exposure duration and the follow-up period after exposure to radiation, with variance among different studies. The threshold values for the lens and the circulatory system have the same incidence of injury, regardless of the acute or chronic exposures during the working life, following a period of more than 20 years. In relation to the public, the annual threshold dose should be scaled down in proportion to the individual's relative lifespan by subtracting the latency period for the onset of lesions (20 years for the lens and 10 years for the circulatory system), in contrast to working life.

There are biological response modifiers that reduce tissue reactions, resulting in threshold dose changes. Further studies on this subject is likely to have an increasing impact in the future.

In Europe, a treaty establishes the European Atomic Energy Community (EURATOM), with the task of contributing to the establishment of conditions for the rapid formation and growth of nuclear industries, requires that its signatory countries establishes basic safety standards for protection of health, workers and the general public against the dangers arising from ionizing radiation.

Currently, EURATOM, in Directive 59 (2013), establishes, as general principles of radiation protection, Justification, Optimization and Dose Limitation, setting the limits of professional exposure (Article 9), effective dose of 20 mSv/year and, in special circumstances or situations, the competent authority may authorize a higher dose limit that may reach 50 mSv in one year, and the average over a consecutive period of 5 years may not exceed 20 mSv. A higher threshold is established in Brazilian legislation, but not mentioning any requirement for special circumstances.

The equivalent dose limit for the lens of the eye is 20 mSv/year or 100 mSv over 5 consecutive years provided that the mean dose in the same year does not exceed 50 mSv and, in relation to the skin and the extremities, the equivalent dose of 500 mSv/year is applied, values equivalent to Brazilian legislation.

For members of the public, the effective dose limit allowed for the exposure is 1 mSv/year, with equivalent doses to the lens of the eye and to the skin, of 15 mSv/year and 50 mSv/year, respectively, in agreement with the Brazilian legislation.

For pregnant and breastfeeding workers (Article 10), the equivalent dose limit parameter received by the unborn child is similar to the Brazilian legislation, in which the dose received unlikely exceeds 1 mSv for at least the remainder of pregnancy, since the company or employers are informed.

For students and apprentices between 16 and 18 years old who are exposed to radiation, the established limit is 6 mSv/year. In addition, the following effective dose limits are defined as 15 mSv/year for the lens of the eye, 150 mSv/year for the skin and also for the extremities. For students and apprentices over the age of 18-year who are exposed to radiation due to the studies, EURATOM, unlike the Brazilian legislation, expressly states the same professional exposure rules as in Article 9 of its Directive 59 (2013).

Radiation protection recommendations in Europe and, in general, in the world, are based on the recommendations of the ICRP, thus making clear the similarity between the compared legislations.

In the United States, there is the USNRC - United States Nuclear Regulatory Commission, which establishes the radiation protection program and defines the dose limits of occupational exposure and members of the public, even, determining that it should be established, for radiation protection, the ALARA principle aforementioned.

The provided effective dose limit for occupational exposure is 50 mSv/year or the sum of the equivalent doses of any individual organ or tissue, other than the lens of the eyes, equal to 500 mSv/year. The annual equivalent dose limit for the lens is 150 mSv, which is the main difference from Brazilian legislation and that provided for by EURATOM, that is 7.5 times greater than the dose of these other legislations. The equivalent dose limit for the skin is 500 mSv/year. There is no dose limitation defined for the extremities.

For minors the dose limit is set at 10% of the annual limit specified for adult workers, a very different determination from the Brazilian and the European.

For members of the public, the effective dose limit is 1 mSv/year, that may reach 5 mSv/year in special circumstances, equivalent to the other legislations. No other limits are defined for public exposure to radiation relevant to the scope of this paper.

For pregnant women, the equivalent dose limit is 5 mSv throughout pregnancy. If the equivalent embryo/fetus dose is 5 mSv at the moment the pregnancy is known, then the equivalent dose of the embryo/fetus should not exceed 0.5 mSv during the remainder of the pregnancy. The limits provided by the US agency, deviate from that recommended by the Brazilian legislation and by EURATOM, as illustrated.

Through this study it is possible to notice that the Brazilian and European legislation are very close, keeping some similarities with the American legislation. Compliances come from the influence of ICRP publications, which, although a non-governmental entity, is the most influential in the context of global radiation protection.

Finally, this ICRP publication No. 118 (2012) concludes that acute doses of up to about 0.10 Gy do not produce functional damage to tissues, this includes the lens, with regard to the risk of cataract, emphasizing that a dose threshold model remains unclear for this tissue. It should also be noted that the stochastic risks of radiation-induced cancer and the hereditary effects are still the main risks to be considered in occupational and for members of the public exposure to radiation. When considering high-dose exposures, there is a significant increase in the risk of tissue reactions, namely deterministic effects, particularly regarding accidents and incidents involving radiation, and exposures arising from medical procedures and interventions.

6 | BIOLOGICAL EFFECTS OF RADIATION

Regarding the biological effects of radiation, the human body is made up of molecules of varying size and complexity, which in turn are formed by atoms bonded by electrical forces. When an ionizing particle has sufficient energy to remove an electron from an atom that forms a particular molecule, such as DNA (deoxyribonucleic acid), there is a destabilization, determining molecular breakdown, which may result in a temporary organic response or in disease (Okuno 2013).

The organic reaction to exposure to radiation depends basically on five factors, namely: 1) total amount of radiation received; 2) total amount of radiation previously received by the body; 3) individuality of the organic constitution; 4) physical damage at the same time of the dose of radiation; and 5) time elapsed during which the total amount of radiation has been received (Soares 2002).

We can divide the radiation actions in the human body in the following stages: a) physical stage: occurs with the ionization of atoms; b) physical-chemical stage: there is a breakdown of the chemical bonds of the ionized molecules, resulting in molecular fragmentation; c) chemical stage: the molecular fragments bind to other molecules; and d) biological stage: biochemical and physiological effects appear, with morphological and functional alterations of the organs, lasting for days, weeks, years or even decades. In this final stage there are expression of symptoms, diseases (radiodermatitis, cancer, leukemia, cataract etc.) and/or genetic effects. It should be emphasized that not every organic change represents disease and may be temporary or even repaired by the body’s defense mechanisms (Okuno 2013).

The most important cellular damage is related to DNA, which can determine instant cell death, somatic changes or hereditary effects. Cellular mutations, whether somatic or hereditary, may originate from specific mutations due to modifications in DNA sequence, structural chromosomal aberrations (chromosome breakage) and aberrations involving the number of chromosomes (Soares 2002).

The biological effects of radiation can be divided into stochastic and deterministic.

Stochastic effects are often expressed after months or years of exposure to radiation, and their occurrence is proportional to the radiation dose received, but with no threshold dose considered safe. Besides, if a cancer develops due to exposure to radiation, for example, its severity is not linked to the greater or lesser amount of exposure to radiation, that is, the cancer will not become more or less aggressive (Soares 2002; Okuno 2013).

On the other hand, deterministic effects occur mostly days or weeks after irradiation of the exposed organ or tissue, only if absorbed a minimum dose of radiation. Also, the higher the dose, the more severe its effect, as, for example, in case of cataracts and radiodermatitis. In case of acute doses of radiation the results can vary from tens of minutes to years in cases of prolonged exposure. Cellular effects are varied, leading to premature cell death, delay or impairment in the division process, or permanent changes and/or hereditary changes (when the genetic material of spermatozoa or egg cells are altered) (Soares 2002; Okuno 2013).

7 I METHODOLOGY

A descriptive and bibliographic research was carried out, which made it possible to correlate already published contents on one or several subjects through a new approach, creating innovative content that provides an auxiliary basis for future research (Marconi and Lakatos 2010).

The Nucleus of Dentistry of a local University (State of São Paulo, Brazil) was used as a study reference. It was possible to evaluate three X-ray equipment by collecting data in technical reports issued by an outsourced company, regarding the control of radiation of the nucleus, allowing to visualize the real condition of the X-ray equipment.

This three dental x-ray equipment were named here RX1, RX2, RX3, and their brands, models and series numbers were suppressed to prevent undesirable exposure of their manufacturer as the objective of these work is not for certification or regulatory matters.

We can explain the omission of equipment information from the fact that it is not an assessment for certification purposes and is outside of NR 17025.

In order to understand the safe practices in environments exposed to radiation, both national and international regulatory rules valid in 2018 were analyzed.

The data were arranged and analyzed by means of descriptive statistics for a better interpretation of the information. Comparing the data collected from all the equipment involved with those of the safety standards, it was possible to verify whether or not the equipment complies with the required safety standards.

8 | RESULTS AND DISCUSSION

The following tables present the values (KVp, Focus-Film Distance used in the preparation of the DFF report, Filter, mGy/s, film, maximum exposure time and ESD) obtained through the technical reports of the radiological protection team for three X-rays of the University Dentistry Nucleus.

Equipment	kVp	DFF(cm)	Total Filter (mm Al)	mGy/s	Film	Max. time (s)	ESD (mGy/s)*Max. Time
RX1	66.5	22.0	3.81	3.77	E	0.9	3.39 mGy
RX2	64.5	22.0	3.81	3.07	E	1.1	3.37 mGy
RX3	67.5	22.0	3.81	3.63	E	1.0	3.63 mGy

TABLE 2 Values obtained from the respective x-ray reports.

	Exposure Time (s)			Air Kerma (mGy)		
Equipment	T1	T2	T3	T1	T2	T3
RX1	0.56	0.75	0.96	2.12	2.81	3.59
RX2	0.59	0.74	0.95	1.74	2.34	2.92
RX3	0.61	0.78	0.98	2.21	2.88	3.48

TABLE 3 Air Kerma values obtained from respective x-ray reports.

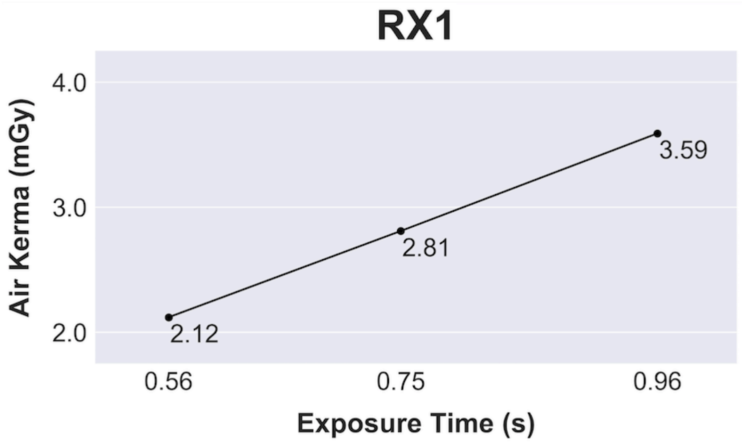

FIGURE 1 Kerma air vs. Exposure time graph from RX1.

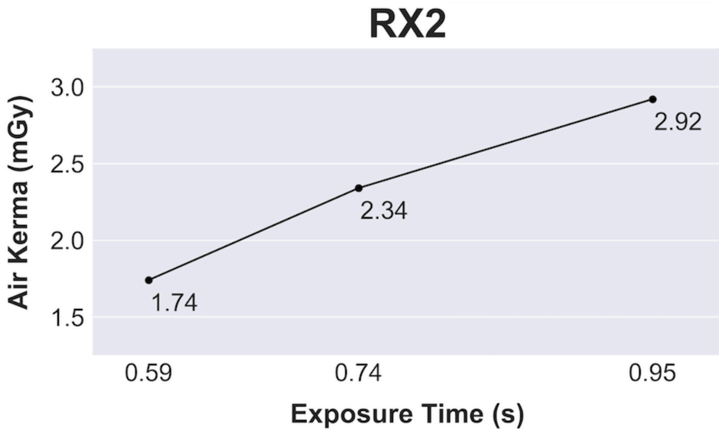

FIGURE 2 Kerma air vs. Exposure time graph from RX2.

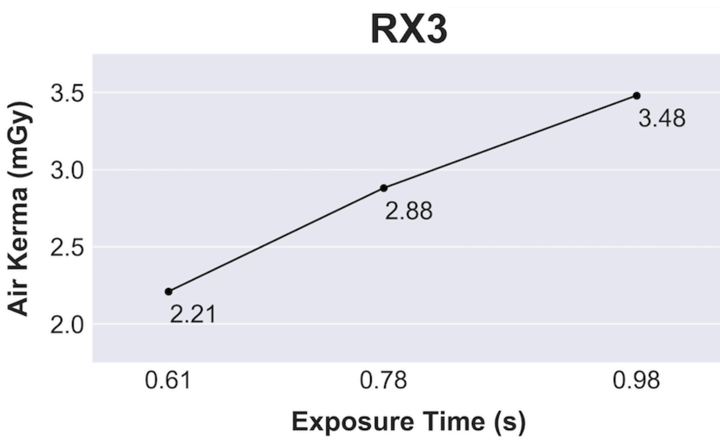

FIGURE 3 Kerma air vs. Exposure time graph from RX3.

According to Brazil (1998), in ANVISA Ordinance 453, in intraoral radiographs the tension in the x-ray tube should preferably be higher than 60 kVp and for extraoral radiographs should not have a voltage lower than 60 kVp. Equipment with a tube tension ≤ 70 kVp must have a total filter of not less than 1,5 mm Al. The Entrance Skin Dose - ESD, in dental radiology for typical adult patients, must not exceed 3.5 mGy for E type filter.

All the equipment evaluated presented voltage values in the X-ray tube (kVp) within ANVISA standards. ESD is defined as the dose absorbed at the center of the beam incident on the surface of the patient undergoing a radiological procedure. Only the RX3 equipment presented a result for the entrance skin dose (ESD) slightly above that recommended by the rules, with an increase of 0.13 mGy, which highlights the importance of a semiannual or annual screening of the X-ray equipment by the institution. A new radiographic report with a smaller field amplitude, at more frequent exposure times throughout the year, would challenge the results obtained in the reports for comparative effect with the legislation.

Thus, it is again sought to highlight the stochastic effects that are expressed after exposure to medium to long-term radiation, once their occurrences are proportional to the dose of radiation received, but without a threshold considered safe. As for the deterministic effects, the higher the dose, the more severe its effect and in the case of higher doses of radiation the results can vary from tens of minutes to prolonged effects over the years. Cellular effects are varied, with premature cell death, delay or impairment in its division process, or even permanent and/or hereditary changes.

9 | CONCLUSIONS

In order to compare the X-ray equipment data with the data contained in the national legislation, we conclude that the studied X-ray equipment are in compliance with the reference values of the standard, except for the divergence of the ESD of the RX3 equipment that presents a risk to the operator and patient mainly to the effect of prolonged exposure, as observed through the biological effects of stochastic and deterministic radiation. The results conformed to the requirements of the standard values reference, except for the divergence about the ESD (0.13 mGy) above the norm for the RX3 equipment and air kerma (3.59 mGy) for the RX1, thus presenting a risk to the operator, especially in relation to the effects of prolonged exposure. The ESD, which is significantly higher than that recommended by the standards, above 0.13 mGy, emphasizes the importance of an annual investigation of the equipment or, preferably, biannual. We also compared the Brazilian, European and North American legislations in relation to the dose limits established for occupational exposure and for members of the public. By demonstrating the biological effects and dose thresholds involved in tissue and organ changes, we emphasize the importance of radiation protection for society, both from the point of view of the worker and individual.

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