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Radiobiological risks in dental X-ray exposure, «personalized imaging» future of radioprotection strategies

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Abstract

Introduction: *Medical imaging plays an important role in dentistry. Low doses of ionizing radiation can increase the risk of longer term effects such as cancer. A sensitive approach to dental imaging is necessary considering age, gender and other individual radiation sensitivity-related factors.*

Material and methods: *A search of PubMed, MEDLINE for a variety of articles, guidelines, reviews, was carried out.*

Results: *The search led to 175 publications published between 2004 and 2024. Publication selection criteria were : knowledge of the dentist regarding radiation protection, ionising radiation and its effects, the possible correlation between dental X ray exposure and the cell damage, age and gender-specific radiation sensitivity, individual factor in the radiation respose, radiation protection guidelines.*

Conclusion: *These review will contribute to a better understanding of X ray-induced genotoxic and cytotoxic effects, resulting in DNA damage. We propose the consept of «personalized imaging». In accordance with this concept, there is a need to consider the individual factor in the radiation response by taking age, gender and other individual radiation sensitivity-related factors into account. In this way, dentiste can be better evaluate radiation sensitivity and radiation-related disease risk and can contribute to improved radiation protection guidelines, which, will benefit the patient.*

Keywords: *Dental imaging, optimization, radiation safety, radiobiological risks, x ray limitation.*

I. Introduction

Radiographs are an indispensable diagnostic aid in dentistry as they allow the detection of disease and other abnormalities, as well as disease progression to be monitored. [1] Many dentists have dental imaging devices in their clinics or their dental center and carry out radiological imaging.

Dentists use radiographs more often than any other health professional. A report by the European Commission estimates that dental X-ray procedures make up 32% of all plain radiography procedures in Europe, with a mean value of 352 dental procedures per 1000 population per year.[2]

Dentists use X-ray devices to obtain two-dimensional (2D) and three-dimensional (3D) radiographic images. An initial clinical examination is required to determine the need of dental imaging. In dentistry we use two main techniques of dental imaging: intraoral radiography or extraoral radiography. Periapical, bitewing, and occlusal radiography are the three main intraoral imaging procedures where the patient's single tooth or multiple teeth can be examined. Extra oral radiography includes imaging of the jaw and facial area (craniofacial) of the patient by three main techniques known as panoramic, cephalometric and cone-beam computed tomography (CBCT).[3]

Operators (Dentists, dental assistants, radiographers and other medical staff) who carry out dental imaging are supposed to know the legal and ethical issues and radiation protection standards and theoretical and practical knowledge of imaging techniques because, exposure to ionizing radiation does not come without risk.

Dental staff should follow radiation protection and radiation safety principles as long as they keep up their profession. In 2014, Georgia enacted a new law of 'Nuclear and radiation safety', which was adopted in order to provide consistency with the new International and European Radiation Basic Safety Standards (BSS) [4]. However, In Georgia only 39.43% of the operators (Dentists, dental assistants, radiographers and other medical staff) follows the radiation protection and radiation safety course. [5] In our previous study revealed a lack of knowledge on the part of dental staff about the rules and guidelines for the practice of radiology and radioprotection. Georgian Dental Association (GSA) is committed to the training of dentists in the field of radiation protection. However, Knowledge, attitude, and behavior of Georgian operators about radiation protection and radiation safety needs to be improved. Our epidemiological study showed that only

26.76% of operators use the position and distance rules correctly for their own protection. 60,27% of operators does note take personal passive dosimeters, when they are performing dental intraoral radiography. 25.36% of the patients hold imaging receptors with hand during intraoral radiography procedure. 61.97% of professionals hold imaging receptors with their own hand and only 12.68% of professionals use film holder. 73.24% of practitioners neglect the rules of optimization and use the same exposure parameters for adult and pediatric patients. Only 26.76% of practitioners maintain radiation exposure history.[5]

In order to accurately estimate radiation-induced health risks, it is important to know how much energy or which dose is absorbed by the human body and its organs. Furthermore, it is important to know the dose–effect relationship. [6]

International commission of radiation protection (ICRP) suggested general principles of radiation protection as three key words: justification, optimization and dose limit.[7]

Many studies have proven the possibility to reduce considerably the dose keeping the imaging quality for diagnosis purposes and/or treatment plan, the translation of optimization, there is still room for improving the translation of optimization in clinical practice. [6] The ALADAIP principle was introduced in 2017 to state that the radiation exposure must be As Low As Diagnostically Acceptable being Indication-oriented and Patient-specific. The addition of two letters, «I» for Indication and «P» for Patient should encourage the clinician to consider personalized optimization. In short, ALADAIP is a reminder to ask two questions before an x-ray examination: Why exactly is this imaging exam requested? and Who is the patient? [8]

II. Aim:

The purpose of this review is to present studies that prospectively investigated biological effects in patients exposed to ionizing radiation in dental imaging. In particular, genotoxic and cytotoxic effects caused by ionizing radiation. Outlining the cytogenetic effects induced by ionizing radiation is necessary to identify the cancer risk and minimize potential risks to patients and medical staff. A specific focus will placed on potential patient-specificity as well as age, gender and other individual radiation sensitivity-related factors. These recommendations aim to help clinicians develop and implement safety practices that will provide optimal diagnostic value while minimizing radiation risks to patients or personnel.

III. Material and methods:

This review presents studies investigating biological and health effects related to exposures using dental X-rays in patients. We searched the PUBMED and MEDLINE databases were carried using specific keywords and Medical Subject Headings (MeSH) terms, combined with the boolean operators "OR" and "AND". Specific keywords were: ("radiography, dental" [MeSH Terms] OR ("radiation" [All Fields] AND "X Ray" [All Fields]) OR "dosimetry" [All Fields] OR "radiobiology" [All Fields]) AND exposure [All Fields] AND ("genotoxic, effects" [MeSH Terms] OR ("cytotoxic, effects" [All Fields] AND "stochastic effects" [All Fields]) AND "Deterministic effect"[All Fields] OR "Cell damage " [All Fields] OR ("radiation sensitivity" [All Fields] AND "X ray justification"[All Fields] AND "X ray optimization" [All Fields]) AND "X ray limitation" [All Fields]) AND "FDI, world dental federation " [All Fields]) AND recommendations [All Fields].

The articles, guidance documents, and regulations were selected based on the following criteria: Publication dates: from 1 January 2004 to 2024; Languages: English, french; Article types: Research articles, Guidelines, Meta-analysis, Systematic Reviews, Reviews. The articles must report the relationship between X-ray exposure and cell damage, dentists' knowledge of radiation safety and its effects on human health, the possible biological correlation between dental imaging and the radiation protection, finally, the additional precautions that the dentist must implement in the X-ray exposure of the children, adolescent and pregnant women.

IV. Results:

The search led to 175 publications including guidelines, meta-analyses, systematic and non-systematic reviews, published between 2004 and 2024. We identified approximately 250 papers. Of each article, abstracts and titles were examined. Articles that were not related to the topic were excluded. We then obtained the full texts of all potentially eligible articles. After the complete reading, 175 articles, guidance documents, and regulations were selected, discarding the remaining ones, deemed unsuitable because they were not pertinent to the purpose of the study. Titles that were repeated in the different searches were also excluded. Articles published after 1 January 2004 concerning the following topics were selected: knowledge of the dentist regarding radiation protection, ionizing radiation and its effects, the possible correlation between dental X ray exposure and the cell damage. A further selection was made based on the level of scientific evidence, taking into greater consideration 33 publications including systematic guidelines, meta-analysis, and reviews. The remaining 142 articles were not altogether excluded from this work because of corresponding to a lower level of scientific evidence.

V. Discussion

Biological effects of ionizing radiation

Radiation is a fact of life - all around us, all the time. There are two classes of ionizing radiation: Natural radiation and Artificial (human-made) radiation. It is well known that dental X-rays can induce cytotoxic effects and cause deoxyribonucleic acid (DNA) damage.[21, 22] Primary target for cell damage from ionizing radiation is DNA in chromosomes of cell's nuclei. At a sub-cellular level, ionizing due to radiation can lead to direct and indirect effects on the DNA: Direct effect-radiation interacts with DNA molecule. Indirect effect-radiation interacts with water and generates reactive free radicals, which then interact with DNA. (Fig.1 and 2). At a cellular or tissue level, effects are categorized as stochastic (radiation-induced cancer) or deterministic (tissue reactions). Deterministic effects have a threshold level below which no damage will occur and the severity increases with dose. It has been suggested that a cataract is a typical deterministic effect on the eye and may be caused by lower doses of ionizing radiation [1]. Radiation carcinogenesis is considered a stochastic effect, and occur at all dose levels as a result of damage to the DNA . The excess risk of dying from a radiation-related cancer is based on age at exposure, gender, total dose, and dose rate. Secondary leukemia may show up after just a few years with a decrease in incidence after about a decade, while secondary solid tumors typically occur after a decade or more. [31]

In-Utero effects of ionizing radiation involve the production of malformations in developing embryos. Typical Effects of Radiation on Embryo/Fetus: Death of the embryo or fetus or induction of: malformation, growth

retardation, functional disturbance, cancer. Factors influencing the probability of effects: Dose for embryo or fœtus and Gestation status at the time of exposure.

Several studies have found an association between dental X-ray exposure and increased risks of brain cancer [23,24], tumors of the parotid gland [25] and breast cancer [26] and thyroid cancer [27,28]. In particular, thyroid cancer is one of the most common cancers in the worldwide, and the side effects from dental radiation exposure are likely to contribute to its incidence due to the location of the thyroid gland. [29] According to a study on dental practitioners and thyroid cancer the risk of thyroid cancer was 13.1 times (95% CI) higher among female dentists and dental hygienists [8]. It is believed that women are more likely to have to thyroid cancer than men due to their hormones. Leukemia and low birth weight have been reported as systemic health outcomes related to dental X-ray exposure.[30] Existing epidemiological and experimental data suggest that radiation sensitivity in the long run is much higher in females than in males receiving a comparable dose. In accordance, recent studies observed an increased cancer risk in (young) females when compared to (young) males when exposed [32,33]. Radiation sensitivity also differs from one individual to another [6]. We propose ways in which the dental office can minimise radiation exposure (appendix 1).

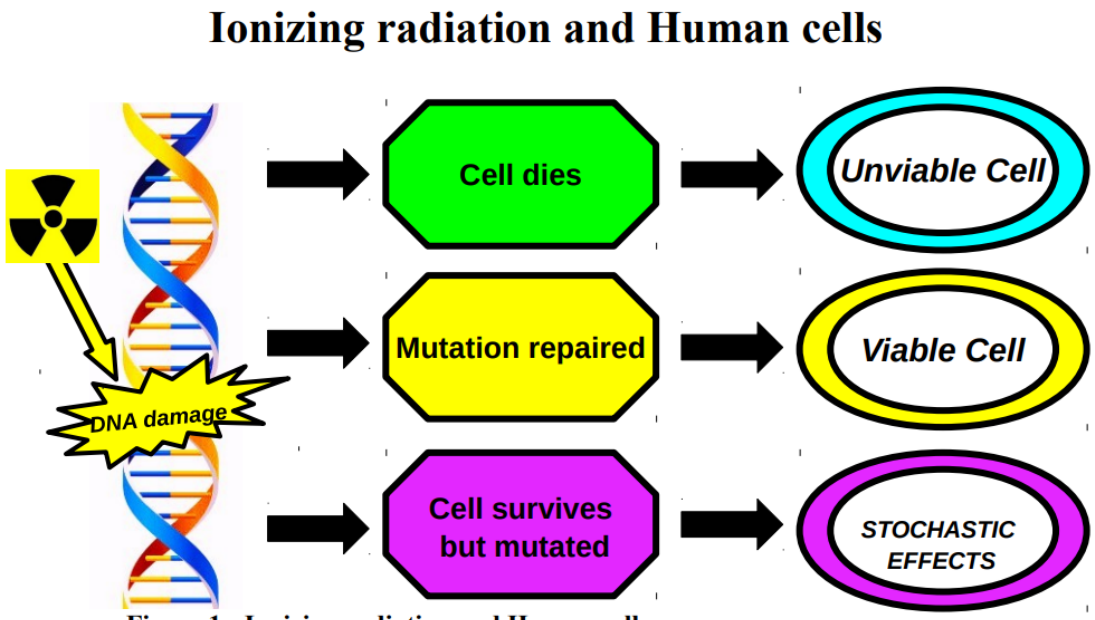

Figure 1 : Ionizing radiation and Human cells

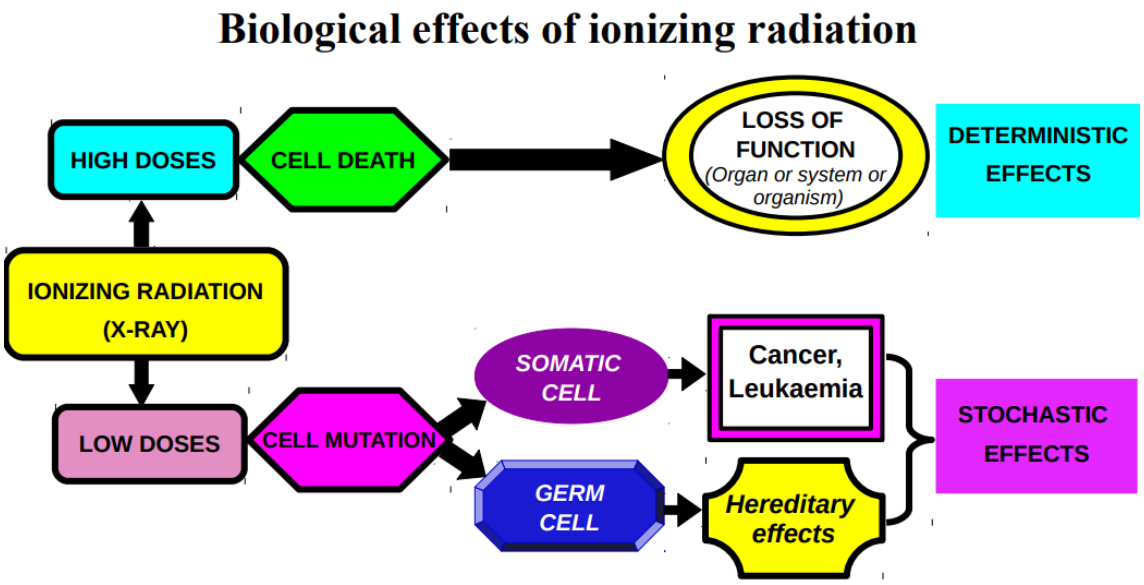

Figure 2 : Biological effects of ionizing radiation

VI. Conclusion

In addition, there is a need to consider the individual factor in the radiation response by taking age, gender and other individual radio sensitivity-related factors into account. We must better evaluate radiation sensitivity and radiation-related disease risk of our patients. Mainly for more sensible population: children, adolescents and pregnant women. We propose a concept of «Personalized dental imaging» that can drive optimization strategies in radiation protection and we encourage all dental staff to adopt patient-specific measures by considering age, gender and other individual radiation sensitivity-related factors. The future radioprotection strategies should be based on the concept of personalized imaging.

Appendix 1

Clinical recommendations and regulatory considerations proposed by FDI (world dental federation), IAEA (International Atomic Energy Agency) and ICPR (International Commission on Radiological Protection)

- An initial clinical examination is required to determine the need for imaging some or all of the tooth-bearing regions and surrounding hard tissues. [9]
- "The justification of medical exposure for an individual patient shall be carried out […] with account taken, in particular for patients who are pregnant or breast-feeding or are pediatrics" [11]
- FDI recommendations are intended to assist the dentist in optimizing protection and keeping the diagnostic value of their radiographs, whilst minimizing the risk to patients, staff and the public. [1]
- Patient shielding: use leaded aprons and thyroid collars whenever possible. [1]
- Quality assurance: protocols should be developed and followed for assessing the integrity of the X ray machine, film processor, digital image receptors, [1]
- **For intra oral equipment IAEA and FDI recommend :**

  •Nominal focal spot size should range between 0.4 and 0.7 mm.

  •Using tube voltage in the range 60 (minimal) to 70 kV. Tube current usually ranges between 3.5 to 8 mA, the exposure time should be below 1s . in every exposition.

  •The X ray tube filtration should be sufficient to reduce entrance skin dose to the patient consistent with producing satisfactory image quality.

•Rectangular collimation is strongly recommended.

•A position indication device which ensures a minimum focus-to-skin distance of 20 cm should be attached to the tube head.

•The fastest available film consistent with achieving satisfactory diagnostic results should be used.[1,2]

Radiation protection of children

- ➔ Extra care is needed when exposing children to radiation because: a) Children receive a higher radiation dose than adults if exposure settings are not adapted b) Children are more sensitive to radiation-induced stochastic effects than adults (i.e. more likely to develop cancer at a given radiation dose) c) When adults and children are exposed using the same FOV, the dose for children will be higher! [12] d) The absorbed dose (for a given combination of exposure settings e.g. tube voltage (kV), tube current (mA), exposure time (s)) increases with a decreasing patient size. i) Radiation-induced cancer risk highly dependent on age at exposure: Ionizations of molecules in a living cell can lead to DNA mutations and other types of damage. Mutations are more likely to be transferred to next generation cells (and eventually manifest as cancer) in cells which are actively dividing. As children are growing, they have a higher proportion of dividing cells than adults. children have a longer life span (higher probability that cancer, which typically occurs several years after exposure, will manifest). [10]
- ➔ Exposures to children can be optimized through adjustment of exposure parameters and the use of shielding. [10]
- ➔ Justification of medical exposures is more stringent in children than adults. [1]
- ➔ Thyroid collars should be used in all examinations where the thyroid may be exposed to the main beam or to a considerable amount of scatter radiation. [17] The salivary and the thyroid glands are among the organs at risk in dental radiology.
- ➔ Is it a good idea to monitor the dental development of children using a panoramic radiograph? No, there is no justification for this routine practice. Radiography may be required when a clinical examination suggests the presence of an abnormality, or when interceptive and active orthodontic treatment is being considered. Clinical indicators, used to identify patients who might benefit from a panoramic radiograph, are effective in excluding children for whom an X-ray examination is not likely to be of value. [18]

Radiation protection of pregnant women in dental radiology

- ➔ A female of reproductive capacity should be considered pregnant unless proved otherwise.[16]
- ➔ Pregnant patients should receive dental imaging only when specifically indicated to manage their dental care. [1]
- ➔ If the radiological examination is considered essential it should be performed and due consideration should be given to optimization and personal shielding. Because of the widespread fears of radiation induced damage to the unborn child, it is reasonable to counsel the woman on level of radiation exposure and associated risks prior to performing the procedure. [16]

Radiation protection of staff in dental radiology

- ➔ Can a pregnant employee continue to work in the dental radiology department? After declaration of pregnancy, should be such that it is unlikely that the fetal dose will exceed 1 mSv during the remainder of the pregnancy. In a dental setting, extensive modifications of the working environment are usually not needed; general protection measures (e.g. personal shielding) suffice. A qualified expert can be contacted to estimate the projected fetal dose based on equipment factors and workload.[15]

- ➔ Who should hold dental film during radiography? Film should not be hand held by a member of the dental practice staff. If necessary it should be held by the patient, but only when it cannot otherwise be kept in position. If the patient can not hold it, and a comforter/career must be involved, then this should be done using forceps or other device (eg., a specifically designed dental film holder) so that fingers are not in primary beam. [15] Receptor holders: use to optimize alignment and minimize repeat exposures [1]
- ➔ Who may be present in the room during radiographic exposure? In the case of a single-chair room, persons must not be present in the room during a radiographic exposure unless their presence is necessary for conduct of the examinations. Persons present must be located behind a shield allowing a view of the patient and the "exposure on" indicator, or wearing protective apron, or at least 2 m from the source of scattered radiation, i.e. the patients head, and not in line with the primary beam. In the case of the multi-chair room, there should be adequate shielding between the chairs. [15]
- ➔ Operators should stand out of the primary beam, at least 2 m away from the source and behind a protective barrier whenever possible [1]
- ➔ Persons operating X-ray devices must have appropriate training, education and certification.[1]

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