DOI 10.51231/2667-9507-2023-002-02-25-32

Radiation measurements in dentistry

A. Pitskhelauri, I. Gotsiridze, R. Esvanjia

Georgian Technical University, Tbilisi, Georgia

Abstract

When patients undergo X-ray examinations, millions of photons pass through their bodies. In dental radiography, the part of the head that receives the greatest dose is the skin in the area where the X-rays enter, including brain, salivary gland and thyroid. The effective usage of radiation in dental practice has been studied for many years and several guidelines have been proposed. While not high doses of radiation are associated with dental radiography in the field of using radiation in dentistry practice it is the most important to provide periodical radiation measurements for radiographs used in dental clinics, to measure such main X-rays specifications, as Kilovoltage Peak (kVp), Dose/Exposure, Dose/Exposure Rate, Exposure Time – Radiographic Modes, Elapsed Time – Fluoro Modes, Average Pulse Rate – Pulsed Fluoro, Average Pulse Width – Pulsed Fluoro and Half-value Layer HVL. Besides these parameters of mAs spesifications da DoseMate specifications also must be measured. Quality control of radiological devices is very important. So, we plan periodical radiation measurements in more than 50 dental clinics in Georgia and hope that results of these measurements will be successful, encouraging. After the measurements, the results will be known to all stakeholders. We will also talk about them in our next publications.

KEYWORDS: radiation; measurements; dose; dentistry

Introduction

Radiation is indispensable in modern medicine. The radio-graphic examination is one of the principal diagnostic methods used in all fields of medical services and contributes to the promotion of the health, including dentistry. Accordingly, a certain amount of radiation is inevitably delivered to patients and populations.

When patients undergo X-ray examinations, millions of photons pass through their bodies. These can damage any molecule by ionization, but damage to the DNA in the chromosomes is of particular importance. Most DNA damage is repaired immediately, but rarely a portion of a chromosome may be permanently altered (a mutation). This may lead ultimately to the formation of a tumour. The latent period between exposure to X-rays and the clinical diagnosis of a tumour may be many years. The risk of a tumour being produced by a particular X-ray dose can be estimated; therefore, knowledge of the doses received by radiological techniques is important.

Radiological examinations play an essential part of dental practice. Because a certain amount of radiation is inevitably delivered to patients, it should be as low as reasonably achievable, a principle known as ALARA. It is also important taken into consideration the number of diagnostic examinations because the risk is directly proportional to the frequency of X-ray exposure.

A unique aspect of radiological protection in medicine, which differs somewhat from other types of radiation exposure, is that the details of a medical radiographic examination are up to the discretion of the clinician. Such decisions are made on the basis of the anticipated health benefit to the patient. The decision is always made based on the professional judgement of the doctor in charge of the patient, with informed consent, which includes not only the expected benefit but also the potential risk [1]. In the case of low risk procedures such as dental and chest radiography, the degree of informed consent may below, even where the cultural or societal factors have to be considered. The benefit of a particular examination in medical practice is qualified by consideration of evidence-based medical literature [2]. The effective usage of radiation in dental practice has been studied for many years and several guidelines have been proposed. Dentists and other dental health care personnel should use these well-thought-out and research-proven guidelines, which benefits patients by reducing not only the radiation dose but also the cost [3,4].

Another aspect of protection in medicine is to consider optimization of radiographic procedures. Reduction in expo-sure dose to patients may be attained by proper management of equipment and the accomplishment of a quality assurance program. The goal of optimization is to keep the dose ‘‘ALARA, economic and societal factors being taken into account,'' and is best described in medical practice as: management of the radiation dose to the patient to be commensurate with the medical purpose.

In dental radiography, the part of the head that receives the greatest dose is the skin in the area where the X-rays enter. A study was performed at the Department of Diagnostic Sciences at the University of North Carolina School of Dentistry in Chapel Hill, North Carolina, using a realistic head phantom and state-of-the-art imaging systems (Ludlow et al. 2008). In the Table 1 are some typical skin and thyroid doses received for the exams indicated. The effective dose is explained below. Of course, these doses vary somewhat from different machines, but the figures listed below are probably within 10 to 20 percent of the actual amounts received by the patient [5].

Table 1. *Patient Doses from Dental X-Ray Exams (Ludlow et al. 2008)*

EXAM	SKIN DOSE (MSV)	THYROID (MSV)	EFFECTIVE DOSE (MSV)
Full mouth (18 exposures)	90-122	117-550	34.9-170.7
Bitewing	26	0	5
Panoramic	4-6	25-67	14.2-24.3

To predict the probability of radiation causing harm, it is necessary to calculate a quantity called the effective dose in units of the millisievert (mSv) or microsievert (µSv), where 10 mSv equals 1 rem in the older radiation dose units. The effective dose takes into account the type of radiation, which is X-rays in this case, and the body parts or organs involved, for example, the skin, salivary glands, bone marrow, mandible, thyroid, etc. The absorbed doses to the individual organs are, unfortunately, also expressed in mSv or µSv. The old unit for organ does was the rad, where 100 millirad (mrad) equals 1 mSv. Doses to individual organs, however, do not represent the risk or harm to the organ, as various cellular repair mechanisms attenuate the radiation effects. Rather, each organ or body part is assigned a tissue weighting factor determined by the International Council on Radiation Protection and Measurements (ICRP 2007). For example, the weighting factor values for the thyroid and skin are 0.04 and 0.01, respectively, and do not have any measurement unit associated with them. The sum of the individual organ weighting factor values equals 1.0. Organs that do not receive radiation do not contribute to the effective dose.

The weighting factor values are derived from review of the epidemiological data that exist for humans exposed to large amounts of radiation, primarily the survivors of the atomic weapon detonations in Hiroshima and Nagasaki. The factors indicate the relative likelihood of harm, such as cancer, birth defects, or increased risk of genetic disorders in future generations, per unit dose. Since the dose to reproductive tissue is much less than 1 μSv for all of the dental exposures here, the only health issue considered is cancer induction.

It is important to point out that in epidemiological studies of humans, no actual increase in cancer incidence has ever been found in groups of humans who have received effective doses below 100 mSv. The effective doses associated with dental exposures are much, much smaller than this. Nevertheless, in order to come up with some estimate of harm for purposes such as setting standards for reasonable levels of exposures in medicine, it is assumed that the probability of harm seen at high doses decreases proportionally with dose and never becomes zero. No exposure to X-rays can be considered completely free of risk.

Despite everything in the field of using radiation in dentistry practice it is the most important to provide periodical quality control of radiological devices used in dental practice, do some radiation measurements. So the purposes of this article are to review the most popular method to measure the radiation parameters and doses in dental radiography. This articles gives the information about planning periodical radiation measurements in Georgian dental clinics.

Materials and Methods

For dose measurements in diagnostic radiology including dental radiology it is important to have a well-defined and easy-to-use method. The measured dose quantities are normally entrance surface dose (ESD), entrance surface air kerma without back scatter (ESAK) or dose area product (DAP) which measures the air kerma area product (KAP). The ESD, ESAK and DAP are all used for the setting of diagnostic reference levels. Conversion factors from DAP to effective dose are available for evaluation of radiation risk, mostly using Monte Carlo generated conversion factors [6].

In Georgia we plan to measure radiation parameters in dental practice using X-Ray Test Tools TNT 12000 by FLUKE BIOMEDICAL. See Figure 1. These tools fully correspond to quality control of all types of dental and non-dental radiological devices. They can measure every X-ray, mAs and DoseMate specifications which is needful for quality control of radiological devices.

Figure 1. TNT 12000 X-Ray Test Tools

The Fluke Biomedical TNT 12000 X-Ray Test Tools (the TNT 12000) are used to calibrate and service diagnostic X-ray imaging systems. These test tools has the following main parts: the X-ray detector which contains an array of solid-state sensors and filters that measure kilovoltage peak (kVp), dose, half-value layer (HVL), and exposure time; the dosimeter detector with its related ion chambers to measure dose and rate on all X-ray modalities including dental; the mAs detector to measure X-ray tube current over time; the display which contains a 320 x 240 color LCD, four navigation buttons, an ENTER button, and a power button. The display controls test-systems functions and shows all system measurements; dose mate/mAs CD that contains an Excel Add-in to control the test-system and import all measurements; AC Power Adapter used to charge the rechargeable batteries in the X-ray detector, dosimeter detector, mAs detector and the display. The TNT 12000 options communicate between the detectors and the display or computer through a wireless or wired (USB) connection.

Using X-Ray Test Tools TNT 12000 it is possible to measure the following main radiation parameters: Kilovoltage Peak (kVp), Dose/Exposure, Dose/Exposure Rate, Exposure Time – Radiographic Modes, Elapsed Time – Fluoro Modes, Average Pulse Rate – Pulsed Fluoro, Average Pulse Width – Pulsed Fluoro and Half-Value Layer (HVL); such mAs specifications as Accuracy, invasive mA/mAs Range, Non-Invasive mA/mAs Range, Trigger Levels, Invasive Shunt, Non-Invasive Clamp and also Dose-Mate specifications.

For example, Table 2. shows means of X-Ray Test Tools TNT 12000 main X-ray specifications for radio/fluoro/dental modes.

Table 2. *TNT 12000 X-rays test tools main X-ray specifications for radio/fluoro/ dental modes*

PARAMETER	UNITS	RANGE	RESOLUTION	ACCURACY
Kilovoltage Peak (kVp)	kV	40kV-150kV	0.1kV	±2% or 1 kV, whichever is great
Dose/Exposure	Roentgens (R) Grays (Gy)	0.5 mR-999R 5mGy-999Gy	1 μR 0.01 μGy	±5%
Dose/Exposure Rate	Roentgens per hour, minute, second, pulse (R/hr, R/min, R/sec, R/Pulse) Grays per hour, minute, second, pulse (Gy/hr, Gy/min, Gy/sec, Gy/Pulse)	8 mR/s-10 R/s 70 μGy/s-100 mGy/s 130 μR/ Pulse-160 mR/ Pulse 12 μGy/ Pulse-1.4 mGy/ Pulse	1 μR/s 0.01 μGy/s 0.02 μR/Pulse 0.2 nGy/Pulse	±5%
Exposure Time – Radiographic Modes	Milliseconds (ms) Pulses	10-9999 ms 1-999 pulses	0.1 ms 1 pulse	1 % or 0.5 ms ±1 pulse
Elapsed Time – Fluoro Modes	Seconds (s)	10-9999 seconds	0.1 second	1 % or 0.5 second
Average Pulse Rate – Pulsed Fluoro	pulses per second (pps)	1-999 pps	1 pps	1 pps
Average Pulse Width – Pulsed Fluoro	Milliseconds (ms)	10-999 ms	0.1 ms	1% or 0.5 ms
Half-value Layer (HVL)	mm Al (equivalent)	1.2-10 mm Al (equivalent)	0.1 mm Al (equivalent)	±10 % or 0.2 mm Al

Table 3. shows means of X-Ray Test Tools TNT 12000 main DoseMate specifications for radiological devices.

Table 3. *TNT 12000 X-rays test tools main DoseMate specifications for radiological devices*

Accuracy	±1 % of rdg ±2 of range resolution steps (see DoseMate Measurement Ranges) over the range of 18 to 280C and ±2 of reading ±2 range resolution steps over the full operating temperature range of 0 to 350C. This accuracy is exclusive of all ion chamber effects. A 3% NIST traceable calibration is provided with each system.
Bias Voltage	300 V. The bias voltage is removed from the triaxial input connector at instrument turn-off.
Ion Chamber Input	Triaxial-BNC input connector, collector and guard positive-biased relative to ion chamber body/dosimeter chassis.
Ion Chamber Cable	1.8 m, Triaxial Male to Male cable.
Test Stand	Machined stainless steel upright tool with baseplate, ion chamber holder, and tray for HVL filters, which includes the ion chamber stem.
HVL Filter Set	Set of nine aluminum filters for half-value layer measurements: one 2 mm, two 1 mm, two 0.5 mm, three 0.1 mm, and one 0.2 m.
Temperature Accuracy	±20C (3.60F)
Pressure Accuracy	±5 mm Hg

Results

No exposure to X-rays can be considered completely free of risk. Quality control of radiological devices is very important. So, we start to provide measurements of such main X-rays specifications, as Kilovoltage Pe ak (kVp), Dose/Exposure, Dose/Exposure Rate, Exposure Time – Radiographic Modes, Elapsed Time – Fluoro Modes, Average Pulse Rate – Pulsed Fluoro, Average Pulse Width – Pulsed Fluoro and Half-Value layer (HVL); such mAs specifications as Accuracy, invasive mA/mAs Range, Non-Invasive mA/mAs Range, Trigger Levels, Invasive Shunt, Non-Invasive Clamp and also DoseMate specifications.

We plan periodical radiation measurements in more than 50 dental clinics in Georgia, After the measurements, the results will be known to all stakeholders. We will also talk about them in our next publications.

Conclusion

While doses and risks for dental radiology are small, a number of epidemiological studies have provided evidence of an increased risk of brain, salivary gland and thyroid tumours for dental radiography.

As quality control of radiological devices used in dentistry we plan periodical radiation measurements in Georgian dental clinics and hope that results of these measurements will be successful, encouraging.

Acknowledgements

Society of Rheology, 405133029; Popularization of Rheology Science Program (PRSP).

References:

1. International Commission on Radiological Protection: Radiological Protection in Medicine. Ann ICRP. Publication 105. Amster-dam: Elsevier; 2008.
2. Montori VM, Guyatt GH. Progress in evidence-based medicine. JAMA 2008.
3. American Dental Association Council on Scientific Affairs: Theuse of dental radiographs. Update and recommendations. 2006.
4. Kim IH, Mupparapu M. Dental radiographic guidelines: a review. Quintessence Int. 2009;40: 389-98.
5. Ludlow JB, Davies-Ludlow LE, White SC. Patient risk related to common dental radiographic examinations: The impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation. Journal of the American Dental Assoc. 2008;139:1237-1243.
6. Helmrot E, Gudrun AC. Measurement of radiation dose in dental radiology. SE-581 85. Linkoping, Sweden, 2005.