IAEA TRAINING RESOURCES ON RADIATION PROTECTION IN DENTAL RADIOLOGY

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Abstract— **The International Action Plan for the Radiological Protection of Patients and the Bonn Call for Action emphasised the need to strengthen radiation protection education and training of health professionals, tailored to the practical needs of different audiences and taking into account their specialties and field of work. The IAEA standard training package and the e-learning on Radiation Protection in Dental Radiology are the newest resources to support education and training in radiation protection of dental professionals. They have been developed in collaboration with several professional bodies. The standard training package of 12 lectures has been designed to support trainers providing radiation protection education and training of different professionals involved in dental radiology – dentists and other dental staff, dental radiation technologists, medical physicists. The e-learning structured in 9 modules is adapted to the self-learning by dentists and other dental professional staff. These training resources are freely available from the Radiation Protection of Patients (RPOP) webpage of the IAEA, www.iaea.org/resources/rpop.**

Keywords— **Radiation protection, Education and training, Training material, e-learning, Dental radiology**

I. IAEA'S STRATEGIC APPROACH FOR SUSTAINABLE TRAINING ON RADIATION PROTECTION IN MEDICINE

International Atomic Energy Agency (IAEA) established in 2002 an International Action Plan for the Radiological Protection of Patients in cooperation with international organizations and professional bodies, with the objective to make progress in patient safety through variety of actions [1]. The education and training of healthcare professionals have been recognized as essential for achieving this goal. Actions to strengthen education and training included the development of standard syllabi and packages for training of health professionals and to train the trainers involved in national training programmes using this material. It has been stressed that the training programmes and training material must be tailored to the practical needs of different audiences, taking into account their specialties and field of work, and to make the material available in the official languages of the United Nations.

The Bonn Call-for-Action, a joint Position Statement issued by the IAEA and World Health Organization (WHO) in 2012, further emphasized in the Action 4 the need to strengthen radiation protection education and training of health professionals, by a) prioritizing radiation protection education and training for health professionals globally, targeting professionals using radiation in all medical and dental areas; b) further developing the use of newer platforms such as specific training applications on the Internet for reaching larger groups for training purposes; c) integrating radiation protection into the curricula of medical and dental schools, ensuring the establishment of a core competency in these areas; d) strengthening collaboration in relation to education and training among education providers in health care settings with limited infrastructure as well as among these providers and international organizations and professional societies; e) paying particular attention to the training of health professionals in situations of implementing new technology [2].

Since 2002 and following the establishment of the Radiation Protection of Patients Unit of the IAEA, different resources have been developed to support education, training and risk communication, all freely available from the dedicated website on Radiation Protection of Patients (RPOP), https://www.iaea.org/resources/rpop. Currently, 14 training packages are available in different areas and specific applications, all developed with the involvement of internationally recognized experts and in close collaboration with appropriate international and professional organizations. These materials contain PowerPoint slides, available in English, Spanish and Russian for free download from the training page of the website [3]. With the purpose to train trainers and receive feedback, the IAEA organizes every year a number of training events based on these standard syllabi and materials. The IAEA packages have become a leading training resource on radiation protection in medicine used worldwide. The material is of particular importance for less resourced countries, where it is translated into local languages, adapted and used by trainers for organizing trainings at national or local level.

The IAEA regularly updates the existing and develops new training material to address the new developments and reach wider audience of health professionals. This includes both new topical areas and new training approaches such as e-learnings for direct self-learning and webinars.

The above-mentioned actions support the implementation in the IAEA Member States of the requirements of the International Basic Safety Standard, GSR Part 3, and the recommendations of the associated Safety Guide SSG-46 related to medical uses of ionizing radiation [4,5].

II. IAEA RESOURCES FOR RADIATION PROTECTION IN DENTAL RADIOLOGY

X-ray imaging is extensively used in dentistry to diagnose, plan and monitor treatments and to follow-up pathoses.

According to the latest report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1.1 billion dental examinations are performed globally every year, that is an increase of 130% from the 480 million examinations per annum estimated in the UNSCEAR 2008 report [6]. Dental examinations account for approximately 26 % of all diagnostic radiological examinations, with the annual frequency estimated to 151 dental examinations per 1,000 population globally, varying from 21 per 1,000 population in low-income countries, to 561 per 1,000 in high-income countries [6].

Dentistry is an independent healthcare specialty. Dental X-ray equipment is often owned by dentists, who refer patients for X-ray procedures performed by themselves. Therefore, dentists have a responsibility for justification of medical exposure and for optimization of radiation protection of patients, and they would be more effective if they have a good understanding of radiation risks and radiation protection and safety. The RPOP website offers answers to frequently asked questions and other information for dental professionals and patients [3].

Specific guidance on radiation protection in dental radiology is provided in the new IAEA Safety Report developed in cooperation with the FDI World Dental Federation, the Image Gently Alliance, the International Association of DentoMaxilloFacial Radiology (IADMFR) and the International Organization for Medical Physics (IOMP) [7].

Radiation protection education and training helps dentist fulfil minimize potential misuses of self-referral and perform exams safely. Although formal processes to require such education and training under a radiation protection and safety framework might be difficult to put in place, a more general approach is recommended for promoting education and training in radiation protection and safety as part of the general university degree curriculum, especially in the course of dental imaging, and/or as part of the corresponding specialty postgraduate education and training programme [5, 7].

The IAEA standard training package on Radiation Protection in Dental Radiology and the e-learning on the same topic are the newest materials to support education and training in this area.

III. STANDARD TRAINING MATERIAL

The standard training syllabus and material on Radiation Protection in Dental Radiology have been designed to support trainers providing radiation protection education and training of different professionals involved in dental radiology – dentists and other dental staff, dental radiation technologists, medical physicists. It can be used by lecturers who teach to students in dental schools and schools for medical radiation technologists. The material is useful for regulators and inspectors who want to enhance their knowledge on specific aspects of radiation protection in dental radiology.

The training is structured in 12 lectures, the topics of which is presented in Table 1.

For each topic, a slide set in Power point (Microsoft Office) is provided, structured in the following sections: Educational Objectives; Overview; Content; References.

Table 1 Training modules of the standard training material

Lecture #	Topic
1	General Principles of Radiation Protection
2	Special Considerations for Radiation Protection in Children
3	X-ray Production and Interaction: Image Formation and Image Quality
4	General Principles of Film and Digital Radiography
5	Fundamentals of Intraoral Radiography
6	Fundamentals of Panoramic Radiography
7	Fundamentals of Extraoral Projectional Radiography
8	Fundamentals of CT and CBCT
9	Justification and Appropriate Use of Dental Radiology
10	Quality Assurance in Dental Radiology
11	Optimization of Protection of Patients in Dental Radiology
12	Protection of Workers and Public in Dental Radiology

Lecture 1, General Principles of Radiation Protection, provides general introduction to ionization radiation, its properties and interaction with matter, dose quantities and their use, different types of radiation risks and factors, and introduces the general principles of radiation protection and their application in the International Basic Safety Standards. At the end of this module, the participant should be able to:

- Understand the importance of adhering to the principles of radiation protection in dentistry;
- Understand the properties of ionizing radiation (especially X-rays), and their effects on living tissue;
- Distinguish between stochastic effects and tissue reactions;
- Distinguish between absorbed dose, equivalent dose and effective dose;
- Understand the linear-non-threshold model and its implication for radiation protection;
- Understand the dose-risk relation of stochastic effects, and the effect of age and gender;
- Understand the principles of justification, optimization of protection, and application of dose limits.

Lecture 2, Special Considerations for Radiation Protection in Children**,** explains why extra care is needed when exposing children to radiation and what are the approaches to protect pediatric patients when performing radiography.

The motivation for this separate module is the high frequency of dental radiographic examinations in children, used in orthodontic treatment, trauma, cleft palate, developmental disorders, tumors and other clinical situation. After learning this module, student should be able to:

- Understand the need for special considerations for radiation protection in children;
- Understand why radiation doses for children are higher than for adults (unless exposure parameters are adapted appropriately);
- Understand why radiation risks for children are higher.

Lecture 3, X-ray Production and Interaction: Image Formation and Image Quality, provides a general introduction to the basic physics of X-ray beam, components of an X-ray tube and key exposure parameters. Interactions of X rays with matter are discussed, as well as the principles of image formation and image quality parameters. After studying this topic, participants should be able to:

- Understand the function of the different components of the X-ray tube;
- Understand the effect of kV, mAs and filtration on the quantity and energy of X-rays;
- Understand the effect of geometric exposure parameters;
- Understand the basic principles of image formation in X-ray imaging;
- Be familiar with the different essential image quality characteristics.

The next five modules focus on important features of the four different X-ray imaging modalities used in dentistry and practical aspects of their proper use for obtaining diagnostic images at reasonably low dose to patients. First, principles of image formation in film and digital radiography are discussed, and further detailing in the next modules specific applications in intraoral, extraoral radiography and CT, including CBCT.

Lecture 4, General Principles of Film and Digital Radiography, has the following learning objectives:

- Understand the principle of image formation in film and digital radiography, and fundamental differences between them;
- Be familiar with image manipulation methods in digital radiography.

Lecture 5, Fundamentals of Intraoral Radiography, has the following objectives:

- Be familiar with the different types of intraoral radiography;
- Understand the difference between (film-based and digital) image receptors used in intraoral radiography;
- Recognize and avoid faulty radiographs (position, under/overexposure, film handling and development, etc.);
- Know when and how to use handheld intraoral radiography machines.

Lecture 6, Fundamentals of Panoramic Radiography, aims to make participants:

- Understand the general principles of image acquisition in panoramic radiography;
- Recognize and identify causes of image distortion and artefacts;
- Able to apply proper patient positioning and alignment;
- Recognize image aberration due to mispositioning.

Lecture 7, Fundamentals of Extraoral Projectional Radiography, has the objective to make participant differentiate between lateral cephalometric, posteroanterior cephalometric, submentovertex, occipito-mental and occipito-frontal projections, in terms of positioning of patient and image receptor and respective clinical applications.

Lecture 8, Fundamentals of CT and CBCT, focuses on the relatively higher dose modalities used in dentistry, which proper use requires the users to be familiar with image formation and factors influencing dose and image quality. Through this module, the student will:

- Understand the general principle of image acquisition and reconstruction in CT and CBCT;
- Understand fundamental similarities and differences between MDCT and CBCT, and how this affects their respective clinical application;
- Be familiar with CT image manipulation and visualization methods;
- Understand the cause and effect of various types of CT artefacts;
- Understand the issues related to density estimations in CBCT.

The next four modules discuss specific aspects of radiation protection of patients, workers and public in dental radiology, based on the international recommendations and good practice.

Lecture 9, Justification and Appropriate Use of Dental Radiology, focuses on one of the two main principles of radiation protection, and approaches for selection of an appropriate imaging technique in a given situation, thus "doing more good than harm". As justification process needs to take into account patient dose, typical doses from different dental modalities are given, discussing also their variation and proper communication (Table 2).

Referral guidelines for imaging, often called "selection criteria" in dentistry, are considered to be an important tool for justification, and examples of such guidelines are given for different clinical applications, such as caries diagnosis, orthodontics, periodontics, endodontics, implant planning, tooth extraction, other surgery, temporomandibular joint imaging.

Table 2 Typical doses from dental imaging procedures

Dental procedure	Typical effective dose	Equivalent period of exposure to natural radiation
Intraoral radiograph	0.3-21.6 µSv	1 h – 3 d
Panoramic radiograph	2.7-38 µSv	10 h – 6 d
Lateral cephalometric radiograph	2.2-14 µSv	8 h – 2 d
CBCT	11-1025 µSv (generally <300 µSv)	1.5 d – 5 m (generally <1.5 m)
CT (mandible)	250-1410 µSv	1 – 7 m
CT (mandible & maxilla)	430-860 µSv	2 – >4 m

At the end of this module, imaging in pregnancy is discussed, and also how to communicate information about risks and benefits to patients.

After studying this module, participants will be able to:

- Understand the general principles regarding the use of radiation in medicine;
- Judge the appropriateness of using 2D and 3D imaging techniques for a given patient;
- Can judge the current referral criteria for CBCT for various clinical applications.

Lecture 10, Quality Assurance in Dental Radiology, presents an overview of general principles of QA and QC, QC test protocols per modality (an example shown on Fig. 1). Dosimetry and dose monitoring and assessment of clinical image quality assessment are also included. Although not aiming to provide detailed guidance on QA and QC tests, it provides reference to published protocols stressing on the leading role of medical physicists.

The learning objectives of this module are to:

- Understand the general aspects of QA in radiology, and particular QA and QC aspects in dental radiology;
- Able to perform QC tests for different dental radiographic equipment (if responsible for such task).

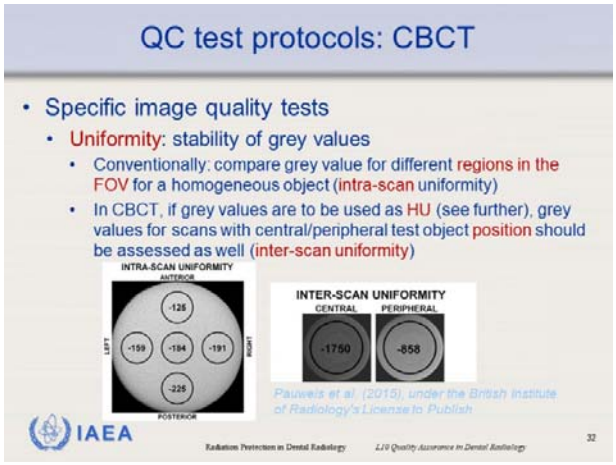

Fig. 1 An example from the training package, Module 10

Lecture 11, Optimization of Protection of Patients in Dental Radiology, discusses strategies to optimize imaging procedures for achieving diagnostic image at appropriate radiation dose to patient from different dental radiographic modalities, and the parameters affecting dose. The use of diagnostic reference levels (DRLs) and examples of available DRLs are presented. At the end of this module, the proper use of patient shielding is discussed. The learning objectives include:

- Be familiar with the equipment and patient factors affecting patient dose;
- Be able to apply various optimization strategies, and estimate the amount of dose that can be saved in a given exposure condition;
- Be able to judge the potential benefit and drawback of using patient shielding in a given situation.

Lecture 12, Protection of Workers and Public in Dental Radiology, presents regulatory and practical aspects of protection of workers when performing dental X-rays, and approaches to ensure protection of public, room design and shielding requirements. At the end of this module, the participants will be able to:

- Understands the scatter distribution for different radiographic modalities;
- Identify the safest position of the operator and public relative to the patient and x-ray tube;
- Understand the need for adequate distance and shielding and be able to apply these principles in clinical practice.

The training package was developed in several steps. First, with the involvement of invited experts, the syllabus and learning objectives were designed, followed by the development of Power point slides to deliver the content.

At the second step, experts from the IAEA, WHO and several international professional bodies representing the professional groups involved in dentistry were invited to review the draft material and provide their feedback. Representatives of all these organizations were invited to Vienna for a consultancy meeting, during which an updated version of the material was prepared, followed by review and approval by the organizations involved in the development of the material: WHO, FDI World Dental Federation, IADMFR, IOMP and Image Gently Alliance.

The approved training material was posted at the RPOP training webpage in 2017. During 2018, the training material was translated into Spanish. The training package on Radiation Protection in Dental Radiology can be downloaded from this link: https://www.iaea.org/resources/rpop/resources/training-material#12.

To promote the new material, IAEA organized two webinars within the RPOP webinar series, with lecturers who were actively involved in developing the training package, on the following topics:

- Optimization of dental CBCT exposures: a practical guide, with Dr. Ruben Pauwels from Belgium;
- Justification of X-ray examinations in dentistry, with Prof. Keith Horner from United Kingdom.

These recorded lectures and two other recent webinars organized jointly with the IADMFR in 2020 are available for free viewing from the RPOP webinar page: https://www.iaea.org/resources/rpop/resources/webinars.

IV. E-LEARNING MATERIAL

The online course on Radiation Protection in Dental Radiology was provided in 2021. Its objective is to provide education in radiation protection for dentists and other dental professional staff. The format is adapted to the self-learning purposes by playing the role of a dental professional at The Family Dental Centre.

It contains nine modules summarised in Table 3, and the learning objectives presented below.

Table 3 Training modules of the e-learning course

Module #	Topic
1	'Rays and grays' 1: Understanding X rays
2	'Rays and grays' 2: What do we mean by radiation dose?
3	How it works: the technology of X ray imaging
4	Choosing the right X ray examination: basic principles
5	Choosing the right X ray examination: children and young people
6	Choosing the right X ray examination: adult patients
7	Optimization: keeping patient doses as low as diagnostically acceptable
8	Optimization: maintaining high quality in radiology
9	Protection of staff and the public who are not patients

Module 1, 'Rays and grays' 1: Understanding X rays, has the following learning outcomes:

- To be able to describe the nature of X rays;
- To explain how X rays are produced in a typical dental X ray set;
- To recognize how exposure settings change the quantity and quality of X rays;
- To outline what happens in X ray attenuation.

Module 2, 'Rays and grays' 2: What do we mean by radiation dose?, has the following learning outcomes:

- To understand how X rays interact with tissues at the cellular level;
- To recognize the difference between stochastic effects and tissue effects;
- To understand what is meant by absorbed dose and effective dose;
- To recall the typical doses seen in dental X ray examinations;
- To be able to explain risks from X rays to patients;
- To recall the fundamental principles of radiation protection.

Module 3, How it works: the technology of X ray imaging, has the following learning outcomes:

- To understand the general principles of image acquisition in intraoral and panoramic radiography;
- To understand the difference between film-based and digital image receptors used in dental radiography;
- To know when and how to use handheld intraoral radiography machines;
- To understand the general principle of image acquisition and reconstruction in cone beam CT.

Module 4, Choosing the right X ray examination: basic principles, has the following learning outcomes:

- To understand the general principles of image acquisition in intraoral and panoramic radiography;
- To understand the difference between film-based and digital image receptors used in dental radiography;
- To know when and how to use handheld intraoral radiography machines;
- To understand the general principle of image acquisition and reconstruction in cone beam CT.

Module 5, Choosing the right X ray examination: children and young people, has the following learning outcomes:

- To develop knowledge of appropriate use of dental imaging for patients who are children or young people in different clinical contexts;
- To recognize the special considerations in justification for imaging children or young people;
- To recognize that it is inappropriate to select any X ray examination without first knowing patient history and carrying out a clinical examination;
- To understand that choice of imaging must be based on the reason for patient attendance (symptoms, clinical signs and past history).

Module 6, Choosing the right X ray examination: adult patients, has the following learning outcomes:

- To develop knowledge of appropriate use of dental imaging for adult patients in different clinical contexts;
- To recognize that it is inappropriate to select any X ray examination without first knowing patient history and carrying out a clinical examination;
- To understand that choice of imaging must be based on the reason for patient attendance (symptoms, clinical signs and past history);
- To recognize that routine screening examinations lead to overuse of X rays.

Module 7, Optimization: keeping patient doses as low as diagnostically acceptable, has the following learning outcomes:

- To recognize what is meant by 'optimization';
- To recall the features of intraoral, panoramic and cephalometric radiographic equipment that affect dose to patients;
- To recall the features of cone beam CT equipment that affect dose to patients;
- To recall the features of image receptors that affect dose to patients;
- To recall the role of shielding in reducing dose to patients;
- To recognize the value of dose surveys and diagnostic reference levels in optimization;
- To apply optimization in practice.

Module 8, Optimization: maintaining high quality in radiology, has the following learning outcomes:

- To recognize what is meant by quality assurance (QA) and quality control (QC);
- To appraise clinical image quality and differentiate between causes of loss of quality;
- To recognize how to perform QA and QC for X ray equipment;
- To recognize how to perform QA and QC for film imaging;
- To recognize how to perform QA and QC for digital imaging.

Module 9, Protection of staff and the public who are not patients, has the following learning outcomes:

- To understand how to limit X ray exposure to staff and the public who are not patients;
- To understand the scatter distribution for different radiographic modalities;
- To recognize the importance of distance, working time and barriers to protection;
- To know whether personal dose monitoring is relevant;
- To apply this knowledge to everyday practice as a dentist.

The final quiz consists of 30 questions and the users need to answer at least 80% correctly in order to obtain a certificate of completion.

The e-learning is currently available in English and Spanish, and since its launching in 2021, more than 3700 people studied it and over 2500 completed the course successfully.

The e-learning on Radiation Protection in Dental Radiology can be accessed from this link: https://www.iaea.org/resources/rpop/resources/online-training#6.

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