Dental Radiography History and Radiation Protection

Core Subject

Aims:

- To give an overview of the history of medical and dental radiographs
- To give an overview on dose quantities and units of ionising radiation
- To present the health risks associated with dental radiographs
- To outline the legislation relating to ionising radiation

Objectives: On completion of this verifiable CPD article the participant will be able to demonstrate, through completion of a questionnaire, the ability to:

- Demonstrate knowledge of the history of dental radiography
- Identify dose quantities and units practical to radiation protection in dentistry
- Identify the threshold dose on whole body exposure and localised exposure to x-radiation
- To demonstrate knowledge of the legislation relating to radiography and radiation protection
- Pass a multiple choice questionnaire, scoring higher than 70%

Introduction

Radiography today is an invaluable tool for the dental professional, providing information that is impossible to obtain by clinical examination alone. Techniques exist for imaging the teeth, mandible, maxilla, temporomandibular joints and the oral and labial soft tissues. Some form of radiographic examination is necessary on the majority of our patients and as a result of this radiographs are often referred to as the clinicians main diagnostic aid.

Most dental practices will have intra-oral units for periapical, bitewing and occlusal radiography and many will have units for extra-oral radiography such as dental panoramic tomography and lateral cephalometry. A few practices may have cone beam computed tomography units, particularly where complex orthodontic and implant work is performed.

This article will discuss the training required for dental radiography, provide a brief history of radiographs and dental radiographs, and will give an overview of the legislation relating to dental radiography.
The History of Radiographs

Wilhelm Conrad Röntgen discovered X-rays in November 1895. There are many different accounts as to how this discovery occurred. One such account is that Röntgen was experimenting with cathode rays (electrons) in a high energy cathode ray tube. Röntgen observed that there was a plate of barium platinocyanide nearby, which glowed in the dark. Röntgen dubbed these mysterious rays capable of passing through glass “X” (for unknown) and subsequently tried to block them with a variety of material. He used aluminium, copper and even the walls of his lab—to no avail. When Röntgen held a piece of lead in front of the electron-discharge tube, it blocked the rays, but he was able to see his own flesh glowing around his bones on the fluorescent screen behind his hand. The image below, said to be of Röntgen’s wife’s hand, is thought to be the first documented radiograph on a human body.

The first medical radiograph

In 1901 Wilhelm Konrad Röntgen was the first recipient of the Nobel Prize for Physics. His discovery revolutionised the medical world, making it possible to look inside the human body without surgical intervention. Within a year, the first radiology department opened in a Glasgow hospital, and the department head produced the first pictures of a kidney stone and a penny lodged in a child’s throat. Shortly after, an American physiologist used X-rays to trace food making its way through the digestive system.²
In 1896, Dr Otto Walkhoff is credited with the first dental radiograph which was in his own mouth and was taken on glass plates wrapped in rubber dam.

The image below is of an early x-ray machine. Although the basic design of the X-ray machine has not changed much, the required exposure time has. An exposure today can be measured in milliseconds, whereas the exposure time for the first dental radiograph was 25 minutes.  

Health Risks

Dr George Pirie was a pioneer in the clinical application to medical radiographs but he was forced to retire due to ill health after 10 years of nearly daily exposure to primitive x-rays. His eyesight began to fail and he developed characteristic tumours in his hands. He lost his right hand and the thumb and part of his little finger on his left hand which eventually was also amputated. Once the danger of exposure to X-rays was realised, early forms of protection included a lead-lined mask with glass goggles. Fortunately, the dose from X-radiation exposure today is much lower than it used to be.

A dose of 1 SV is a very large dose and enough to cause radiation injuries. However,
during routine dental radiography, doses to employees and patients are measured in thousandths and millionths of a Sievert. The table below denotes the fractions of a Sievert that are used to measure doses in radiography.

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Prefix</th>
<th>Abbreviation</th>
</tr>
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<tbody>
<tr>
<td>1/1000th</td>
<td>Milli</td>
<td>m</td>
</tr>
<tr>
<td>1/1000 000th</td>
<td>Micro</td>
<td>u</td>
</tr>
<tr>
<td>1/1000 000 000</td>
<td>Nano</td>
<td>n</td>
</tr>
</tbody>
</table>

As far as the risks to health are concerned, the probability of developing cancer from ionising radiation is derived from studies of populations that have received known and usually significant radiation doses. These include:

- The survivors of the nuclear disaster at Chernobyl.
- Radiation workers.
- Person’s exposed during certain medical procedures.

The radiation exposures for these populations have been relatively high, with doses received mainly from acute exposures. Thus knowledge of the risk of these high levels does exist, but our knowledge of the risks at low exposure is more limited. However, it is estimated to follow a roughly linear line (figure 1) and no dosage of radiation, no matter how small, is without risk. This is called the ‘no threshold theory’.

![Figure 1 The Risk of Developing Cancer from Ionising Radiation](image)
The table below shows the effect of ionising radiation and corresponding threshold dose. However, the values apply only in respect of acute doses when the dose is received in a single exposure, or over a short period of time. Where the dose is received over a longer period of time the effects may be very much less pronounced.4

<table>
<thead>
<tr>
<th>Effect</th>
<th>Approximate Threshold Dose</th>
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<tbody>
<tr>
<td><strong>Whole Body Exposure</strong></td>
<td></td>
</tr>
<tr>
<td>Detectable chromosome changes</td>
<td>0.1 SV</td>
</tr>
<tr>
<td>Detectable changes in blood count</td>
<td>1 SV</td>
</tr>
<tr>
<td>Radiation sickness</td>
<td>1 SV</td>
</tr>
<tr>
<td>Death possible</td>
<td>3 SV</td>
</tr>
<tr>
<td>Death certain</td>
<td>10 SV</td>
</tr>
<tr>
<td><strong>Localised Exposure</strong></td>
<td></td>
</tr>
<tr>
<td>Erythema (radiation burn)</td>
<td>5 SV</td>
</tr>
<tr>
<td>Depilation (hair loss)</td>
<td></td>
</tr>
<tr>
<td>-temporary</td>
<td>4 SV</td>
</tr>
<tr>
<td>-permanent</td>
<td>7 SV</td>
</tr>
<tr>
<td>Desquamation (skin loss)</td>
<td>20 SV</td>
</tr>
</tbody>
</table>

When comparing radiation dosage it is also important to be aware that every day, we are exposed to natural background radiation. The table below highlights some natural sources of radiation that an individual receives each year from background radiation.5

<table>
<thead>
<tr>
<th>Radiation Source</th>
<th>Average Annual Dose (uSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic rays</td>
<td>300</td>
</tr>
<tr>
<td>External exposure from the earth’s crust</td>
<td>400</td>
</tr>
<tr>
<td>Internal radiation from certain foodstuffs</td>
<td>370</td>
</tr>
<tr>
<td>Exposure to radon and its decay products</td>
<td>700</td>
</tr>
</tbody>
</table>

In mSv, these annual amounts of radiation are equal to approximately 2.7 mSv. If this is compared to the ionising radiation that is received from a dental bitewing (0.001-
0.008 mSv), it can be seen that the radiation dose received from a dental x-ray is comparatively small when compared to the natural background radiation each individual receives on a daily basis. However, the dental team need to consider that every radiograph that is taken adds to the amount of ionising that the patient has received.

Radiation Protection

There are two sets of regulations in the UK governing the use of ionising radiation. These are:

- The Ionising Radiation Regulations 1999 (IRR99) which are primarily concerned with the radiographic equipment, the workers and the public and is enforced by the Health and Safety Executive. The Ionising Radiation (Medical Exposure) Regulations 2000 IR(ME)R2000 (amended in 2006 and 2011) which are primarily concerned with the protection of the patient. These are enforced in the UK by: the Care Quality Commission (CQC) in England; the Healthcare Inspectorate Wales (HIW) in Wales; the Scottish Executive (SE) in Scotland; and, the Regulation and Quality Improvement Authority (RQIA) in Northern Ireland.

These both form part of the Health and Safety at Work Act 1974.

1) Ionising Radiation Regulations 1999

These regulations primarily protect the dental team. However, they also include references to the equipment and aspects of patient protection. Some of the essential legal requirements of IRR99 are outlined below:

- The Health and Safety Executive must be notified of the routine use of dental x-ray equipment and any change of practice ownership or premises
- The installer is responsible for a critical examination and report of all new or significantly modified dental equipment
- All equipment must be routinely tested as part of the quality assurance programme
- A risk assessment must be undertaken before work commences and this must be subject to a regular review
- A Radiation Protection Advisor (RPA) must be appointed. This is an individual who is able to advise on how to comply successfully with the legislation
- A Radiation Protection Supervisor should be appointed. This differs from the RPA in that it may be a member of the dental team
The international commission on radiological protection cover all aspects of radiological protection. The recommended system of dose limitation is summarised into three basic components. That is that there should be:

- Justification of practice.
- Optimisation of radiation protection.
- Dose limits for individuals at work and for members of the public.\(^9\)

The primary concern is to keep exposures at the lowest practicable level. In English law this is known by the acronym ALARP which is keeping exposures:

As
Low
As
Reasonably
Practicable

This requirement is specifically included in the Ionising Radiations Regulations 1999 and employers deemed not to be keeping exposures as low as they reasonably can, could be at risk of prosecution.

- Information, instruction and training needs to be provided as appropriate, and records need to be kept. Practices should have a radiation protection file

- The legal person and employee must:
  
  - not knowingly expose themselves or any other person to x-rays to an extent greater than is reasonably necessary for the purposes of their work
  - exercise reasonable care when working on any aspect of dental radiology
  - Immediately report to the legal person whenever they have reasonable cause to believe that an incident or accident has occurred with the x-ray equipment and they or some other person have received an overexposure.

- All practices should have a set of Local Rules. Information should include:
  
  - the name of the RPS
  - identification and description of the controlled area
  - summary of working instructions including names of staff qualified to use the x-ray equipment and details of their training as well as instructions on the use of equipment
  - contingency arrangements in the event of an equipment malfunction and/or accidental exposure to radiation
  - the name of the person with legal responsibility of compliance with the regulations
  - the name and contact details of the RPA
  - details and results of dose-investigation levels (a does constraint of no higher than 1 mSv per year us recommended for practice staff)
2) The Ionising Radiation (Medical Exposure) Regulations 2000 (amended in 2006 and 2011)\(^8\)

The Ionising Radiation (Medical Exposure) Regulations 2000 (IRMER) concern the protection of the patient.

The regulations require that radiographs are reproduced at optimum quality and with minimum exposure to the patient and that every exposure is justified.

Practices should keep an inventory of each item of equipment and the maintenance history. Clinical audits must be carried out and these topics can include the various aspects of the quality assurance programme. Such topics may include:

- image quality
- patient dose
- darkroom, films and processing
- training

IR(ME)R 2000 define positions of responsibility. These are:

- The employer
- The referrer- The registered dental professional entitled to refer a patient to a practitioner for a medical exposure
- The practitioner- No exposure can take place unless it is justified by the IRMER practitioner. For an exposure to be justified the benefit to the patient from the diagnostic information should outweigh the detriment of the exposure. The 2013 Selection Criteria in Dental Radiography states that there is no justification for routine radiographs to be taken on new patients.\(^9\)
- The operator who is the person conducting any practical aspect of a medical exposure (for example processing the films or reading phosphor plates.)

**Training**
Dental hygienists, dental therapists and dental nurses who are IR(ME)R Practitioners and operate x-ray machines must have received adequate training in accordance with the relevant regulations. The National Radiological Protection Board describes an adequately trained DCP as one who “possesses a Certificate in Dental Radiography conforming to the syllabus prescribed by the College of Radiographers.” Following qualification, the National Radiological Protection Board state that those who operate x-ray machines are recommended to attend a continuing education and training course every five years to comply with The Ionising Radiation (Medical Exposure) Regulations 2000. Appropriate courses would be expected to cover:

- the principles of radiation physics;
- risks of ionising radiation;
- radiation doses in dental radiography;
- factors affecting dose in dental radiography;
- the principles of radiation protection;
- statutory requirements; and,
- quality assurance.\(^9\)

DCPs whose duties include other duties in relation to radiography, such as film processing, clinical evaluating of radiographs and quality assurance must have received adequate and documented training, specific to the tasks they undertake, and this training may be provided ‘in house.’ In addition, the General Dental Council advise that DCPs should undertake five hours of verifiable CPD in Dental Radiography and Radiation Protection in each five year CPD cycle.

The Guidance Notes for Dental Practitioners on Safe Use of X-Ray Equipment state that “Dental nurses who ‘press the exposure button’ as part of a patient exposure that has been physically set up by an adequately trained operator, may only do so in the continued presence, and under the direct supervision, of that operator. They must have received documented instruction appropriate to this task.”\(^9\)

**Dental Radiographic Examinations**

It has been reported that dental radiographic examinations represent the most widespread use of x-ray in medicine. Although typical doses from dental radiographs are low, a review of patient dose which was undertaken in 2002, found that dentists are responsible for over 30% of all dental and medical radiographic examinations in the UK. Therefore, it is important that doses from x-ray examinations are kept as low as reasonably practicable. This requirement is the main focus of the IRR99 and IRMER2000.\(^4\)

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**Non-Verifiable CPD Tips**

We recommend that you carry out non verifiable CPD related to this subject. The following documents are available to you from the non verifiable CPD section of the website:

- The Ionising Radiation Regulations 1999 (IRR99)
- The Ionising Radiation (Medical Exposure) Regulations 2000 (IRMER)
References
10. FGDP UK (2013) Selection criteria for dental radiography 3rd edn. Faculty of General Dental Practice