John Rout

Jackie Brown

This article counts towards one of the five core subjects introduced in 2007 by the GDC.

Ionizing Radiation Regulations and the Dental Practitioner: 1. The Nature of Ionizing Radiation and Its Use in Dentistry

Abstract: Legislation governing the use of ionizing radiation in the workplace and in medical treatment first became law in 1985 and 1988, being superseded by the Ionizing Radiations Regulations 1999 (IRR99)[1] and the Ionizing Radiation (Medical Exposure) Regulations 2000, (IR(ME)R 2000),[2] respectively. This legislation ensures a safe environment in which to work and receive treatment and requires that those involved in the radiographic process must be appropriately trained for the type of radiographic practice they perform. A list of the topics required is detailed in Schedule 2 of IR(ME)R 2000 and is paraphrased in Table 1, with the extent and amount of knowledge required depending on the type of radiographic practice undertaken.

Clinical Relevance: Virtually all dental practitioners undertake radiography as part of their clinical practice. Legislation requires that users of radiation, including dentists and members of the dental team, understand the basic principles of radiation physics, hazards and protection, and are able to undertake dental radiography safely with the production of high quality, diagnostic images.

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The aim of this series of three articles is to complement existing theoretical knowledge acquired at undergraduate level required, particularly for *practitioners* and *operators,* as defined by the Ionizing Radiation Regulations and outlined in Table 1. They are not meant to be a comprehensive account nor are they designed to replace attendance at update courses on radiation protection, but to outline aspects of the regulations. For a full account, the reader is referred to the legislation itself,[1,2] the documentation that accompanies the legislation, in particular the Guidance notes for Dental Practitioners,[3] by consulting the relevant texts, such as that produced by Whaites[4] and by keeping up-to-date by reading journal articles.

John Rout, BDS, FDS RCS, DDR RCR, MDentSci, FRCR, Consultant Radiologist, Department of Radiography, Birmingham Dental Hospital, St Chad's Queensway, Birmingham and **Jackie Brown**, BDS, MSc, FDS RCPS, DDR RCR, Consultant Dental Radiologist, KCL Dental Institute of Guy's, King's College and St Thomas' Hospital, London SE1 9RT, UK.

Radiation physics

The legislation requires an appropriate knowledge of radiation physics, the nature of ionizing radiation and its interactions. As these take place at the atomic level, a brief description of the atom now follows.

Principles of radiation physics
Risks of ionizing radiation
Radiation doses in dental radiography
Factors affecting doses in dental radiography
Principles of radiation protection
Statutory requirements
Selection criteria
Quality assurance

Table 1. A shortlist of requirements for working in a radiographic environment.

The atom

All matter consists of atoms. The traditional concept of the atom is of a central nucleus made up of protons and neutrons around which electrons orbit at defined distances from the nucleus (Figure 1), much as the planets circle around the sun. The atomic structure is far more complex and this conventional concept has been replaced by the theory of electrons inhabiting regions of space around the nucleus called orbitals. In this

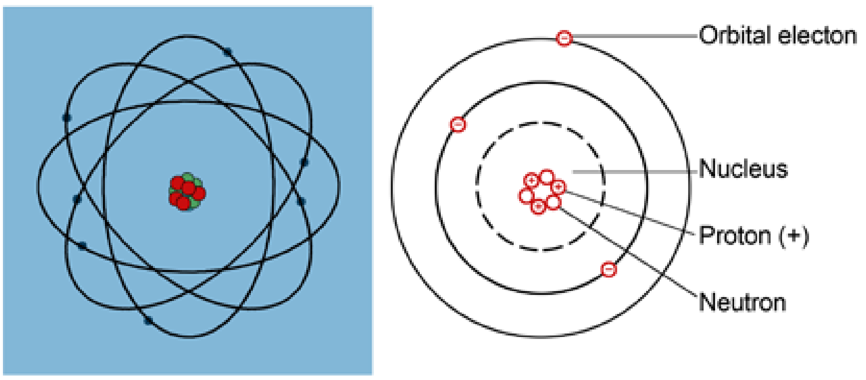

Figure 1. Basic structure of the atom.

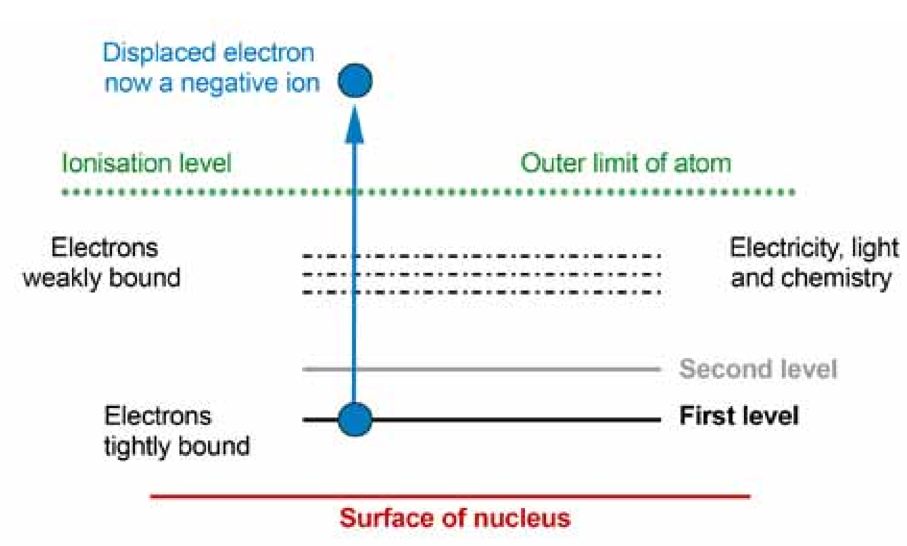

Figure 2. Line diagram illustrating ionization.

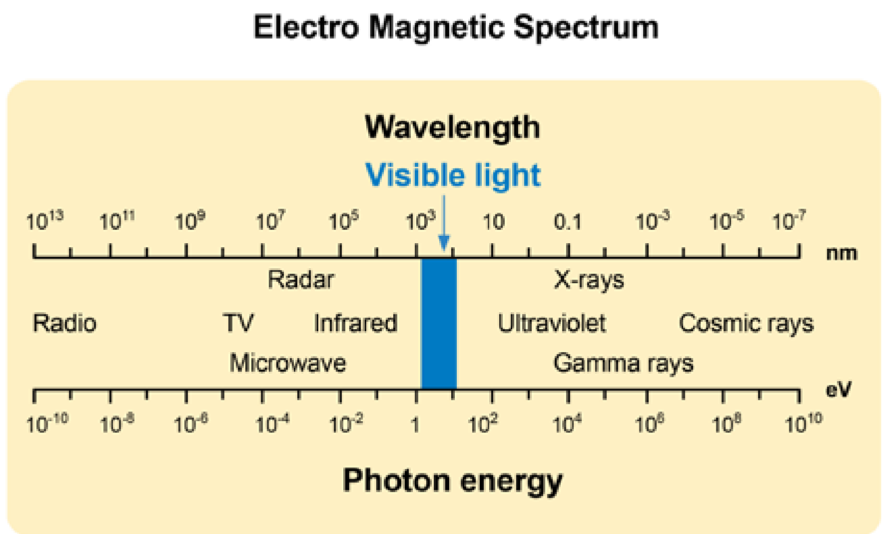

Figure 3. Diagrammatic representation of the electromagnetic spectrum.

format, electrons look more like clouds that indicate the probable position of an electron at any given time. Different atoms and their orbitals vary in shape, size and complexity, so for simplicity, the traditional model for the atom, as shown in Figure 1, is used in this article to describe X-ray interactions.

Each proton has mass and a positive charge whilst the neutron has a similar mass to the proton but no charge. The number of protons defines the element and determines its atomic number (Z). Each atom has the same number of electrons as protons. An electron has virtually no mass but a negative charge which balances out that of the proton. Provided there are equal numbers of protons and electrons there is electrical and thus atomic stability. Electrons are held in their orbits by electrostatic or binding forces, produced by the nucleus. The bigger the atom the greater are the number of protons and neutrons within the nucleus. The larger the nucleus, the stronger are the 'binding' forces holding the electrons within the atom. To remove an electron from its orbit requires enough energy to overcome the binding forces produced by the nucleus. When this happens the electron becomes a negative ion and the atom a positive ion, the process being called ionization (Figure 2). There are certain radiations that have sufficient energy to displace electrons and these are called the ionizing radiations.

Ionizing radiation

There are two basic types of ionizing radiation:

- Particulate radiation;
- Electromagnetic radiation.

Particulate radiation

Particulate radiation, as its name implies, is made up of particles such as neutrons and electrons. For example, isotopes of uranium give off alpha particles, which consist of 2 protons and 2 neutrons. In atomic terms alpha particles are very heavy and this, combined with its double charge, makes them highly reactive and particularly damaging to the tissues.

Electrons, on the other hand, are light, having very little mass, each one possessing just a single negative charge.

As a consequence, they are much less reactive than alpha particles and are less likely to cause tissue damage. High speed electrons are also called beta radiation or beta particles.

Electromagnetic radiation (EMR)

Electromagnetic radiation (EMR) is the movement of energy through space and, as it does so, it gives off electric and magnetic fields at right angles to each other. One can see from a diagrammatic representation of the electromagnetic spectrum (Figure 3) that, as the wave length becomes shorter, the photon energy increases and the properties of the radiation change. There comes a point when the energy level is sufficiently powerful to displace an electron from the binding forces holding it within the atom (ionization). X-rays, gamma rays and cosmic rays all have enough energy to cause ionization.

The properties of electromagnetic radiation can in part be explained by the wave theory (eg reflection of light), whilst other actions, such as those of X-rays, are more easily understood by the quantum theory. This theory regards electromagnetic radiation as being made up of packets, or finite bundles, of energy called photons. A dental X-ray beam consists of lots of photons at different energy levels.

Ionizing radiation occurs naturally and has done so since the beginning of time. It is found in our environment from naturally occurring radioactive substances and it also comes from space in the form of cosmic radiation. The largest contribution of natural background radiation is alpha particles that are emitted from radon gas which seeps out from the ground. Concentrations of radon gas vary in different regions, being particularly high in the south-west region of the UK. The average UK radiation dose from radon is 1.3mSv, however, in Cornwall the average radon dose is 7.8mSv.

Following the discovery of X-rays, we have been adding to the amount of natural background radiation to which we are all exposed, so that artificial sources now account for approximately 16% of the typical annual exposure in the UK. Medical radiography, including dental radiography, is the largest contributor of artificially made radiation (15%), other sources coming from industry, consumer products and nuclear weapons testing.

Figure 4 shows the distribution of the average doses from both naturally occurring and man-made ionizing radiation that a person in the UK is likely to receive. Radiation from natural sources typically accounts for 84% of the total dose in the UK, although this will vary, depending on where one lives and with occupation. For example, cosmic radiation levels increase with distance from the ground, so frequent fliers, such as aircrew, receive larger doses of cosmic radiation than those who work at ground level. A single transatlantic flight can result in a dose of up to 0.07mSv compared to a full dental panoramic radiograph of about 0.02mSv (HPA 2012).

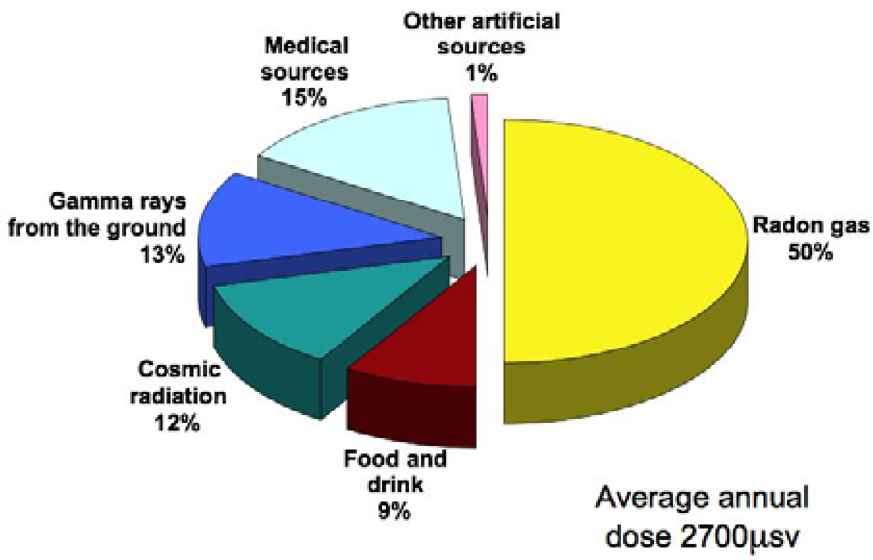

Figure 4. Pie chart of the average annual radiation doses expressed as percentages to the UK population.

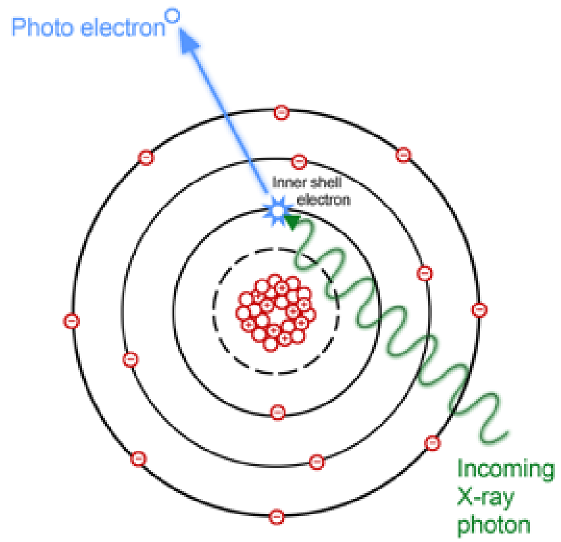

Figure 5. X-ray photon interacting with an inner orbiting electron resulting in absorption.

X-radiation

In 1895, X-rays were discovered by Wilhelm Röntgen who found that they could penetrate matter and produce an image on a photographic plate. The first known radiograph was that of a hand thought to be either that of his wife or his assistant. The news of the discovery of X-rays spread rapidly and, within one month of Röntgen's announcement, the first dental radiograph was taken on glass plates wrapped in rubber dam with the exposure time being in excess of 20 minutes. Initially, it was thought that these images of teeth and bones were formed by some mysterious ray, or X-ray, that emanated from the electrical apparatus, 'X' denoting the unknown factor.

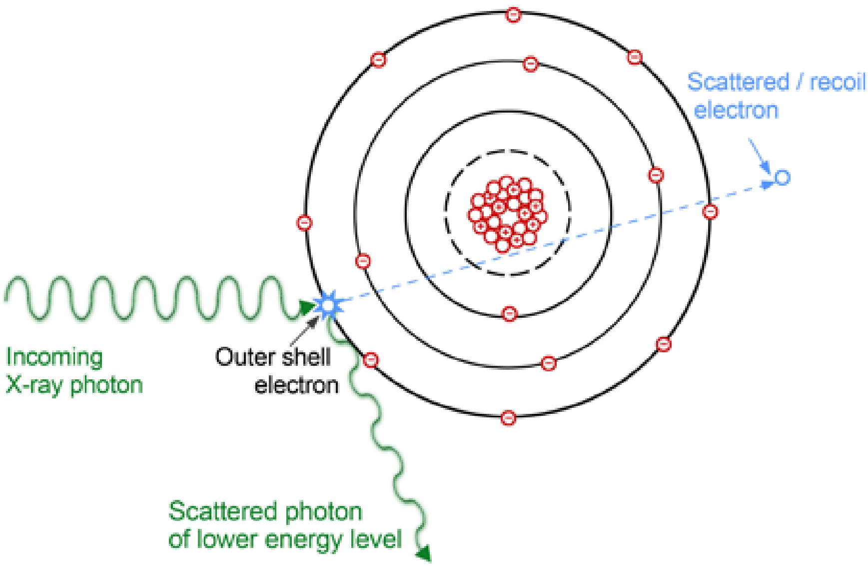

Figure 6. X-ray photon interacting with an outer orbiting electron resulting in scatter.

Radiation Type	Radiation Weighting Factor (W_R)
X-rays	1
Fast neutrons	10
Alpha particles	20

Table 2. Some of the radiation weighting factors.

X-ray interactions

When an X-ray photon passes through matter there may be no interaction and so it passes completely through unaffected, or it may be absorbed and/or scattered.

Absorption

Absorption (photoelectric effect) occurs when an X-ray photon interacts with a tightly bound, inner electron which it displaces from the atom, as shown in Figure 5. In this process all the energy of the photon is used up in displacing the electron, now called a photo-electron, which then undergoes further interactions. The lost electron is replaced by rearrangement of the remaining electrons with the release of characteristic radiation. Absorption accounts for about a quarter of interactions in dental radiography.

It is proportional to density, and is markedly dependant on the atomic number of the absorber: in fact it increases by the cube of the atomic number (Z^3). This is why high atomic number elements, such as lead, are used in radiation protection.

However, absorption is inversely proportional to the energy of the photon ($1/E^3$), thus low energy photons (soft X-rays) are more likely to be absorbed than higher energy photons, which have much greater penetrability.

The ability of different substances to absorb X-rays by varying amounts is the reason for the production of an image (different shades of grey) on the radiograph. Accordingly, the soft tissues, which have a low atomic number and density, absorb far fewer photons so more reach the film, producing a dark shadow which appears radiolucent. Dense substances, such as cortical bone, dentine and enamel appear as different shades of radio-opacity, and higher atomic number substances, such as metals, eg amalgam, as densely radio-opaque.

Compton scatter

Compton scatter accounts for about half of X-ray interactions occurring during dental radiography. Scatter is proportional to tissue density and so is more likely to result from interactions with the teeth and cortical bone than with the soft tissues. It occurs when a photon displaces an outer or weakly bound electron from the atom and, in doing so, loses only some of its energy, as shown in Figure 6. The attenuated scattered photon continues to travel, but in a different direction, having further interactions. The amount of attenuation varies, however, about 40% of scattered photons have sufficient energy to exit the patient, the remainder travelling within the individual giving dose to distant organs and tissues. Scatter is an unwanted effect of imaging as it contributes to patient and operator dose and causes film fogging.

Radiation dose

Both absorption and scatter result in dose. Dose can be regarded as the amount of energy taken from an X-ray beam and deposited in the tissues through ionization. Different types of ionizing radiation vary in their ability to cause ionization and tissues vary in their sensitivity to the effects of radiation. Thus some types of radiation are more harmful than others and some tissues are more affected by radiation than others. There are several dose measurements units.

Absorbed dose (D)

The absorbed dose is simply a measure of the amount of energy absorbed from the radiation beam. It is measured in Grays (Gy).

Equivalent dose (H)

This dose measurement allows for the fact that different types of ionizing radiation vary in their ability to cause tissue damage. Radiation is weighted according to its damaging effects. Some of the weighting factors are shown in Table 2.

To obtain the equivalent dose the radiation weighting factor is multiplied by the absorbed dose. The dose unit is the Sievert (Sv).

Equivalent dose (H) = radiation weighting factor (W_R) x radiation absorbed dose (D)

Tissue	1990 WT	2007 WT
Bone marrow	0.12	0.12
Breast	0.05	0.12
Colon	0.12	0.12
Lung	0.12	0.12
Stomach	0.12	0.12
Bladder	0.05	0.04
Oesophagus	0.05	0.04
Gonads	0.20	0.08
Liver	0.05	0.04
Thyroid	0.05	0.04
Bone surface	0.01	0.01
Brain	–	0.01
Kidneys	–	0.01
Salivary glands	–	0.01
Skin	0.01	0.01
Remainder tissues	0.05	0.12

Table 3. The tissue weighting factors (WT) for 1990 and the 2007 revised values.

Effective dose (E)

This is one of the most frequently used dose measurements in radiation protection. It takes into account both the type of radiation and tissue radio-sensitivity. Tissues or organs are weighted according to their susceptibility to radiation. The most radiosensitive organs and their weighting factors are shown in Table 3. These values were revised by the International Commission on Radiological Protection (ICRP) in 2007 based on new evidence of the stochastic effects of radiation and, for the first time, included the salivary glands as radiosensitive tissue (Table 3). This has implications for dental panoramic radiography (OPG or DPT) because this examination delivers a relatively high dose to the salivary glands, which lie in the primary beam. As a consequence, the effective dose, and thus the risk of producing a stochastic effect for an OPG or DPT, is now double that when compared to the 1990 data.

The effective dose is obtained by measuring and summating the doses to critical organs exposed in a particular radiographic examination, and converting this to a dose value equivalent to a whole body exposure. It allows the dose from any radiographic examination to be compared and an estimation to be made of the risk associated with an examination, be it from a bitewing, dental panoramic radiograph or CT scan. The unit of measurement of the effective dose is the Sievert (milliSievert mSv).

The measurement is obtained by multiplying the equivalent dose (H) to each organ, measured on a tissue equivalent phantom, by the tissue weighting factors W_T.

Effective dose (E) = equivalent dose (H) x tissue weighting factors (W_T)

This dose allows the dentist to be aware of the comparable risks of producing a stochastic effect (defined below) and is part of the decision-making process when choosing the most appropriate choice of X-ray examination.

Collective dose

Dental radiography is one of the commonest radiographic examinations in the UK, thus the dentist should be mindful of the collective dose measurement. It is simply the dose to a population from a particular radiographic investigation. It is obtained by multiplying the effective dose by the exposed population and is measured as the man-Sievert.

Hazards associated with radiation

The harmful effects associated with radiation were noticed soon after Röntgen's discovery. These resulted from long exposure times, large radiation fields, inefficient X-ray sets and slow image receptor speeds. Initially, there was little in the way of personal protection for the operator or patient. The radiologist would often stand in the primary beam with little or no protection and the dentist frequently held the film in the patient's mouth during the exposure. As a consequence, some of the initial X-ray pioneers suffered repeated exposures to radiation, resulting in tissue damage with a number subsequently developing cancer. Studies into these harmful effects showed that those cells that divide frequently, such as epithelium, were more sensitive to the effects of radiation than those which divided infrequently.

Effects of radiation

The effects of radiation are classified as:

- Deterministic (certainty)
- Stochastic (random).

Deterministic effects

For a deterministic effect to occur a threshold level of radiation must be reached. As the dose increases beyond the threshold level, the severity of the effect increases, so the higher the dose the more marked the effect. Deterministic effects include skin redness, mucositis, ulceration, endarteritis and blood cell changes. Such effects do not occur during routine diagnostic radiography, where dose levels are well below the threshold level.

Stochastic effects

Stochastic effects occur in a random fashion being governed by chance, so the probability of an effect is dose-related. There does not appear to be a threshold level so any dose of radiation, however low, has the potential to produce a stochastic effect, even just one bitewing. A low dose has a low probability of causing an effect but the likelihood increases

Age in years	Stochastic risk multiplication factor
Below 10	× 3.0
10–20	× 2.0
20–30	× 1.5
30–50	× 0.5
50–80	× 0.3
Over 80	Negligible

Table 4. Risk of cancer induction from ionizing radiation in relation to age.

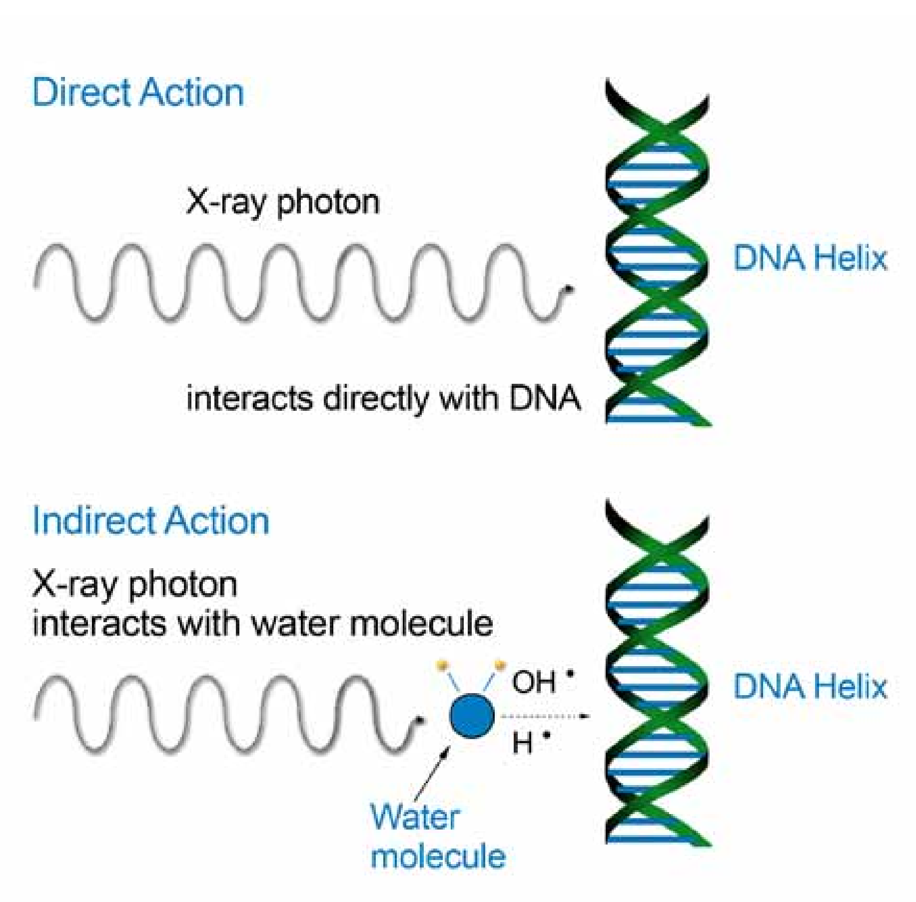

Figure 7. Diagrammatic representation of damage to cellular DNA.

as the dose level increases. The effects from dental radiography come under this category. The stochastic effects include the development of malignant tumours and genetic abnormalities.

There have been several studies of individuals who have received exposure to high levels of radiation, most notably on the survivors of the atomic bombs dropped on Hiroshima and Nagasaki, both of which gave off neutrons and gamma radiation (particulate and electromagnetic radiation). These studies showed that there is a long latent period after the exposure to radiation before a malignancy becomes apparent. This is usually less than 10 years for leukaemia but can be in excess of 20 years in the case of solid tumours such as sarcomas and carcinomas.

Although there is much evidence which links cancer formation and radiation exposure at high doses, there are few human studies on the effects of exposure to low levels of radiation. A recently published investigation by Muirhead *et al* [5] looked at the long-term effects on individuals who received doses from occupational exposure to radiation, ie low levels of radiation. This study began in 1976 and, by correlating the findings with the cancer registry showed that, as the dose increases, so does the risk for developing a cancer, supporting other previous work on the linear relationship of dose to a stochastic effect.

There is an association of exposure to radiation and the subsequent development of cancer. It appears that the nucleus, particularly the DNA, is the target for the radiation. With low doses, the damage to the DNA is usually minor and there are systems and enzymes in the body that repair the altered DNA. As the dose increases, more severe damage occurs, such as a single or double helix strand break, much of which is not repaired with the altered DNA being transferred each time the cell divides.

The damage is thought to occur by two mechanisms, the direct method and the indirect method. In the former, the X-ray photon disrupts the chemical bonds that hold biochemical molecules together. There is more than sufficient energy in X-ray photons to do this.

In the indirect method, the X-ray photons interact with water in the tissues forming ions and free radicals. These are highly reactive and result in the formation of cellular toxic products, such as hydrogen peroxide, or the free radicals and ions, such as hydroxyls, that damage the biochemical make-up of the DNA. The direct and indirect effects are illustrated diagrammatically in Figure 7. Probably both mechanisms take place but it seems that the direct effects are more likely to occur with alpha particles where there are numerous interactions in a small area and the indirect effects with radiation such as X-rays, where there are less frequent events per unit volume.

The more frequently a cell divides the more susceptible it is to the effects of radiation. This has an implication for children, whose cells have a faster turn over than the elderly, making them much more sensitive to the effects of radiation and thus at greater risk of cancer induction from ionizing radiation. Table 4 shows the risk in relation to age. From this table it can be seen that a child under the age of 10 years has a ten times greater risk of a

Figure 8. (a) Thyroid collar; **(b)** thyroid shield.

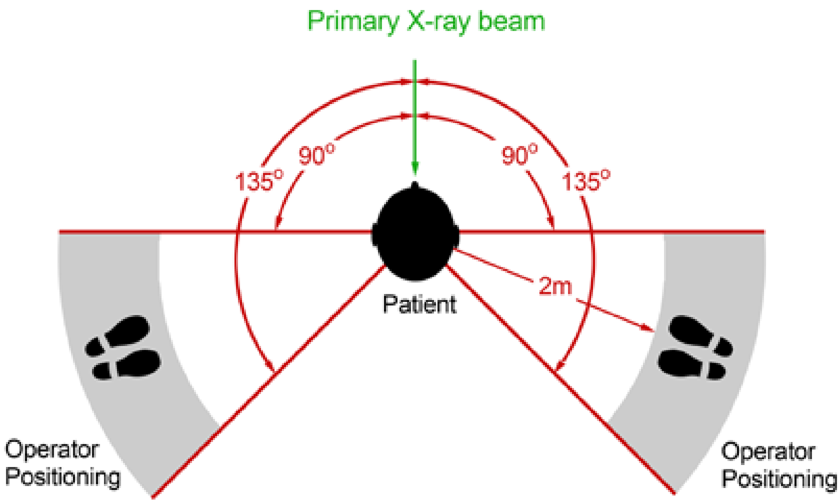

Figure 9. 'Footprints' showing where scattered radiation levels are least.

stochastic effect from an X-ray examination than a person who is over 50 years of age. Or, put another way, 10 dental panoramic radiographs (OPG/DPT) taken on someone aged over 50 years carries the same risk as taking just one dental panoramic radiograph on a child under 10 years of age.

Because dental radiography is a low dose technique, the risk of causing a stochastic effect is low. However, dental radiography is one of the most frequently undertaken medical radiographic examinations, accounting for about one-third of all X-ray examinations in the UK. As the stochastic effect is a random event, the larger the number of examinations to a population, the greater the chance there is of producing a stochastic effect to that population.

Dose limitation

Dose limitation can be brought about by:

- Reducing the amount of radiation required to produce a radiograph whilst still maintaining a diagnostic image. This is the ALARP principle – keeping doses As Low As Reasonably Practicable.
- Being selective when radiographs are taken and using those views that are likely to provide the relevant information and so benefit the patient – selection (referral) criteria.

Great strides have been made in recent years to reduce patient doses from dental radiography and some of these are now briefly discussed.

The X-ray set

Although the basic concept of the X-ray set has changed little over the last 100 years, the design of dental X-ray sets has improved markedly, especially in the last 30 years. The use of higher kilovoltages has resulted in a more penetrating beam so that fewer X-ray photons are absorbed by the soft tissues which are non-contributory to the image and has resulted in lower effective patient dose. Direct current (DC) technology, now used in many dental X-ray sets, improves the efficiency of X-ray photon production, shortening exposure times and reducing patient skin dose. However, using direct current and higher kilovoltage (eg 70kV) sets produces an image that has less contrast when compared with one made using a lower kilovoltage, eg 50kV, typical of sets used during much of the 20th century. It is thus important to ensure optimal film processing as inappropriate processing could result in further contrast loss.

Early dental sets used a short focus to skin distance (short cone) resulting in a divergent beam, whereas current dental X-rays sets use a 20 cm focus to skin distance resulting in a narrower field of radiation and lower patient dose. The dose can be reduced further by using rectangular rather than round collimation. The aperture at the end of a rectangular collimator is the same size and shape as that of a size 2 periapical film. This significantly reduces radiation field size and so the dose to the patient is reduced by up to 50%, when compared to a set fitted with a 6 cm round collimator.

Lead protection

Lead aprons were at one time the mainstay of radiation protection used in dental radiography. However, in 1994, the National Radiological Protection Board (NRPB), now part of the Health Protection Agency (HPA), stated that there was no need for the routine use of lead aprons during dental radiography, when using modern equipment and techniques, because the beam is not directed at the organs covered by the lead apron, but gave the operator a false impression that the patient was protected. However, for certain maxillary projections where the thyroid gland (a radiosensitive organ) is likely to be in the primary beam, it is advisable to use a thyroid shield or thyroid collar (Figure 8). For panoramic

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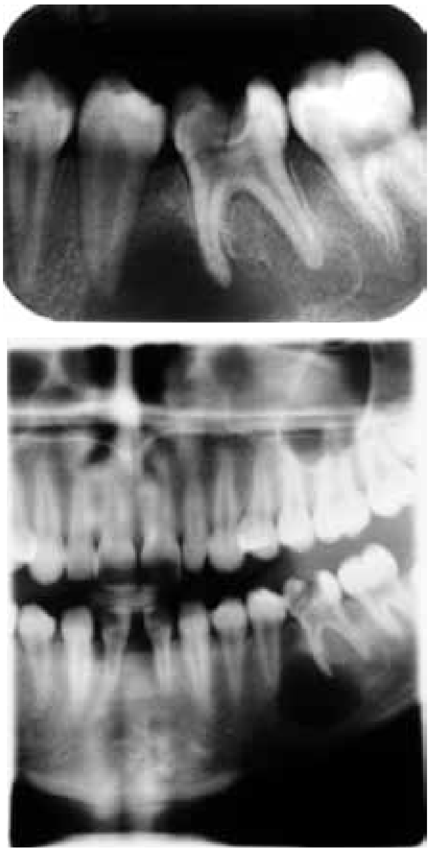
b


Figure 10. (a,b) An example where a sectional panoramic radiography depicts the whole of the lesion not fully shown on the periapical film.

radiography, the use of lead aprons was positively discouraged as it could intersect the primary beam before reaching the patient so obscuring part of the image.

However, lead aprons should be kept to protect anyone, apart from the patient, who enters the controlled area. This might be a carer or parent who is required to support a patient, such as a child, during the exposure. Lead aprons and thyroid shields should have an equivalent of at least 0.25 mm lead protection.

An appropriate lead screen can be used as a protective barrier when it is not possible for the operator to stand in a safe position. When not using a lead barrier, the operator must stand at least 2 metres from the patient and X-ray set and never in the primary beam. Figure 9 shows where the amount of scattered radiation is at its least and thus the preferred place for the operator to stand.

Lead may also be necessary to prevent transmission to adjacent rooms, however, other substances with a suitable lead equivalence may be a cheaper alternative. The advice of the Radiation Protection Advisor should be sought on such matters.

The image receptor

Intra-oral film speed has increased over the last 30 years or so. At one time 'D' speed film was the mainstay of dental radiography. The introduction of 'E' and 'F' speed film has halved exposure times, producing 50% reduction in patient dose compared with D speed film. Improved film emulsion design has increased film speed whilst maintaining film contrast and resolution.

Advances in extra-oral film technology have improved the light gathering capability of extra-oral film emulsion. This, coupled with more efficient rare earth intensifying screens, has reduced patient dose for dental panoramic and cephalometric radiography. It is important to match the type of extra-oral film with the appropriate rare earth intensifying screens as films are either green or blue light sensitive and screens either emit green or blue light.

Intra-oral solid state digital sensors and stimulable phosphor plates require less radiation to produce an image than with intra-oral dental film, which can be as much as 50% when compared with E speed film. However, there is less dose reduction for some types of extra-oral digital imaging systems when compared with extra-oral film.

Radiographic technique

The operator must be adequately trained in the techniques he/she undertakes. The use of film holders has been shown to reduce the number of retakes, as well as providing a dimensionally accurate image. For panoramic radiography, accurate patient alignment is crucial and positional aids, such as linear light beam positional indicators, are essential. Image quality is discussed further in the section dealing with quality assurance.

Film processing

Film processing is a weak link in the chain of image production. Film development is a complex process and must be performed with strict control for optimum image quality. Under development produces films lacking contrast, which may unwittingly cause the operator to increase the X-ray exposure to compensate for the resultant pale film. In the UK, undertaking quality control is a legal requirement and is covered in the section on quality assurance.

Personal monitoring

Personal monitoring is probably not necessary for routine dental radiography provided the operator undertakes appropriate radiation safety measures. However, monitoring is advisable if the operator has a workload in excess of 100 intra-oral films per week or more than 50 panoramic films each week. In this case, the advice of the Radiation Protection Advisor should be sought.

Selection criteria

Selection criteria, or referral criteria, is part of the justification process used to restrict patient exposure. The decision whether to take a radiograph is dictated by the clinical examination, which includes the dental history and examination of each patient. It is also based on the prevalence of disease, the rate of progression of the disease, in part on the age of the patient and by choosing the technique that is most likely to show the presence or absence of an abnormality.

To help the operator with the choice and timing of an examination, national and international guidelines have been produced.[6–8] All practices must have access to selection criteria to which staff can refer. Selection criteria are, where possible, evidenced-based. However, for some conditions the evidence may not be that strong, in which case an expert panel reviews the available evidence and provides an opinion on what they regard as good practice. Referral criteria have been available in the medical field for many years.[9]

There is no justification for

taking radiographs as a screening exercise, in the hope that one might serendipitously find an abnormality. The clinician must have a good clinical reason for exposing the patient to ionizing radiation. In making the decision to take a radiograph, the clinician should consider whether the information can be obtained from other methods, eg using existing radiographs, the use of apex locators in endodontic therapy, transillumination for dental decay, or utilizing imaging techniques that do not utilize X-rays, such as ultrasound or magnetic resonance imaging (MRI).

The choice of radiograph will also depend on whether an intra-oral radiograph will provide sufficient information or whether the area to be examined lies outside the region covered by a periapical radiograph.

It is not the intention of this article to provide a full account of selection criteria, but the following outlines some basic guidance.

Intra-oral radiography imparts a low dose to the patient, provides excellent resolution and so is an ideal technique for examining the teeth and adjacent bone. Intra-oral films/sensors should be regarded as the first line choice when undertaking radiography of disorders affecting the teeth and its immediate investing bone.

Bitewings are indicated for examining the crowns, particularly when dental decay is suspected, and they accurately depict alveolar crest bone levels provided there has not been excessive periodontal bone loss, as determined from the clinical examination. Vertical bitewings are suggested when the bone loss exceeds 6 mm but, like horizontal bitewings, do not show the whole of the root to the apex which may be needed for determining the remaining amount of bone support.

A periapical radiograph will show the whole tooth with about 2-4 mm of bone beyond the tooth apex and so is useful:

- To demonstrate dental decay;
- For early periapical disease;
- Following dental trauma;
- To assess retained roots;
- During endodontic treatment;
- For assessing partly erupted teeth;
- In advanced periodontal disease.

Periapical radiographs are of limited value for conditions that extend more than several millimetres beyond the apical region. They may be suitable for assessing partly erupted teeth, but for many wisdom teeth this may not be the case, particularly if the wisdom tooth is deeply placed creating film positioning difficulties or limited patient compliance. A completely unerupted tooth is unlikely to be adequately demonstrated on a periapical radiograph. In this situation a larger film format is required, for example an occlusal radiograph for assessing an unerupted maxillary canine, or an extra-oral view, such as a dental panoramic radiograph or an oblique lateral mandible. Similarly, large film formats are indicated when cysts, tumours or other conditions cannot be completely shown on periapical films.

A complete dental panoramic radiograph results in a higher dose when compared with intra-oral radiographs. Thus, in adhering to the ALARP principle, one must be clear that there is good clinical reason for choosing this type of view over an intra-oral examination. Panoramic radiographs are not good at demonstrating early dental carious lesions, particularly on the proximal surfaces, and may result in false positive and false negative findings. Remember that the anterior region of the jaws is often not well shown and may not demonstrate root fractures or periapical lesions involving the anterior teeth. Technical errors in patient positioning can result in further image distortion, making the image unsuitable for diagnosis.

Where patient compliance is lacking and there is difficulty in obtaining a satisfactory periapical film, consideration should be given to sectional panoramic views omitting areas of the jaws that are not required in the diagnostic process (Figure 10). When undertaking a radiographic assessment of the wisdom teeth, the anterior or middle section of the jaws is not normally required. Omitting this region will result in a lower patient dose.

Panoramic radiography is not suitable for all patients, particularly for those who have marked spinal curvature, are unco-operative and those who are unable to keep still for long enough. A useful alternative when an extra-oral view is needed is the oblique lateral mandible, which has a lower dose than for a panoramic radiograph and can be performed using a conventional dental X-ray set.

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CPD ANSWERS

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1. B, C	**6.** C
2. B, C	**7.** A, B
3. A, D	**8.** A, C
4. A, B, C, D	**9.** A, B, C
5. C, D	**10.** A, C, D