FROM THE VITAL ARCHIVE

Vital guide to radiography and radiation protection

- How is dental radiography used?
- How can radiation risks be minimised?
- What are the recommended techniques?

VITAL GUIDE TO Radiography and radiation protection

Stuart Grange* explains some of the key features of safe and effective dental radiography, and the legal requirements.

Dental radiography

In the dental setting, techniques exist for imaging the teeth, mandible, maxilla, temporomandibular joints and the oral and labial soft tissues. Virtually all dental practices will have one or more intra-oral units for periapical, bitewing and occlusal radiography. Many will have units for extra-oral radiography such as dental panoramic tomography and lateral cephalometry. A few centres may have cone beam computed tomography units, particularly where complex orthodontic and implant work is performed.

Due to the risk of radiation induced injury or misdiagnosis from incorrectly produced images, radiography should only be undertaken by appropriately trained personnel and under well-designed systems of work. Maximising diagnostic benefit and minimising radiation risk requires that practitioners are judicious in their selection of techniques for each patient.

Radiation protection

Radiation protection refers to the implementation of practices to reduce radiation exposure to patients, workers and the public. The fundamental aim of radiation protection is to reduce risk of harm by ensuring that any dose received is justified and 'as low as reasonably practicable' (ALARP).

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We may consider harmful effects from x-rays to fall into two types, deterministic or stochastic.[1] For deterministic effects, the subject must be exposed to considerable amounts of radiation before any damage becomes apparent. Skin burns and cataracts in the lens of the eye fall into this category. We should never expect to observe these effects from dental radiography due to the small amount of radiation used. Stochastic effects include the development of cancer – a known potential outcome of exposure to ionising radiation. Increasing exposure is believed to be associated with increasing risk, and therefore there is no unequivocally safe maximum dose.

Patients may ask about the risk from exposure to x-rays. Dental professionals physically directing exposures should be able to give information to the patient that helps them set any risk from the exposure in context. The risk of adverse effects from dental radiography is very small, but it is inaccurate to state that it is non-existent. It is helpful to compare the risk from radiography to other readily understood and accepted risks from everyday life, for example, the amount of radiation received from natural background radiation or from short-haul air flights. Persons requesting and conducting radiographic investigations should be familiar with the size of doses from specific examination types. Table 1 shows typical dose from common dental exposures.

Radiation effects

Deterministic effects – **the severity** of the effect is related to the amount of exposure, and only occurs after a certain threshold is exceeded.

Stochastic effects – **the risk** of the effect is related to the amount of exposure. Theoretically, there is no maximum limit below which stochastic effects, such as cancer induction, may occur.

We should never see deterministic effects from dental radiography and we must seek to minimise the risk of stochastic effects.

Legislation governing medical radiography

There are two pieces of legislation which embody the legal requirements for use of ionising radiations in the UK: The Ionising Radiation Regulations 1999 (IRR 99),[3] and The Ionising Radiation (Medical Exposure) Regulations 2000 (IR[ME]R 2000).[4] Together they provide the legal framework to ensure that risks from the use of ionising radiation are minimised.

The Regulations are of course written in the kind of legalese that is inaccessible for many people, and for that reason are accompanied by Approved Codes of Practice[5] that help to interpret the relevant features and legal obligations. For dental radiography, the National Radiological Protection Board produced the Guidance Notes for Dental Practitioners in 2001.[6] They are primarily

Table 1 Typical doses from dental radiography[2,13]

	Typical effective doses (mSv)	Equivalent period of natural background radiation
Teeth (single bitewing or periapical)	0.002	A few hours
Teeth (panoramic)	0.01	<1.5 days
Chest (single PA film)	0.02	3 days
Return flight to Spain	0.02	3 days
UK average background radiation = 2.2 mSv per year		

IR(ME)R 2000 key principles

Justification
Medical exposure to x-rays should always be justified. The person authorising (practitioner or operator) the exposure should anticipate a significant benefit to treatment decision-making from having the information that the radiograph provides.

Optimisation
Where justification is present, the amount of x-ray exposure used should be the smallest necessary to achieve a diagnostic image. IRR99 and IR(ME)R 2000 use the words 'As low as reasonably practicable' to express this concept.

intended to be used as guidance by dental practitioners outside of the hospital sector, where access to medical physics experts is less readily available. All staff involved in radiography would benefit from familiarity with these. They may be downloaded from the Health Protection Agency website.

IRR 99[3] relates to the responsibilities of the employer in ensuring safe working environments for employees and the general public. This is achieved by:

- Appropriate restriction of personnel and the public from areas where radiation is used by designation of 'controlled areas'; practically in dental radiography this means outside of the primary x-ray beam and 1.5 metres away from the x-ray tube or patient in any other direction[6]
- Local rules which identify the controlled area, persons entitled to operate the equipment and a summary of operating instructions
- Having a radiation protection supervisor; a suitably trained member of staff who is sufficiently senior that they have authority to ensure compliance with the local rules
- Presence of safety features on equipment that restrict exposure
- Regular maintenance.

IR(ME)R 2000[4] is primarily concerned with protection of the patient. The principles of justification and optimisation are core to these regulations. IR(ME)R also identifies a number of roles of people involved in exposing a patient to radiation. These help to ensure that an appropriate chain of responsibility exists when referring for and undertaking radiography.

- Referrer – the registered medical or dental practitioner referring the patient for radiography
- Practitioner – the registered medical or dental practitioner that justifies the exposure to x-rays as having sufficient net benefit
- Operator – the adequately trained person permitted to undertake practical aspects of radiography. This may include direct involvement with the x-ray exposure, processing the film or carrying out quality assurance procedures.

In general dental practice, the dentist may undertake all three roles or may delegate the role of operator to another adequately trained dental care practitioner such as a nurse, hygienist or therapist.

Practical dose reduction

Doses to patients may be minimised in the following ways:

1. Justification of exposure and optimum selection of technique
2. Optimised equipment
3. Careful execution of technique
4. Quality assurance programme.

1. Justification of exposure and optimum selection of technique

An x-ray should only be taken where it is likely to affect the patient's dental management. General radiographic screening of new patients prior to clinical examination is not justified.[7] The radiograph taken should include only that which is required to answer the diagnostic question. Selection of bitewings or periapical films in preference to panoramic films is recommended where these are likely to adequately demonstrate the problem. Dental radiography of pregnant patients is permissible so long as the exposure is justified, and the dose kept to the practical minimum. Foetal doses from dental radiography are very small, and correspondingly, risk of foetal harm is extremely low.[14]

2. Optimised equipment

Doses from dental radiography have come down as equipment design and features have improved.[8] However, there is some evidence that dental practices do not always take full advantage of all the opportunities that exist to reduce dose.[9]

Rectangular collimation and film holders

A rectangular collimator reduces the beam dimensions in periapical and bitewing radiography (Fig. 1). The fixed collimation of older intra-oral units is often circular giving a larger beam area than necessary for rectangular films.

A greater degree of accuracy is required when using the rectangular collimator to avoid 'coning', that is, missing part of the film with the beam. Accurate beam alignment with the film is facilitated by the use of beam aiming devices such as film holders (Fig. 2). They also confer image quality advantages:

a) The film is more parallel to the tooth and allows a more reproducible and less distorted image to be taken. Periodontal bone levels are far more accurately assessed using paralleling as opposed to bisecting angle techniques
b) Most film holders incorporate a stalk which is outside the mouth that allows accurate location of the x-ray beam to cover the film

Fig. 1 Rectangular collimator on an intra-oral x-ray unit

Fig. 2 Film holder and film showing beam aiming ring

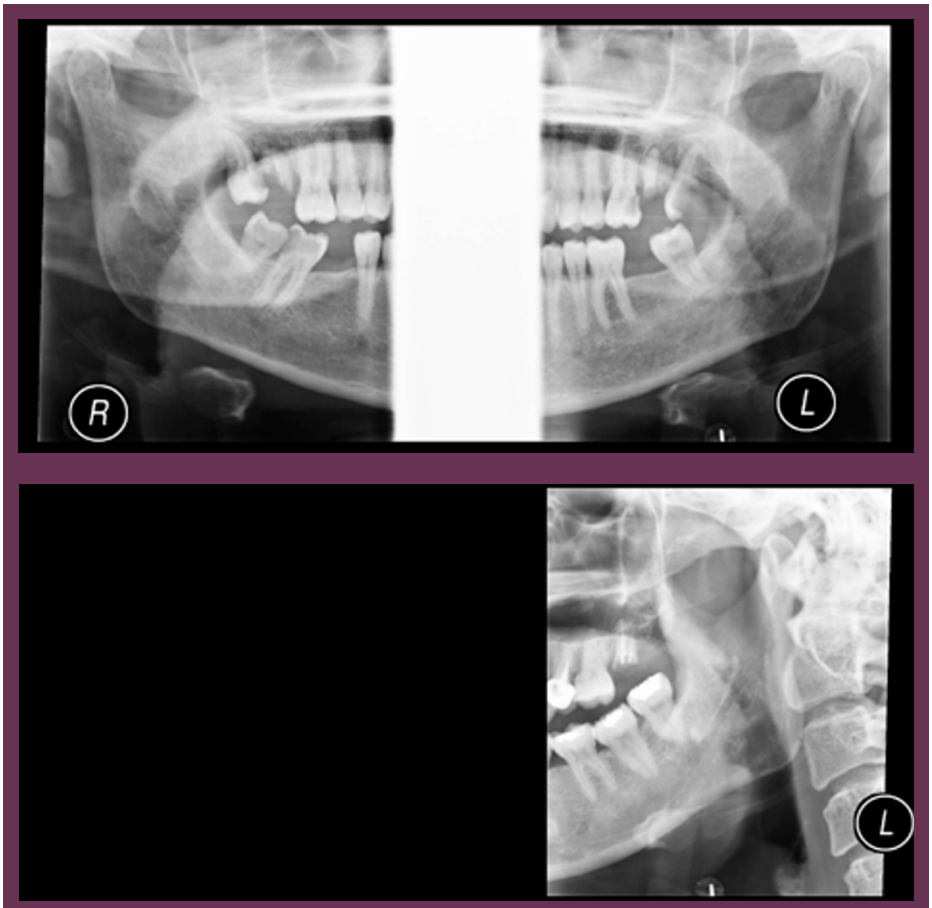

Fig. 3 Examples of exposure restriction in panoramic tomography

c) Used properly the film is less likely to move than if held by the patient.

Beam limitation in panoramic tomography

Where the facility exists consideration must be given to the limitation of the exposed area to only that portion of the dentition considered relevant to the clinical problem under investigation eg one quadrant, the anterior teeth, the TMJs etc (Fig. 3).

Film speed

The current recommendations are that an intra-oral film of at least E speed is used.[6] If all other exposure factors are equal the use of E or F speed film results in a dose reduction relative to D speed film of 45% and 60% respectively. The slight increase in image graininess that results is not likely to affect the diagnostic efficacy of the image.

For extraoral radiographs using intensifying screens, increasing speed of the system is expressed in increasing numbers eg 100, 200, 400, 800 and so on. It is recommended that intensifying screens utilise rare earth technology rather than older calcium tungstate to take advantage of the higher intensifying factor and thus reducing the dose required.

Digital radiography

Digital radiography is able to accept a greater range of exposures and still produce a diagnostically acceptable radiograph. The operator may electronically manipulate the image with post-processing software to adjust contrast and brightness for optimum viewing. With film radiography a significant under or over exposure will probably result in a useless radiograph.

Nevertheless, it is important that exposure times are adjusted to give only enough radiation to obtain a diagnostic image. Overexposure of a digital detector is unlikely to result in an unacceptable radiograph, but gives an unacceptable dose since it is not as low as reasonably practicable. Manufacturers should be able to advise on the necessary level of exposure for adequate image formation.

3. Careful technique

Careful technique includes:

- Good communication with patient to let them know what is expected
- Head immobilisation using head rest for intra-orals or chin rest and head clamp for panoramic films
- Correct positioning of film and angulation of tubehead for intra-orals
- Correct set up of anatomical planes for panoramic radiographs
- Use of film holders to help achieve the correct relationship of teeth, film and beam
- Correct exposure selection
- Removal of radiopaque objects prior to exposure. Earrings, necklaces, braces, spectacles will all cause obvious artefacts on the image, and may obscure important features.

4. Quality assurance programme

Quality assurance (QA) is an essential part of dental radiography. The purpose of QA is to set standards according to the available evidence for best practice, to regularly audit that these standards are being met and to record compliance. Implementation of QA procedures allows identification of equipment problems, or working practices that are not up to standard. These can then be corrected.

a) Image quality

Every radiograph should be rated for quality and the rating recorded in patient notes to identify if there are consistent problems. A 1-3 scale has been suggested for this purpose.[6]

b) Patient dose and x-ray equipment

Typical doses (diagnostic reference levels) for particular examinations should not be exceeded. Regular maintenance and testing of equipment to ensure correct functioning of warning lights and audible alarms, and stable radiation output should help to ensure this.

Image evaluation

1 **Excellent**. No errors of patient preparation, exposure, positioning, processing or film handling.

2 **Diagnostically acceptable**. Some errors of patient preparation, exposure, positioning, processing or film handling, but which do not detract from the diagnostic utility of the radiograph.

3 **Unacceptable**. Errors of patient preparation, exposure, positioning, processing, or film handling, which render the radiograph diagnostically unacceptable. Errors should be identified and film retaken.

The HPA offers a Radiation Protection Service for dentists that will assist in complying with the Regulations.[10]

c) Darkroom, films and processing

Poor quality film handling and processing will negate any advantages from good technique if the resultant image quality is compromised. Processing is one of the most obvious areas that will benefit from a well thought out QA programme. Processors must be regularly serviced, checked for light tightness and undergo regular cleaning of rollers and chemical tanks. Solutions should be tested, to ensure the correct strength of developer and fixer, and be changed when necessary. Film should be stored in a cool, dry place and rotated to ensure that older stock is used first.

d) Training

IR(ME)R 2000[4] stipulates that all practitioners and operators involved in exposing patients to x-rays must be 'adequately trained'. Schedule 2 of these regulations details aspects of radiation science and practice as are deemed relevant for safe radiography.

Qualified dentists receive their training in dental radiography as part of their BDS qualification. Dental nurses, hygienists and therapists may access approved training courses provided by the British Dental Association, and certain dental and radiography schools within the UK. The National Examining Board for Dental Nurses administrates the nationally recognised exam leading to the Certificate in Dental Radiography entitling them to take radiographs unsupervised.[11]

It is expected that all dental professionals involved in requesting or taking radiographs should be updated every five years on the use of ionising radiation.[6] A QA programme should note the date of the last update and when another is due. As well as reiterating important principles in radiation protection, updates should expose practitioners to up-to-date guidance that helps ensure they are using the best practice as it is understood at the time.

Adequate training on individual pieces of equipment is essential since it cannot be assumed that an understanding of one sort of equipment will transfer to the use of another. Dental panoramic tomography is particularly susceptible to compromise of image quality due to machine-based variations. Practitioners should be trained in the use of equipment by an experienced and suitably qualified member of staff, or by the manufacturer; most will provide staff training as part of the sales package negotiated at the time of purchase.

None of the training described above is deemed sufficient to enable practitioners to operate cone beam CT equipment. The Health Protection Agency recommends at least half a day's training from the manufacturer or other well qualified person such as dento-maxillofacial radiologist or specialist radiographer.[12]

e) Audit

Audit is the basis on which the effectiveness of a QA programme is verified. The date of audit and its outcome should be recorded within an audit record. Regular assessment of how well an establishment matches up to its own standards will allow deficiencies to be identified and remedial action to be taken. Frequency of individual aspects of QA must be established locally based on accepted norms, but overall review of the QA programme as a whole should be conducted not less than annually to ensure that it continues to be effective and includes up-to-date practices.

Conclusion

Radiography is an essential tool in clinical diagnosis and treatment decision-making. Extensive legislation exists to protect the patient, public and workers. Careful application of the Ionising Radiation Regulations together with the employment of best practices in radiation protection help to ensure that the risk to all from x-rays is kept as low as possible.

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