GUIDELINES

FOR THE USE OF

RADIOGRAPHS IN

CLINICAL ORTHODONTICS

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FOREWORD

In 1994 The British Society for the Study of Orthodontics (BSSO) asked the Standards Committee to develop guidelines for the use of radiographs in orthodontics, which formed the basis for the first edition. This was one of the first published sets of guidelines for dentistry. The initial work done by the members of the Committee has been the basis for further editions. In 2000 the Ionising Radiation (Medical Exposure) Regulations (IRMER) were published and these were incorporated into the subsequent editions.

The need for a fourth edition is due to the increasing availability of Cone Beam Computed Tomography (CBCT) which usually enables dento-maxillofacial imaging with a lower exposure than conventional CT. Such machines are now readily available and are being promoted as 3D imaging techniques for the teeth and jaws. Some orthodontists are using them as part of orthodontic treatment planning and, although the exposure is usually less than a conventional CT, it can be at least 20 times greater than normal dental radiography.

CBCT imaging has a useful place in selected cases and European evidence-based guidelines for their use have been formulated by the SEDENTEXCT project. In this edition a new section on CBCT imaging has been added which takes these European guidelines into account and discusses their place in orthodontic treatment. The majority of changes in this fourth edition are due to the expertise of the dental and maxillofacial radiologists Keith Horner and Eric Whaites.

Keith G Isaacson

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PUBLIC HEALTH ENGLAND (PHE)

John Holroyd of PHE Dental X-ray Protection Services for permission to reproduce figure 2 and material from Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment (2001), Department of Health.

ELSEVIER


The British Orthodontic Society is indebted to the authors who have waived their entitlement to the royalties arising from the sale of these Guidelines.


THE purpose of guidelines is to improve the effectiveness, and efficiency, of clinical care. To serve a useful purpose they must be reviewed regularly. Despite the availability of these guidelines the practice of taking routine orthodontic radiographs for children as a matter of course, often before a clinical examination, persists. This puts these children at unnecessary risk.

These guidelines are designed to assist the general practitioner, the orthodontic specialist and the hospital practitioner on the choice and timing of radiographs in clinical orthodontic practice. The existence of guidelines does not mean that compliance is necessary and non-compliance does not equate with negligence. They are recommended as current best practice and as selection criteria to comply with the requirements of IRMER.

REVIEW OF THE FOURTH EDITION

"In The Wealth of Nations, Book I, Chapter X, Adam Smith noted that, ‘People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices.’ In the present 4th Edition of Guidelines for the Use of Radiographs in Clinical Orthodontics, the authors with the British Orthodontic Society have conspired instead to protect the public from needless and costly exposure to ionizing radiation. Given the reluctance of many societies to go beyond platitudes when it comes to specifying professional standards, this edition of Guidelines probably will become the de facto benchmark in the world of orthodontics. Well done, indeed!”

Lysle E Johnston Jr, DDS, MS, PhD, FDS RCS(Eng)

REVIEWS OF THE THIRD EDITION

"Perhaps the AAO might be inspired to publish a more meaningful set of radiographic guidelines after the exceptional example set by their British colleagues." 2

"I was impressed with the sensible approach taken, based on published science. I do believe the BOS points us in a direction that could result in more ideal care for our patients." 3

"Of importance, however, are the patient selection criteria which provide acceptable and, hopefully, non-contestable reasons for routine orthodontic radiographs and when those radiographs might be taken." 4

"Overall this is an excellent book and has been updated very well. It remains essential reading to any orthodontist or member of the orthodontic team." 5

"The stated aims of this excellent booklet to assist the orthodontist to achieve sound clinical practice with desired outcomes are successfully met." 6

"The logical structure provides an easy expeditious read." 7

"You have always been ahead of us in areas like this... particularly clinical guidelines... I can only hope that those involved... will take heed of these diagnostically useful ‘magic rays’ could also cause cancer and genetic harm.

In 1921 the first formal recommendations on radiation protection in the UK were made by the British X-ray and Radium Protection Committee. In 1928 The International Commission on Radiological Protection (ICRP) was established. The ICRP is still in existence and regularly publishes reports and recommendations on radiation protection which are accepted as the basis for national legislation by almost every country in the world to try to limit the damaging effects of ionising radiation. As a result, the use of ionising radiation in clinical practice is governed by law – criminal law – in the UK.

Ionising radiations, including X-rays, are dangerous and have the potential to cause damage to human tissue, including fatal malignant change. Radiographic examinations put patients at risk. Children are at the greatest risk. The legislation is designed to protect patients by ensuring that all radiographic procedures are necessary, appropriate and as safe as possible so that patients are not placed at unnecessary risk. UK law requires that all radiographs must be clinically justified. These guidelines are primarily designed to assist orthodontists in this ‘justification’ process.

Awards 'Highly Commended' in the British Medical Association Medical Book Competition 2009.
THE different damaging effects on human tissue are currently divided into two major categories:

- **Tissue reactions (deterministic effects)**
- **Stochastic effects**, subdivided into:
  - Cancer induction
  - Heritable effects (genetic effects).

**Stochastic effects** are the chance or random effects, governed by the laws of probability, that patients may develop from any dose of radiation. In dental X-ray imaging, the risk of heritable (genetic) effects is considered negligible, so the stochastic effect of concern is the risk of cancer induction. For this, the ICRP continues to support the so called ‘Linear Non-Threshold’ model which is based on the principle of no known threshold dose. In other words, any exposure to ionising radiation carries the possibility of causing damage including cancer induction. The likelihood of any damage being induced (the risk) is proportional to the dose. The lower the dose, the lower the risk. However, it is very important to remember that the **size of the exposure does not affect the severity of the damage induced**. If, during low dose orthodontic radiography, cancer induction occurs, the cancer that subsequently develops could be fatal.

**THE AIMS OF RADIATION PROTECTION**

There are two overall guiding aims in radiation protection:

- To prevent the tissue reactions (deterministic effects) by having rules and guidelines based on scientific evidence.
- To limit the stochastic effects to acceptable levels.

Orthodontists, like all clinicians, have the responsibility of deciding what a justifiable level of risk is for their patients. One of the guiding principles of the ICRP in determining an ‘acceptable’ level of risk, is that of ‘justification’ – no practice shall be adopted unless its introduction produces a net positive benefit – and this is re-enforced in the UK legislation which states that ‘No person shall carry out a medical exposure unless it has been justified…’

The importance of radiation protection in dentistry has been underlined by the publication of:

- The third edition of Selection Criteria for Dental Radiography published by the Faculty of General Dental Practice (UK) 2013.
- The Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment by the Health Protection Agency in 2010.
- Radiation Protection: Cone beam CT for dental and maxillofacial radiology – guidelines published by the SEDENTEXCT European Consortium in 2012.
UK LEGISLATION RELATING TO THE USE OF IONISING RADIATION

There are currently two sets of legislation in the UK, based on European Directives and following ICRP recommendations, namely:

- The Ionising Radiations Regulations 1999 (IRR 99) which are primarily concerned with the safety of workers and the general public, and
- The Ionising Radiation (Medical Exposure) Regulations 2000 (IRMER 2000) which are concerned with the protection of patients.

The European Commission has also published guidelines. The legal requirements of IRR 99 and IRMER 2000, together with the guidelines, are primarily concerned with the safety of workers and the general public, and in 2010 in the Health Protection Agency’s booklet Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment.

ESSENTIAL LEGAL REQUIREMENTS OF IRR 99

- The Health and Safety Executive must be notified of the routine use of dental X-ray equipment.
- A prior risk assessment must be undertaken before radiography commences and be subject to regular review.
- There is an over-riding requirement to restrict radiation doses to staff and other persons to levels that are as low as reasonably practicable (ALARP).
- X-ray equipment, particularly all safety features, must be maintained.
- Contingency plans must be provided in the Local Rules.
- A Radiation Protection Adviser (RPA) must be consulted.
- Information, instruction and training must be provided for all staff.
- A ‘controlled area’ should be designated around each piece of X-ray equipment.
- Local Rules are required.
- A Radiation Protection Supervisor (RPS) must be appointed.
- A quality assurance programme is required.
- All employees should be aware of their specific duties and responsibilities.

ESSENTIAL LEGAL REQUIREMENTS OF IRMER 2000

- Positions of responsibility are defined:
  - The Employer (Legal Person)
  - The Referrer
  - The Practitioner
  - The Operator

- IRMER Employers are responsible for providing the overall safety and radiation protection framework and for ensuring that staff and procedures conform with the regulations, and for providing ‘Written Procedures’ for all medical exposures.
- IRMER Referrers are responsible for supplying the IRMER Practitioner with sufficient information to justify an appropriate exposure.
- IRMER Practitioners are clinically responsible for, and must justify, all medical exposures. Justification must be based on consideration of:

  - The specific objectives of the exposure
  - The total potential benefit to the patient
  - The anticipated detriment to the patient
  - The efficacy, benefits and risks of alternative techniques.

- The ‘justification’ process is the responsibility of the IRMER Practitioner – the medical or dental practitioner who takes responsibility for an individual medical exposure. All general dental practitioners and specialist orthodontists in practice are IRMER Practitioners, and are therefore required by law to justify every radiograph that they take. In hospitals, orthodontists are IRMER Referrers if they refer their patients to an X-ray department to be imaged. As such they are responsible for supplying sufficient clinical information so that the IRMER Practitioner within the X-ray department can justify the exposures. These legal implications are one of the reasons the General Dental Council in 2006 included ‘radiography and radiation protection’ as one of their three essential subjects in Continuing Professional Development (CPD). IRMER Operators are responsible for conducting any practical aspect of a medical exposure including exposing the radiograph or processing the image.

- IRMER Operators and IRMER Practitioners must have received adequate training.
- IRMER Operators and IRMER Practitioners must undertake continuing education.

Dental care professionals (DCP’s) involved in taking orthodontic radiographs are designated as IRMER Operators and therefore must be adequately trained. Since May 2005, dental nurses who undertake radiography have been required to possess a post-qualification Certificate in Dental Radiography.

In addition there are essential legal requirements regarding equipment:

- All doses must be kept as low as reasonably practicable (ALARP).
- Provision must be made for clinical audit.
- An equipment inventory must be kept and maintained.
**RADIATION Dose Delivered by Diagnostic Imaging and the Magnitude of the Risks Involved**

*Radiation* dose is complicated by the fact that several different measurements of ‘dose’ exist. The main terms are:

- Absorbed dose \( (D) \)
- Equivalent dose \( (H_T) \)
- Effective dose \( (E) \)

**Absorbed Dose \( (D) \)**

This is a measurement of the amount of energy absorbed from the X-ray beam per unit mass of tissue. It is measured in Joules/kg. The special name given to the Standard International (SI) Unit is the gray (Gy).

**Equivalent Dose \( (H_T) \)**

This is a measurement of radiation dose that takes into account the radiobiological effectiveness of different types of radiation on different tissues. Each type of radiation is allocated a different radiation weighting factor \( (w_i) \). X-rays and gamma rays have a weighting factor of 1, while the more damaging protons and alpha particles have weighting factors of 10 and 20 respectively.

The equivalent dose in a particular tissue \( (H_T) \) is calculated by multiplying the radiation-absorbed dose \( (D) \) the amount of energy absorbed by the tissue, by the radiation weighting factor \( (w_i) \) for the type of radiation being used. It is again measured in Joules/kg and the special name of the SI unit is the sievert (Sv).

**Effective Dose \( (E) \)**

This is a measurement which allows doses from investigations of different parts of the body to be compared, by converting all doses into an equivalent whole body dose. The ICRP has allocated each tissue a numerical value, known as the tissue weighting factor, which represents the weighting factor for the whole body. The recommendations of the ICRP in 2007 for tissue weighting factors are shown in Table 1.

The effective dose \( (E) \) from an individual clinical radiograph, where the beam is absorbed by different tissues, is calculated as follows:

\[
E = \sum H_T \times w_i
\]

The Standard International unit is also the sievert (Sv). Doses delivered by most medical radiographic techniques are only fractions of a sievert, and are usually expressed as \( \mu \text{Sv} \) (micro sievert—one millionth of one sievert) or \( \text{mSv} \) (milli sievert—one thousandth of one sievert). The effective dose measurement can be used to compare doses from other investigations of other parts of the body.

From an orthodontic point of view skin, bone, bone marrow, thyroid and salivary glands are the tissues of particular importance when radiographing children and calculating the effective dose (Figure 1).

**Table 1: Recommendations of the ICRP (2007) for tissue weighting factors**

<table>
<thead>
<tr>
<th>Tissue</th>
<th>2007 w.</th>
<th>2007 w.</th>
<th>2007 w.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BONE MARROW</td>
<td>0.12</td>
<td>LIVER</td>
<td>0.04</td>
</tr>
<tr>
<td>BREAST</td>
<td>0.12</td>
<td>THYROID</td>
<td>0.04</td>
</tr>
<tr>
<td>COLON</td>
<td>0.12</td>
<td>BONE SURFACE</td>
<td>0.01</td>
</tr>
<tr>
<td>LUNG</td>
<td>0.12</td>
<td>BRAIN</td>
<td>0.01</td>
</tr>
<tr>
<td>STOMACH</td>
<td>0.12</td>
<td>KIDNEYS</td>
<td>0.01</td>
</tr>
<tr>
<td>BLADDER</td>
<td>0.04</td>
<td>SALIVARY GLANDS</td>
<td>0.01</td>
</tr>
<tr>
<td>OESOPHAGUS</td>
<td>0.04</td>
<td>SKIN</td>
<td>0.01</td>
</tr>
<tr>
<td>GONADS</td>
<td>0.08</td>
<td>REMAINDER TISSUES</td>
<td>0.12*</td>
</tr>
</tbody>
</table>

\* Adrenals, extrathoracic airways, gall bladder, heart wall, kidneys/lymphatic nodes, muscle, pancreas, oral mucosa, prostate, small intestine wall, spleen, thymus, uterus/cervix

**Effective Doses and Risks from Exposure to X-Rays in Orthodontic Practice**

Two publications, one from the Health Protection Agency\(^25\) and the other from the European SEDENTEXCT consortium,\(^26\) on radiation dose have been used to produce the comparative figures of effective dose \( (E) \) from common orthodontic radiographic examinations and other medical examinations (Table 2). Further details regarding effective doses from different CBCT examinations are given in Section 11.
TABLE 2: Frequency and collective dose for medical and dental X-ray examinations in the UK

<table>
<thead>
<tr>
<th>X-RAY EXAMINATION</th>
<th>Effective dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRA-ORAL PERIAPICAL/BITEWING</td>
<td>0.0003 – 0.022</td>
</tr>
<tr>
<td>PANORAMIC</td>
<td>0.0027 – 0.038</td>
</tr>
<tr>
<td>UPPER STANDARD OCCLUSAL</td>
<td>0.008</td>
</tr>
<tr>
<td>LATERAL CEPHALOMETRIC</td>
<td>0.0022 – 0.0056</td>
</tr>
<tr>
<td>CHEST</td>
<td>0.014 – 0.038</td>
</tr>
<tr>
<td>BARIUM SWALLOW</td>
<td>1.5</td>
</tr>
<tr>
<td>BARIUM ENEMA</td>
<td>2.2</td>
</tr>
<tr>
<td>CT MANDIBLE AND MAXILLA</td>
<td>0.25 – 1.4</td>
</tr>
<tr>
<td>DENTO-ALVEOLAR (small volume) CBCT</td>
<td>0.01 – 0.67</td>
</tr>
<tr>
<td>CRANIOFACIAL (large volume) CBCT</td>
<td>0.03 – 1.1</td>
</tr>
</tbody>
</table>

**Estimated Risks**

Orthodontic patients are generally examined using low dose radiographic examinations and are primarily at risk from the stochastic effect of cancer induction. ICRP currently estimate that there is a 1 in 20,000 chance of developing a fatal cancer for every 1 mSv of effective dose of radiation. Using this figure, an estimate of risk from various X-ray examinations can be calculated and is shown in Table 3.

TABLE 3: Estimated risk of fatal cancer from diagnostic X-rays

<table>
<thead>
<tr>
<th>X-RAY EXAMINATION</th>
<th>Estimated risk of fatal cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRA-ORAL PERIAPICAL/BITEWING USING 70kV, RECTANGULAR COLLIMATION, F SPEED FILM/DIGITAL RECEPTORS</td>
<td>1 in 10,000,000</td>
</tr>
<tr>
<td>PANORAMIC</td>
<td>1 in 1,000,000</td>
</tr>
<tr>
<td>UPPER STANDARD OCCLUSAL</td>
<td>1 in 2,500,000</td>
</tr>
<tr>
<td>LATERAL CEPHALOMETRIC</td>
<td>1 in 5,000,000</td>
</tr>
<tr>
<td>CHEST</td>
<td>1 in 1,000,000</td>
</tr>
<tr>
<td>BARIUM SWALLOW</td>
<td>1 in 13,300</td>
</tr>
<tr>
<td>BARIUM ENEMA</td>
<td>1 in 9,100</td>
</tr>
<tr>
<td>COMPUTED TOMOGRAPHY                                                               Range of risk</td>
<td></td>
</tr>
<tr>
<td>CT MANDIBLE AND MAXILLA                                                           1 in 80,000 to 1 in 14,300</td>
<td></td>
</tr>
<tr>
<td>DENTO-ALVEOLAR (small volume) CBCT                                                 1 in 2,000,000 to 1 in 30,000</td>
<td></td>
</tr>
<tr>
<td>CRANIOFACIAL (large volume) CBCT                                                  1 in 670,000 to 1 in 18,200</td>
<td></td>
</tr>
</tbody>
</table>

Risk is age dependent, being highest for the young (most orthodontic patients) and lowest for the elderly. The estimated risks shown in Table 3 are based on a 30 year old adult. The 2004 European Guidelines on Radiation Protection in Dental Radiology recommended that these should be modified by the multiplication factors shown in Table 4, which represents averages for both males and females.

TABLE 4: Age risk relationship

<table>
<thead>
<tr>
<th>AGE GROUP (year)</th>
<th>Multiplication factor for risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>x 3</td>
</tr>
<tr>
<td>10 – 20</td>
<td>x 2</td>
</tr>
<tr>
<td>20 – 30</td>
<td>x 1.5</td>
</tr>
<tr>
<td>30 – 50</td>
<td>x 0.5</td>
</tr>
<tr>
<td>50 – 80</td>
<td>x 0.3</td>
</tr>
<tr>
<td>80 +</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

Young orthodontic patients are particularly at risk and especially when potentially high dose CBCT examinations are undertaken.

Figures for dose and risk such as those detailed above are derived from laboratory studies using controlled conditions and specific types and combinations of equipment. The ‘real world’, in contrast, is full of variables and it is important to recognise that doses delivered may vary significantly depending upon the X-ray equipment used (Figure 2).

X-RAY GENERATING EQUIPMENT

From a radiation protection point of view, X-ray generating equipment cannot be considered ‘safe’, unless it is in good order both electrically and mechanically and delivers a dose at or below the recommended diagnostic reference levels (DRLs). To try to ensure that equipment is ‘safe’, all units must be subjected to the following tests:

- ‘Critical examination’ test by the installer
- ‘Acceptance’ test by a medical physicist or radiation protection adviser (RPA) before the equipment is used clinically
- ‘Routine’ tests by a medical physicist or radiation protection adviser (RPA) after appropriate intervals (3 years) and after any major maintenance procedure
- Dose measurements to assess patient doses – usually part of the ‘acceptance test’.

The legislation requires an equipment log to be maintained, containing details of the equipment’s installation and maintenance record. In addition the 2001 Guidance Notes make specific recommendations for different types of X-ray equipment. 50

DENTAL X-RAY EQUIPMENT

- The operating range should be in the range of 60–70 kV
- The equipment should operate within 10% of the stated or selected kV
- Equipment operating at less than 70 kV should include 1.5mm of aluminium filtration, and 2.5 mm if operating over 70 kV
- Beam diameter should not exceed 60 mm at the patient end of the spacer cone or beam indicating device but ideally should include rectangular collimation (40 mm x 50 mm)
- Equipment should have film speed controls and finely adjustable kV, mA and exposure times
- Equipment should ideally have DC or constant potential output
- Focal spot position should be marked on the tubehead casing
- The focus-to-skin distance (fsd) should be 200 mm (Figure 3).

Figure 3. X-ray tubehead showing focus to skin distance (fsd)

CEPHALOMETRIC EQUIPMENT

- The equipment must be able to ensure the precise alignment of the X-ray beam, image receptor and the patient
- The focus to film distance should be in the range of 1.5 –1.8 m to minimise magnification effects
- Should be triangular collimated to avoid unnecessary exposure of the cranium.

ALL EQUIPMENT

- There should be a light on the control panel to show that the power supply is on
- Audible and visible warning signals during an exposure should be fitted
- Exposure switches (timers) should only function while continuous pressure is maintained on the switch and terminate if pressure is released
- Exposure switches should be positioned so that the operator can remain outside the controlled area and at least two metres from the X-ray tubehead and patient
- Exposure times should be terminated automatically.


IMAGING EQUIPMENT AND TECHNIQUES AVAILABLE FOR ORTHODONTIC RADIOGRAPHY

PANORAMIC UNITS

- Equipment should have a range of tube potential settings, preferably from 60 to 90 kV
- Beam height should not be greater than the image receptor in use (normally 125 mm or 150 mm)
- Equipment needs to be provided with patient positioning aids, incorporating light beam markers (Figure 4)
- New equipment should provide facilities for field-limitation techniques.

Figure 4. Light beam markers to aid in patient positioning
CONE BEAM COMPUTED TOMOGRAPHY (CBCT)

Low dose cone beam CT technology has been developed specifically for use in the dental and maxillofacial regions. The concept of a three dimensional radiograph may seem attractive as the imaging modality of choice. Whilst it has many applications on oral surgery, implantology and periodontology, its use in orthodontics is limited. This is discussed fully in Section 11.

Equipment and theory

CBCT technology, for use in the dental and maxillofacial regions, was developed in the late 1990s. Its development has proliferated over recent years. It shares some technological characteristics with conventional CT, but is not identical to it. CBCT is probably best described as ‘volumetric imaging’ as the technique uses X-rays in a different way to conventional radiography: to image different sized spherical or cylindrical volumes, described as small, medium or large fields of view (FOV).

Several machines are currently available with new developments constantly being launched. Designs vary but essentially resemble panoramic units (Figure 5). The equipment employs a cone-shaped X-ray beam (rather than the flat fan-shaped beam used in conventional CT) and a special detector – typically a flat panel (either amorphous silicon or CMOS) or an image intensifier which captures the attenuated X-ray beam. The X-ray tube has a potential which may be fixed or variable within a range of 60 kV to 120 kV.

IMAGE RECEPTORS – FILM AND DIGITAL

Modern image receptors available include:

Radiographic film

- Direct action film, also referred to as packet film (intra-oral)
- Indirect action film used in conjunction with rare-earth intensifying screens in a cassette (extra-oral).

Digital receptors

- Solid-state sensors

These consist of a scintillator that converts X-radiation to light, mounted on a photodetector, and associated electronics encased in a small, thin, flat, rigid, plastic rectangular housing. Underlying technology involves either amorphous silicon-based charge-coupled devices (CCD) or complementary metal oxide semiconductors (CMOS). Suitable size sensors are available for periapical/bitewing, panoramic and skull radiography. Occlusal sized sensors are not available. After exposure the image appears immediately on the computer monitor.

- Photostimulable phosphor plates

These typically consist of a layer of barium fluorohalide phosphor on a flexible plastic backing support. Suitable sized phosphor plates are available for all dental radiographic techniques. After exposure the plates are read by a laser scanning device, following which the image appears on the computer monitor.

Figure 5
Patient positioning for CBCT showing light markers, head restraint and thyroid collar.
Image Creation
The scanning/image creation process divides into three stages: (Figure 6)

Stage 1 – Data acquisition. The patient is positioned within the unit and their head secured. The equipment orbits around the patient, taking approximately 10 – 40 seconds, and in one scan, images the cylindrical or spherical field of view (FOV). As all the information is obtained in the single scan, the patient must remain absolutely stationary throughout the exposure. The size of the cylindrical or spherical field of view varies from one machine to another. Using a medium-sized field of view (typically 15 cm diameter) most of the maxillofacial skeleton fits within the cylindrical or spherical shape. The hard tissues, teeth and bones, are imaged well, but little detail is provided on the soft tissues.

Stage 2 – Primary reconstruction. The information from the entire scan is collated by computer which then divides the volume into tiny isotropic cubes or voxels (ranging in size from 0.076 mm$^3$ and 0.4 mm$^3$) and calculates the X-ray absorption in each voxel. As with pixels in two dimensional digital imaging, each voxel is then allocated a shade from the grey scale from black through to white. Typically one scan contains over 100 million voxels.

Stage 3 – Secondary or multiplanar reconstruction. The computer software displays a set of images in the axial, sagittal and coronal planes on the monitor which can then be scrolled through in real time (Figure 7). Selecting and moving the cursor on one image, automatically allows the image in the selected plane to be scrolled through simultaneously. Multiplanar reconstruction also allows the creation of linear or curved cross-sections within the volumetric dataset, for clinical use. For example, this enables the creation of panoramic images made up of the voxels that coincide with the plotted arch shape. In addition it is also possible to reconstruct or synthesise lateral cephalometric images and with appropriate software to produce so-called volume rendered or surface rendered images.

Digital Image Storage
Digital images need to be securely saved and backed up to an appropriate computer/server. In most hospitals this storage is accomplished using a Picture Archiving & Communication System (PACS). PACS allows the storing, transmission and viewing of digital images at sites remote from the site of production.

Stated benefits of PACS
- Images cannot be lost or destroyed
- Images are always available
- Fast transfer to remote locations via an appropriate network
- The identical image can be viewed at the same time in different locations which may be of benefit when seeking opinions.

These stated benefits rely on efficient IT facilities and interactions (software and hardware).
METHODS OF RADIATION PROTECTION INCLUDING QUALITY ASSURANCE

The various practical and physical methods available for reducing or limiting the dose to patients, and thereby limiting the risk, from orthodontic radiography can be summarised into four categories:

- Equipment
- Staff training
- Radiographic techniques used
- Clinical judgement on the need/justification and ability to interpret, therefore maximising the diagnostic information contained within, the image.

Together, these first three factors determine the quality of the images produced and should be subject to a quality assurance (QA) programme.

**EQUIPMENT**

X-ray generating equipment should:

- Operate at high voltage (60 – 70 kV for intra-oral equipment)
- Incorporate adequate aluminium filtration
- Incorporate appropriate beam collimation
- Be both critically examined and acceptance tested
- Include modern exposure controls allowing very short exposure times
- Incorporate warning signals.

Digital image receptors should:

- Be used with exposures that have been optimised in consultation with the Radiation Protection Advisor (RPA).
  
  **Note:** Different types of receptors require different exposure settings.

Film based image receptors should:

- Be the fastest available film speed – typically F speed
- Involve rare-earth intensifying screens for extra-oral radiography.

**STAFF TRAINING**

IRMER Practitioners and IRMER Operators should:

- Be adequately trained. The British Society of Dental and Maxillofacial Radiology has defined adequate training in its latest core curricula in dental radiography and radiology for different members of the dental team. It is the responsibility of the employer to ensure that all staff who are involved in medical exposures have received adequate and appropriate training in the field of radiation protection
- Regularly update their knowledge. The legislation not only requires adequate training initially but also requires IRMER practitioners and IRMER operators (including DCPs) to regularly update their knowledge and skills. The Department of Health’s 2001 Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment specified the content of update courses. The General Dental Council (GDC) currently highly recommends “Radiography and Radiation Protection” as one of their verifiable Continuing Professional Development (CPD) subjects, suggesting five hours within a five yearly CPD cycle.

**RADIOGRAPHIC TECHNIQUES USED**

Intra-oral periapicals and bitewings should:

- Involve the use of image receptor holders and beam aiming devices
- Be taken using rectangular collimation
- Ensure accurate positioning to avoid retakes
- Involve the minimum number of images
- Be digitally or chemically processed correctly.

(Figures 8a & 8b)

**THE Data Standards**

Core Curricula in Dental Radiography and Radiology for the Dental Team
wwwbsdmar.org.uk

32. Department of Health (2001)
Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment. London, the Stationery Office
Intra-oral occlusal radiographs should:

- Be taken using rectangular collimation
- Include the use of a thyroid shield or collar if the thyroid gland lies in the primary beam (not indicated for a lower occlusal) (Figure 9).

Panoramic radiographs should:

- Ensure accurate patient positioning assisted by light beam markers (Figure 10).
- Allow field limitation techniques and appropriate collimation of panoramic images such as dentition only, which results in a 50% dose reduction (Figure 11).

True lateral cephalometric skull radiographs should:

- Ensure accurate patient positioning assisted by light beam markers
- Include triangular collimation, facilitated by a light beam diaphragm, so as not to irradiate the whole of the cranium and neck
- Include an aluminium wedge filter, ideally at the X-ray tubehead, to facilitate the imaging of the soft tissues.

Note: There are three main designs of modern digital combined panoramic/cephalometric units available that utilise different techniques to produce lateral cephalometric images:

One shot – using a phosphor plate or a solid state receptor
Horizontal scanning – using solid state receptor (Figure 12)
Vertical scanning – using a solid state receptor

At present these units do not enable triangular collimation nor incorporate aluminium wedge filters.

Cone beam imaging should:

- Ensure accurate patient head position using light beam markers
- Keep patient’s head stationary by use of suitable head restraints
- Allow FOV size to be adjusted – small, medium or large – as required to select the smallest field of view compatible with the clinical situation
- Allow resolution protocols/sets to be selected consistent with diagnostic needs
- Allow kV and mAs to be varied to optimise image quality and minimise radiation dose
- Use a thyroid shield if available, and certainly for larger fields of view (Figure 5, page 9).
QUALITY ASSURANCE (QA)

The World Health Organisation has defined radiographic quality assurance programmes as:

‘…an organised effort by the staff operating a facility to ensure that the diagnostic images produced by the facility are of sufficiently high quality so that they consistently provide adequate diagnostic information of the lowest possible cost and with the least possible exposure of the patient to radiation’. 33

Terminology

• Quality control  The specific measures for ensuring and verifying the quality of the radiographs produced

• Quality assurance  The arrangements to ensure that the quality control procedures are effective and that they lead to relevant change and improvement

• Quality audit  The process of external reassurance and assessment that quality control and quality assurance mechanisms are satisfactory and that they work effectively.

QA in dental radiography should ensure that optimum diagnostic information can be obtained from radiographs while radiation doses to patients and staff are kept as low as is reasonably practicable (ALARP). While this should be principally a matter of professional ethics, much of the ethical responsibility has been complemented by the need to operate in accordance with relevant statutory requirements in which many of the necessary operational objectives are specified. Both the IRR 99 and IRMER contain elements relating to QA.

All dental practitioners are required to maintain a QA programme, which must include standards of both equipment and techniques together with quality control procedures to assure that these standards are achieved and maintained. Full details of Quality Assurance are provided for film-based imaging in the 2001 Guidance Notes. 34

A well-designed QA programme should not only be comprehensive, but also inexpensive to operate and maintain. Standards should be well-defined and require infrequent modification. The maintenance of the necessary records will necessitate a systematic and methodical approach.

REPORTING

In the context of reporting conventional radiographs, it is reasonable to assume that the possession of a registered dental qualification, supplemented by relevant CPD during the course of a career, is evidence of adequate training to comply with IRMER.

The following are the clinician’s legal requirement:

• To examine the requested radiographs
• To evaluate the findings
• To record the findings in the patient’s clinical notes.

CLINICAL JUDGEMENT

The use of selection criteria together with clinical judgement should ensure that the appropriate information is gained at minimal risk to the patient. This is considered in the next section.


IT MUST be remembered that the prescription of a radiograph is a procedure with a low, but nevertheless inferred, risk and therefore each radiograph must be clinically justified as required by IRMER. This will involve an assessment as to whether the information can be gained by less invasive means (such as, study casts or clinical examination).

Additional information may be required from radiographs when a clinical examination suggests the presence of an abnormality, or when interceptive and active orthodontic treatment is being considered.

Such as:
- The presence or absence of permanent teeth
- The presence and position of misplaced or supernumerary teeth
- The stage of development of permanent teeth
- The morphology of unerupted, and sometimes erupted, teeth
- The presence and extent of dental disease
- The presence, extent, and type of any developmental anomalies.

For treatment planning it is frequently necessary to be able to assess accurately the relationships of the teeth to the jaws, and the jaws to the rest of the facial skeleton.

In addition, radiographs may be used in the presence of clinical indicators to assess treatment progress and growth changes.

Where appropriate they may be used in teaching and research.

**INTRA-ORAL RADIOGRAPHS**

**Periapical views**

These can be taken to determine the presence and position of unerupted teeth, the presence or absence of apical disease or root form (Figure 13).

When canines are ectopically positioned, periapical views can form part of a parallax technique and, in certain cases, allow assessment of resorption of lateral incisor roots. Other periapical views may also be indicated when a clinical examination, a panoramic radiograph, or a treatment history, necessitates further investigation.

Full mouth periapical views are rarely indicated as dental panoramic radiographs offer a similar amount of information with a much-reduced exposure.

**Upper standard occlusal radiograph**

This image shows the maxillary incisor region and may be taken when there is a clinical indication of potential underlying disease or developmental anomaly in this area.

An occlusal image is helpful in assessing the position of misplaced and unerupted canines. With the parallax technique used in conjunction with a periapical image or a panoramic radiograph the bucco-palatal position of unerupted teeth can be determined (Figures 14a & 14b).
The principal use of panoramic radiographs for orthodontic patients is to confirm the presence, position and morphology of unerupted teeth (Figure 15a). Only gross caries will be detected with acceptable accuracy on panoramic radiographs. Caries diagnosis requires clinical examination supplemented by selected special tests, including bitewing radiography.

One limitation of panoramic radiographs is that the focal trough is relatively narrow particularly in the incisor region. If a tooth is inclined or malpositioned, the crown, root and apex may not all lie within the focal trough. As a result, parts or all of the tooth may appear out of focus or even invisible.

Indications for dental panoramic radiographs

The Faculty of General Dental Practice (UK) in their 2013 Selection Criteria for Dental Radiography booklet specified criteria for the use of panoramic radiographs in general dental practice, of which the most relevant to orthodontics is:

- ‘A panoramic radiograph is commonly used to provide information on the state of the dentition and is often appropriate when orthodontic treatment is being considered’.

In addition the following warning is given:

- ‘Routine screening of children cannot be justified’.

These criteria rule out the practice of taking panoramic radiographs for all new patients, and for using this type of imaging to ‘screen’ asymptomatic patients. They also explain that panoramic radiography is not appropriate for investigation of most patients presenting with symptoms of temporomandibular joint disorders [see Section 13].

The flow charts (Figures 17 & 18) give guidance for the use of orthodontic radiographs.

**Lateral Cephalometric Radiographs**

Cephalometric images may be used to aid diagnosis and treatment planning and when appropriate provide a baseline for monitoring progress (Figures 15b & 16). The images must be analysed to obtain the maximum clinical information. In malocclusions where the incisor relationship does not require significant change such radiographs are unlikely to be required.

Patients who may require lateral cephalometry include those with a skeletal discrepancy when functional appliances or fixed appliances are to be used for labio-lingual movement of the incisors.

In addition, cephalometric radiographs can be of assistance in the location and assessment of unerupted, malformed, or misplaced teeth and to give an indication of upper incisor root length. There is no evidence that a single lateral cephalometric radiograph is of use in the prediction of facial growth and images should not be taken for this purpose.

Additional indications are:

- To obtain views of the incisor region when detailed information is required concerning the incisor apical region
- Occasionally to supplement a panoramic radiograph when a possible abnormality is suspected on examination of the panoramic image.

**Bitewings**

- Where teeth have a questionable prognosis bitewing radiographs may be necessary, although communication with the clinician who placed the restoration, and who may have a recent radiograph, will often avoid the need for an additional image
- Bitewings may be indicated to check the caries status of a high risk patient who is to undergo fixed appliance treatment.

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Indications for lateral cephalometric radiography

The flow charts (Figures 19 & 20) give an indication as to when lateral cephalometric images may be required. If clinicians choose to take lateral cephalometric radiographs for other reasons than those suggested, they must have clinical reasons to justify their decision.

Cone beam CT

Because of recent advances the use of CBCT is considered separately and in detail in Section 11.

OTHER VIEWS

Over the years, a number of other views have been advocated but have not gained wide acceptance. Postero-anterior views of the skull may be of use in those patients who present with facial asymmetry, and may occasionally be helpful in the assessment of certain jaw or dental anomalies. The vertex occlusal view has few, if any, indications and is no longer recommended and is only of historical interest.40

The use of hand wrist radiographs to predict growth spurs has been shown not to be sufficiently accurate to be of value.41, 42

It has been suggested that the skeletal maturation of a patient can be assessed from the stages of calcification of the cervical vertebrae using the method reported by Bacetti,43 provided the lateral skull has not been collimated and the vertebrae are included in the image. However, both this approach and that of the use of hand wrist radiographs appear to have limited clinical application.44

WHEN ARE ORTHODONTIC RADIOGRAPHS INDICATED?

Following a clinical examination and before requesting radiographs the following questions should be asked:45

- **Do I need it?** Does the management of the patient’s condition depend upon a radiograph?
- **Do I need it now?** Is it likely that the condition will resolve or progress?
- **Has it been done already?** Repeated radiographs deliver additional radiation dose. The introduction of digital transfer of data may reduce this.
- **Is the correct radiograph being requested?**
- **Is a radiograph essential for diagnosis and justified?**
- **Have I made a clinical assessment?**

To make an assumption that a radiograph is necessary to complete a diagnosis and request a radiograph before a clinical examination, in order to facilitate patient flow through a clinic or practice, is unlawful.

ASSESSMENT AND TREATMENT PLANNING

The clinical examination of a patient forms the most important part of assessment and treatment planning, to which radiographs are complementary. This has been demonstrated in a number of research projects.

One such study found that 74% of radiographs taken for orthodontic purposes did not alter the initial diagnosis or treatment plan.46 The same group of authors later found that the use of algorithms reduced the need for radiographs by 36%.47 Other work has shown that radiographic findings altered treatment planning decisions in fewer than 10% of cases.48, 49

Deciduous dentition

There are few non-syndromic conditions that require radiographs in the deciduous dentition.

Mixed dentition

A high proportion of orthodontic patients will be referred in the mixed dentition.

If, following the clinical examination, active orthodontic treatment or interceptive extractions are not thought necessary radiographs to check the presence or otherwise of developing successional teeth are not indicated.

There may be patients who require early treatment, often with removable appliances, where extractions are not indicated. In such cases, in the absence of specific factors, treatment may be carried out without the need for radiographs.

When a clinical examination clearly suggests the need to extract deciduous or permanent teeth it is essential to ascertain the presence and position of unerupted permanent successors with the use of appropriate radiographs.

In patients who require functional appliances it is often appropriate to obtain cephalometric images at the commencement of treatment in order to monitor the changes that may be taking place during treatment.

Adolescent dentition

In older patients where all successional teeth including the second molars have erupted, radiographs may not be necessary.

Radiographs are not essential prior to carrying out orthodontic tooth movement unless there are clinical indicators. They may be required to assess the presence or absence of third molars where that may influence extraction choice. In these situations field limitation (dentition only) techniques should be used.

Where the incisor relationship will remain relatively unaltered during treatment cephalometric radiographs are unlikely to be required.

When a significant alteration in the incisor relationship is planned or functional appliances are to be used a lateral cephalometric radiograph may be indicated.
Where waiting lists are in operation and treatment may be required it is advisable to delay the exposure of radiographs until they can be shown to be necessary to influence the treatment plan.

**Adult dentition**

In patients with a healthy dentition and supporting structures, orthodontic treatment may be carried out without the need for radiographs. History of previous orthodontic treatment needs investigation, and localised intra-oral radiographs may be required.

When a significant change in the incisor position is planned or where the periodontal condition is in question, appropriate radiographs may be required.

Where a combination of orthodontics and orthognathic surgery is indicated the guidelines issued by the BOS/British Association of Oral and Maxillofacial Surgeons (BAOMS) should be followed.

**Monitoring of Treatment**

Radiographic monitoring may be needed during treatment but it is important to make a careful clinical assessment to ensure that the patient will benefit from further imaging.

**Unerupted teeth**

Monitoring the changes in the position of unerupted teeth may only be satisfactorily achieved with radiographs. It is important to ensure that the repeat images are taken in a position similar to the original to ensure a reliable comparison. Periapical or standard occlusal views may be needed to assess changes in the position of unerupted teeth.

When a panoramic radiograph is requested to monitor the changes in position of unerupted teeth, appropriate limitation of the field size (dentition only) should be used.

**Iatrogenic factors**

If there is evidence of excessive tooth mobility during treatment, intra-oral radiographs may be necessary to provide an accurate assessment of the underlying reason. Similarly, where there is abnormal delay of tooth movement or an indication of apical disease, intra-oral radiographs may be indicated.

Minor resorption of roots is common during orthodontic treatment with fixed appliances. However, there are cases where resorption is appreciable. The indications for intra-oral radiographs during treatment are:

- If there is evidence of excessive tooth mobility during treatment
- Where there is abnormal delay in tooth movement
- Where treatment extends over a long period of time
- Loss of vitality
- In patients having a repeat course of treatment.

**End of active tooth movement**

In some cases the taking of a cephalometric image a month or two before the completion of active treatment will enable the clinician to check that treatment targets have been achieved and allow planning of retention. The need to take radiographic records when the active appliance is removed should be carefully assessed for each patient and is unlikely to be indicated except for patients with severe malocclusions.

**Post treatment**

The clinical justification for radiographs after treatment or at the end of retention is difficult to define and has to be assessed for each patient. They may be indicated in patients where stability is uncertain either as a result of a specific type of treatment or because unfavourable growth is anticipated. Radiographs may be required if there are clinically observed changes at the end of retention in order to provide a baseline from which to assess further movement. The need for such radiographs must be clearly explained to the patient or parent and consent obtained.

Ideally every radiograph should be of benefit to the individual patient, but the practice of orthodontics has benefited from the analysis of post-treatment cephalometric views. If images are to be taken after treatment, or after retention, for all patients this must be part of a long-term research project. Such a project must be designed to improve the clinician’s understanding of malocclusion and therapeutics and the information gained is used for the benefit of the population at large. Approval from a local ethics committee is essential and informed consent obtained from every patient participating. Approval for a correctly structured research programme should not be difficult to obtain (see Section 12).

The indications for differing radiographic projections are summarised in Table 5.

<table>
<thead>
<tr>
<th>TABLE 5: Choice of view for radiographic examination</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FUNCTION</strong></td>
</tr>
<tr>
<td>Identification of the developing dentition</td>
</tr>
<tr>
<td>Confirmation of the presence/absence of teeth</td>
</tr>
<tr>
<td>Confirm the presence of unerupted teeth</td>
</tr>
<tr>
<td>Parallax localisation either with a panoramic or perapical</td>
</tr>
<tr>
<td>To identify supernumery teeth</td>
</tr>
<tr>
<td>Identification of developmental anomalies</td>
</tr>
<tr>
<td>Localisation of unerupted teeth</td>
</tr>
<tr>
<td>Assess root morphology</td>
</tr>
<tr>
<td>Assess root resorption</td>
</tr>
<tr>
<td>Assess apical disease</td>
</tr>
<tr>
<td>In combination with a standard occlusal or second perapical to localise unerupted teeth by parallax</td>
</tr>
<tr>
<td>Identification and assessment of severity of caries</td>
</tr>
<tr>
<td>Demonstration of periodontal bone levels (complementing a thorough clinical examination)</td>
</tr>
<tr>
<td>Assessment of existing restorations</td>
</tr>
<tr>
<td>Assess skeletal pattern and labial segment angulation</td>
</tr>
<tr>
<td>Monitor the effects of treatment</td>
</tr>
<tr>
<td>In selected cases to localise impacted teeth with particular reference to the position of adjacent teeth and possible resorption</td>
</tr>
<tr>
<td>To assess dental structural anomalies, e.g., germination, fusion, supernumeraries</td>
</tr>
<tr>
<td>In some cases of dental trauma where there is suspected root fracture</td>
</tr>
<tr>
<td>For some complex cases of skeletal abnormality</td>
</tr>
<tr>
<td>Some cleft palate cases.</td>
</tr>
</tbody>
</table>

---

Figure 17.

INDICATIONS FOR RADIOGRAPHS –
CHILD PATIENT LESS THAN 10 YEARS OF AGE

- Have all the incisors erupted?
  - Yes
  - No

- Are incisors well aligned or mildly crowded?
  - Yes
  - No

- Is overjet within normal limits?
  - Yes
  - No

- Have first molars erupted?
  - Yes
  - No

- Is there a clinical reason to suspect an abnormality?
  - Yes
  - No

- Is there gross crowding, marked rotation or displacement?
  - Yes
  - No

- Is overjet significantly increased or reversed?
  - Yes
  - No

- Are first molars overdue?
  - Yes
  - No

Review

X-RAY

Consider X-RAY

Consider X-RAY

Consider X-RAY
Are incisors well aligned or mildly crowded?

Is overjet or overbite within normal limits?

Are deciduous molars submerging or retained past normal age?

Have canines erupted?

Are canines in a normal position?

Is there gross crowding, displacement or marked rotation?

Class II or Class III?

Are canines palpable and in a favourable position?

Have second molars erupted?

Is patient over 14?

Figure 18.
INDICATIONS FOR RADIOGRAPHS – PATIENT OVER 10 YEARS OF AGE
Is the overjet between 1mm and 5mm?

Is the skeletal pattern Class III?

Is the patient about to start treatment?

Is only the upper arch to be treated?

Are functional appliances and/or upper and lower fixed appliances to be used?

Is occlusion Class 2 div/ii or bimaxillary proclination or compensated Class III?

Are upper and lower fixed appliances planned?

Consider CEPH

Not indicated

Consider CEPH

Consider CEPH

Not indicated

Figure 19. IS A PRE-TREATMENT LATERAL CEPHALOMETRIC RADIOGRAPH INDICATED IN A PATIENT AGED 10–18?
Is the patient over 18 years of age?

Is the patient below 10 years of age?

Is the occlusion a marked Class II or Class III which may need early treatment or monitoring?

Does the patient want orthodontic treatment or orthognathic surgery?

Is the occlusion a significant Class II or Class III?

Is the occlusion a bimaxillary proclination or compensated Class III?

Figure 20.

**IS A PRE-TREATMENT LATERAL CEPHALOMETRIC RADIOGRAPH INDICATED IN A PATIENT OVER 18 YEARS OR BELOW 10 YEARS?**
APPLICATIONS OF CONE BEAM COMPUTED TOMOGRAPHY (CBCT) IN ORTHODONTICS

IN ORTHODONTICS, CBCT might be used for a variety of reasons. Since the previous edition of these guidelines in 2008, the literature has grown considerably. Establishing the diagnostic efficacy of an imaging technique ideally requires evidence at all levels, starting with technical efficacy (e.g., measurement accuracy, reproduction of detail), diagnostic accuracy (e.g., sensitivity, specificity), impact on treatment planning decisions or patient outcomes and, at the highest level, the cost-effectiveness at the societal level.

It is important to be aware that most knowledge on CBCT relates to the lower levels of diagnostic efficacy. In the absence of comprehensive evidence, this technique should be used cautiously and in carefully selected situations. Cephalometric and panoramic radiographs appear to be sufficient in most circumstances and should not be replaced with CBCT imaging.

USES OF SMALL FIELD OF VIEW (FOV) CBCT

Unerupted maxillary canines

The majority of CBCT examinations of young people are undertaken for a localised examination of the anterior maxillary region to assess the position of unerupted canine teeth and suspected root resorption of incisors. There are now a number of retrospective studies comparing orthodontists’ decisions made on such clinical cases, with and without the availability of CBCT imaging, which suggest that treatment plans are changed in a minority of cases. The evidence suggests that clinicians’ confidence and consistency in treatment planning decisions is improved.

There is improved accuracy of localisation of unerupted maxillary canine teeth and identification of root resorption in incisor teeth using a three-dimensional imaging technique. In most cases, however, there is agreement between localisation and presence of root resorption made using conventional radiographs and CBCT imaging.

Previous UK and European guidelines have suggested that CBCT may be appropriate for the examination of unerupted maxillary canines in selected cases where conventional radiographs fail to provide adequate information. Such an approach seems sensible. For example, conventional radiographs may show root resorption of an incisor tooth with sufficient detail to allow a treatment plan to be devised. CBCT could then be reserved for equivocal cases or those with potential complications.

TABLE 6: Ectopic canine selection criteria for localised CBCT examination

| 1. Take at least two conventional radiographs, permitting use of parallax. This may be achieved using two intra-oral radiographs or one intra-oral radiograph and a panoramic radiograph |
| 2. Consider whether this is sufficient to make a treatment plan |
| 3. If yes, no further imaging needed. If no, then consider localised CBCT |

Cephalometric synthesis

The ability to produce a cephalometric image from a CBCT scan is an attractive proposition. The images produced in this way are described as synthesised cephalometric images. Some research projects have compared conventional cephalometric images with synthesised images. These have been carried out both on skulls and also on patients. Much of the research has been related to identifying the common cephalometric landmarks which can be more accurately defined using CBCT.

To obtain a synthesised cephalometric image using CBCT necessitates a large FOV scan which includes the sella turcica. However, a small localised field of view is all that is usually appropriate for most orthodontic treatment planning. When such cases need cephalometric assessment then a separate standard cephalometric image should be used.

The practice of taking a large volume FOV CBCT in order to obtain cephalometric data is not indicated.

GENERALISED USES OF CBCT

The use of large FOV CBCT to image the entire dentition in orthodontic assessment has been the subject of controversy. Studies have shown that root angle and position of teeth is shown more accurately by CBCT than on panoramic radiography. There is, however, almost no evidence for the impact of CBCT on diagnosis and treatment planning in orthodontics apart from for the impacted maxillary canine.

Hodges et al (2013) studied cases where treatment plans were made with conventional radiographs and study models.

Other uses of small FOV CBCT

Other localised uses of small FOV CBCT can be considered, such as assessment of unerupted dilacerated incisor teeth, as this view can provide an accurate measurement of the angulation of the dilaceration which might assist in treatment planning.

Surgical planning may also benefit from three-dimensional information. An example is where unerupted teeth or supernumerary teeth are to be surgically removed, but when they are located in the region of important anatomical structures. If the neurovascular structures cannot be shown to be at a safe distance from the area of surgery on conventional radiographs, then localised small FOV CBCT would be justified.

The use of CBCT for the assessment of cleft palate can be justified where CT scans have been used in the past, as small/medium FOV CBCT is likely to have a lower radiation dose. As described in a recent review, CBCT can allow quantification of the bone defect volume in the context of grafting, as well as localisation of ectopic teeth which may be associated with clefts.

and compared them with those made with CBCT. They concluded that it contributed to treatment planning in cases with an unerupted tooth, root resorption or a severe skeletal discrepancy, but that CBCT should not be used routinely.

Large FOV CBCT allows the possibility of three-dimensional measurements to be made. A recent systematic review found limited evidence on efficacy of three-dimensional measurement methods, of only moderate quality. Furthermore, there is no standardised system of analysis. In the absence of any evidence to show that three-dimensional measurements improve treatment outcomes, they cannot be currently recommended.

Recent European guidelines did not support the use of large FOV CBCT as a routine part of orthodontic practice. UK guidelines specifically condemned the practice if the intention was solely to use the CBCT data to reconstruct panoramic and synthesised cephalometric images. Radiation dose with CBCT

As with all radiographic imaging systems, the radiation dose received by the patient is determined by many different factors. It is not possible to give single dose value or to compare the dose with numbers of conventional or panoramic radiographs. Similarly, the same CBCT examination may result in a higher effective dose in a child than in an adult, usually because the thyroid gland is closer to the FOV. Many manufacturers of CBCT equipment describe their product as ‘low dose’, a phrase that should be read with considerable caution as the comparison is often with conventional CT systems.

Data on effective doses from CBCT systems are available, covering extremely wide ranges of effective dose for CBCT examinations (Table 7). The more recent publication, a meta-analysis, provides dose data for specific models of CBCT equipment. While a few CBCT machines have a single fixed FOV, most new machines will offer a choice. There is a correlation between the size of the FOV and the effective dose, so this is a straightforward means of optimisation. As well as its radiation protection advantages, a smaller FOV will require a shorter time for performance interpretation and will generally exclude anatomical regions requiring specialist radiological evaluation.

With CBCT, as with all digital radiographic systems, there is broad latitude for exposure settings. Keeping doses as low as reasonably practicable, in this context, means reducing exposures to a level consistent with adequate image quality. The challenge for clinicians is to identify the appropriate exposure settings. Manufacturers may advise higher exposure settings than are necessary because this will tend to improve the aesthetics of images. Certain diagnostic tasks require a higher level of detail than others. For example, detection of subtle root resorption, root canals, and undisplaced root fractures will require higher image resolution than tooth localisation. Children will need a lower exposure than an adult for acceptable image quality. The advice of the Radiation Protection Adviser/Medical Physics Expert should be sought on appropriate exposure settings to be used. It should be noted that a few CBCT machines use an automatic exposure control (AEC). If a CBCT machine offers a ‘high resolution’ option, it should be recognized that this is only achieved by increasing the tube current exposure time product (mAs) and, hence, the effective dose. A few machines offer the option of partial rotations (reduced number of image slices). This is essentially reducing the exposure time and can be a convenient way for the operator to lower doses.

There is evidence that thyroid shields are effective in reducing dose with large FOV CBCT examinations. With limited FOV examinations the thyroid gland should be well away from the primary X-ray beam but a thyroid shield should be used if available, and certainly for larger fields of view. It is more

<table>
<thead>
<tr>
<th>Field of view dimensions</th>
<th>Use the smallest FOV consistent with the diagnostic needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube operating potential (kV) and tube current exposure time product (mAs)</td>
<td>The combination of the lowest kV and lowest mAs settings consistent with an adequate image quality should be selected</td>
</tr>
<tr>
<td>Resolution settings</td>
<td>The lowest resolution consistent with the diagnostic needs should be chosen</td>
</tr>
<tr>
<td>Shielding</td>
<td>The use of thyroid shields containing suitable X-ray absorbing material should be considered</td>
</tr>
</tbody>
</table>

### TABLE 7: Effective doses for adult and child CBCT examinations

<table>
<thead>
<tr>
<th>Field of view height (cm)</th>
<th>Effective dose (μSv)</th>
<th>Table 8: Factors which can be used to reduce effective doses in CBCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 cm</td>
<td>(45°) (16°) (86°)</td>
<td>Use the smallest FOV consistent with the diagnostic needs</td>
</tr>
<tr>
<td>&gt;10 cm</td>
<td>(17°) (16°) (86°)</td>
<td>The combination of the lowest kV and lowest mAs settings consistent with an adequate image quality should be selected</td>
</tr>
<tr>
<td>10-15 cm</td>
<td>(16°) (11°) (86°)</td>
<td>The lowest resolution consistent with the diagnostic needs should be chosen</td>
</tr>
<tr>
<td>&gt;15 cm</td>
<td>(16°) (11°) (86°)</td>
<td>The use of thyroid shields containing suitable X-ray absorbing material should be considered</td>
</tr>
</tbody>
</table>

While higher effective dose levels are seen in children compared with adults when the same equipment is used, fewer paediatric studies have been performed, accounting for some higher values for adults in these reviews. It can be concluded that for most CBCT examinations, the effective doses delivered are typically an order of magnitude greater than those for conventional radiographic techniques.

### Dose optimisation

If a decision to use CBCT has been made, then it is essential to follow the principle of keeping all doses as low as reasonably practicable (ALARP). There are many factors which influence radiation dose with CBCT, some of which are in the control of the operator and some which are not. Those that are chosen by the operator are shown in Table 8.

- **Field of view dimensions**
- **Tube operating potential (kV) and tube current exposure time product (mAs)**
- **Resolution settings**
- **Shielding**

important in children and young people, as the thyroid is more likely to be close to the primary beam and to secondary (scattered) radiation. Care should be taken, however, to avoid the shield intruding into the primary beam. There is no need to use abdominal protection (‘lead aprons’) for CBCT examinations.  
All practitioners with CBCT equipment should ensure that the Radiation Protection Adviser/Medical Physics Expert has been consulted about appropriate clinical exposure factors for their CBCT machine. At the time of writing, a national Diagnostic Reference Level (DRL) has yet to be established but ‘achievable dose’ levels for adult and child CBCT examinations, based on dose-area-product measurement (mGy cm²), have been set in the UK as a guide to what is considered ‘reasonably achievable’. The Radiation Protection Adviser/Medical Physics Expert should establish local DRLs for individual machines for typical examinations. Doses given to patients should be recorded and audited in conjunction with the Medical Physics Expert at least once every three years. Some machines provide a dose-area-product readout but where this is not available the actual exposure settings used should be recorded. For further information, national guidance should be consulted.  

**TABLE 9: Strategy for optimisation: low dose protocol**

<table>
<thead>
<tr>
<th>When planning a CBCT examination:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assess patient size and be prepared to adjust exposure factors accordingly</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Select the smallest field of view consistent with the diagnostic task</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Consider the diagnostic task in question and whether there is a need for high levels of detail</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Make a final choice on exposure factors</strong></td>
<td></td>
</tr>
</tbody>
</table>

**REPORTING OF CBCT**

Under IRMER, the employer must ensure that all tasks in radiology are performed by persons who have adequate training. The clinical evaluation (‘reporting’) of CBCT scans is one such task that must be performed and for which a written record must be kept. Because the technology of CBCT is relatively new, interpretation of the scans is not included in the undergraduate curriculum or as part of specialist orthodontic training. Thus, practitioners using CBCT as part of their practice need either to undergo additional training or ensure that CBCT scans are reported by another person who has adequate training. It is feasible for dentists, through further training, to build on their existing skills and become able to interpret small FOV CBCT examinations of the dento-alveolar region. This region has been defined as the teeth and their supporting bone, including the mandible and the maxilla up to the floor of the nose. Curricula for further training for dentists undertaking radiological interpretation of CBCT have been established. Large FOV CBCT scans extend to include regions of the head and neck outside the dento-alveolar region (e.g., base of skull) and in such cases the reporting should be performed by a specialist dental and maxillofacial radiologist or a clinical (medical) radiologist. This is particularly relevant for orthodontists using large FOV CBCT. Where orthodontic patients are referred to an external provider of CBCT services, there needs to be clarity about who will perform the clinical evaluation (report). Some providers will offer a specialist reporting service in addition to providing the scan images. When this option is not chosen by the referrer, an alternative arrangement needs to be arranged to satisfy IRMER. UK guidance deals with this in greater detail.

**THE use of radiographs in research is incorporated in IRMER.**  
All clinical research involving ionising radiation must be reviewed by a Research Ethics Committee (REC). Details of ethics committees are given on the National Research Ethics Service (NRES) website. In a formal orthodontic postgraduate training programme appropriate records for reporting and research are needed. Latent cephalometric radiographs may be necessary in order to quantify changes, which may have occurred as a result of growth and treatment. In selected cases, additional images may be required towards the end of active treatment and occasionally after completion of retention.

If radiographs are taken for research purposes, and are in addition to the normal clinical requirements, they must form part of a properly constructed audit or research project, or conform to nationally agreed standards. For example, the Clinical Standards Advisory Group (CSAC) protocols for the long-term follow-up of patients with cleft lip and palate. A favourable ethical opinion does not replace the statutory requirement for exposures to be individually justified by IRMER. Practitioners under current legislation (see paragraph 3.22 of reference), full details of which are available. Local rulings vary, but in many cases formal approval will be deemed to be unnecessary where the research is retrospective using existing records and where there is no intention of recalling patients for further examination or investigation. Practitioners who are not working in a teaching environment but wish to undertake research that necessitates additional radiographs should also seek approval from their local district ethics committee.

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86. Central Office for Research Ethics Committees [http://www.carec.org.uk](http://www.carec.org.uk)
IMAGING OF THE TEMPOROMANDIBULAR JOINT

Both general practitioners and orthodontists will encounter patients with a range of temporomandibular joint (TMJ) disorders. Modern imaging of the TMJ is dependent on facilities available and the suspected underlying disease based on the patients clinical signs and symptoms. Imaging could include:

- Conventional panoramic radiography
- Specific field limitation TMJ panoramic programmes
- Transpharyngeal radiography
- Multidirectional tomography
- Cone beam computed tomography (CBCT)
- Computed tomography (CT)
- Magnetic resonance (MRI).

The main pathological conditions that can affect the TMJ include:

- TMJ pain dysfunction syndrome (myofascial pain dysfunction syndrome)
- Internal derangements
- Osteoarthritis (degenerative joint disease)
- Rheumatoid arthritis.

TMJ (myofascial) pain dysfunction syndrome is the most common clinical diagnosis applied to patients with pain in the muscles of mastication, often worse in the morning or evening, with occasional clicking and stiffness. The aetiology is said to include malocclusion, bruxism, trauma and psychological factors. Symptoms may develop during orthodontic treatment particularly if there is evidence of subclinical problems at the start. 88 The bony components of the TMJ – the condylar head and the glenoid fossa – are usually normal so conventional imaging is of limited value. 88, 89 The Royal College of Radiologists state that in relation to TMJ dysfunction, radiographs ‘do not add information as the majority of these temporomandibular joint problems are due to soft tissue dysfunction rather than bony changes, which appear late and are often absent in the acute phase’. 90

Whilst it has been common practice to take conventional radiographs of the joints in patients with TMJ pain dysfunction, this practice can no longer be justified and is therefore no longer recommended.

Treatment for the majority of patients with TMJ pain dysfunction that will be encountered in orthodontic practice in most cases is conservative and will include reassurance, exercises or the fitting of biteguards. This treatment would not be altered in anyway as a result of radiographic findings, hence the recommendation that radiographs are not required. 91

Although much attention is given to the position of the disc within the TMJ, the disc cannot be visualised directly on conventional radiographs or on CBCT. Satisfactory soft tissue images can be obtained using MRI which does not use ionising radiation. However, abnormal position of the disc does not necessarily equate with disease – research using MRI has shown altered disc position in over 30% of symptomless volunteers. 92 MRI imaging of the TMJ is generally reserved for those patients with persistent symptoms following conservative treatment when surgical intervention is being considered.

It has been argued that the absence of pre-treatment radiographs could be considered negligent when TMJ pain dysfunction symptoms develop during or after orthodontic treatment. Conventional radiographs are no longer recommended for investigating TMJ pain dysfunction so the need to have any radiographs taken in advance of treatment in order to avoid possible later claims of negligence cannot be justified. 93 There have been suggestions that orthodontic forces or the extraction of teeth, as a part of orthodontic treatment, can cause symptoms of TMJ pain dysfunction. However, there is ample evidence to refute these suggestions and in an extensive review of the literature Luther suggested that ‘neither possession of malocclusion nor orthodontic treatment can be said to cause or cure TMJ pain dysfunction’. 94, 95

In patients suspected of having disease affecting the bones of the TMJ, conventional radiographs, particularly panoramic radiographs, are still only of limited value. These patients could possibly benefit from CBCT imaging but only if the additional information obtained is likely to influence management or subsequent treatment.

The advice remains to take an adequate history and to examine the patient fully before starting orthodontic treatment. 96

MEDICO-LEGAL ASPECTS OF RADIOGRAPHY FOR ORTHODONTIC PURPOSES

NEED FOR RADIOGRAPHY

The International Principles of Ethics for the Dental Profession formulated by the Federation Dentaire Internationale (FDI) state “The primary duty of the dentist is to safeguard the health of patients.” 97

The clinical decision about the need for radiography is influenced by many factors. It is unethical to take radiographs for medico-legal, administrative reasons or ‘just in case’ if there is no clinical need. It has been stated by the Royal College of Radiologists that ‘if, as a result of careful clinical examination, you decide that an X-ray is not necessary for the future management of the patient, your decision is unlikely to be challenged on medico-legal grounds.’ 98

It is the legal responsibility of all clinicians to be aware of all relevant current legislation relating to radiography.

STORAGE AND RETENTION OF RADIOGRAPHS

Radiographs are a diagnostic aid that form part of a patient’s clinical records. The Data Protection Act (1998) 99 entitles patients to see their clinical records whether in computerised or manual form.

Whilst patients are legally entitled to copies of their records it is important that the practitioner retains the original records. 100, 101

The ownership of records can be summarised as:

• NHS General Dental Services records should be considered to be the property of the individual orthodontist or primary care organisation, although NHS authorities have certain rights of access to these records

• Private patient records are the property of the individual practitioner but the legal position with regard to ownership of radiographs is uncertain and to date has never been tested in law. 102

• Records should be kept for 10 years after completion of treatment and those relating to children should be kept until the patient’s 25th birthday, or 26th if an entry was made when the person was 17 years old.

The recommended time to retain records for legal purposes is complex and for England and Wales the principle guidance is contained in Records Management: NHS Code of Practice. 105

The Consumer Protection Act (1987) 106

• A patient is entitled to compensation if damaged by a defective product. It is not necessary to demonstrate negligence. An action arising from this Act (Injury from Defective Product) may occur 10 years after the knowledge of such an episode. It would therefore seem wise to arrange to retain radiographic records until 11 years after the last record entry (making a one year allowance for the due process of law), or 25 years of age, whichever is the longer

• Some Defence and Protection organisations advise that from a dento-legal perspective all records should be retained indefinitely. This may prove difficult.

More detailed advice on record keeping is provided in the BOS guidelines, Orthodontic Records: Collection and Management. 105

The European Union Directive on Data Protection 106 specifies that data must be obtained and processed fairly and lawfully, held and processed only for specified, explicit and legitimate purposes. This directive also outlines the need for ethical approval and individual consent for research and audit purposes.

Transfer of radiographs

When a patient is referred to a specialist for orthodontic treatment or opinion the relevant radiographs and clinical information must be forwarded. 107

If the images are retained for the duration of orthodontic treatment and subsequent monitoring, the orthodontist must ensure the safe storage of the radiographs to comply with current recommendations for the retention of records. This will necessitate liaison with the original referring clinician. Clearly, the availability of digital radiology facilitates copying of images and transfer when required.

Good records are often critical in refuteing allegations of negligence. Defence may prove impossible if:

• Radiographs were not taken when there were justifiable clinical grounds for doing so

• Radiographs have been lost

• Radiographs that have been taken are of such poor quality that they are of little or no clinical use or diagnostic value

• Radiographs are not reported or interpreted correctly

• Radiographic reports are not retained as part of the patient health record.

102. MDDC Journal (1995) 11, 43
CONCLUSIONS

GOOD quality radiographs provide a valuable record to assist in the assessment and management of malocclusion, clinical audit, and research.

Many of the suggestions in this document are a matter of common sense. For example, avoiding repetition of recent images, being satisfied that there is a clinical need before requesting a radiograph, or making use of other less invasive procedures.

Radiographic exposure is an invasive procedure. It is appropriate to seek a sensible risk/benefit balance in its use for orthodontic purposes. This requirement is particularly relevant to the use of CBCT in orthodontics.

These Guidelines should not be interpreted as absolute rules, but rather are offered to provide help in an area of clinical practice where attitudes are changing rapidly. For guidelines to serve a useful purpose they must be monitored and updated in line with current practice, developments and legislation. It will be important for both clinicians and the British Orthodontic Society to keep this balance under review, as has been attempted with this 4th Edition.

In summary, careful assessment and the justification of need for a radiographic examination, meticulous technique, quality assurance and understanding the advantages and disadvantages of the different imaging techniques available, are the keys to the best clinical practice of radiography in orthodontics.

Clinicians should note:

- A radiograph should only be taken after a clinical examination, when it is deemed to provide sufficient benefit to the exposed individual and will influence clinical management
- All radiographs should be evaluated (reported) and this evaluation should be recorded
- There is no known safe level of radiation exposure
- The benefits of diagnostic radiology generally outweigh the risks
- The level of risk is only justified when the patient receives a commensurate health benefit from a minimum dose.

There is little evidence to support the use of radiographs for the following practices:

- Monitoring the developing occlusion
- Assessing a patient who is likely to be placed on a waiting list for treatment
- Evaluating post-treatment occlusal changes.

There is no indication for the following practices of taking or requesting:

- Radiographs before a clinical examination
- Radiographs when only minimal tooth movement is planned
- Full mouth periapical views before treatment
- A cephalometric lateral radiograph for the prediction of facial growth
- Radiographs of the hand and wrist to predict the onset of the pubertal growth spurt
- Radiographs for investigation of temporomandibular disorders associated with TMJ (myofascial) pain dysfunction
- Prospective radiographs only for medico-legal reasons i.e., the practice of ‘defensive dentistry’
- Post-treatment radiographs for professional examinations and clinical presentation
- Routine Cone Beam CBCT for all orthodontic patients.

THE ESSENCE OF THESE GUIDELINES IS:

Take radiographs ONLY when justified clinically

This is a legal requirement in the UK
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AEC</td>
<td>Automatic exposure control</td>
</tr>
<tr>
<td>ALARP</td>
<td>As low as reasonably practicable</td>
</tr>
<tr>
<td>BAOMS</td>
<td>British Association of Oral and Maxillo-Facial Surgeons</td>
</tr>
<tr>
<td>BOS</td>
<td>British Orthodontic Society</td>
</tr>
<tr>
<td>BSDMFR</td>
<td>British Society of Dental and Maxillofacial Radiology</td>
</tr>
<tr>
<td>BSSO</td>
<td>British Society for the Study of Orthodontics</td>
</tr>
<tr>
<td>CBCT</td>
<td>Cone Beam Computed Tomography</td>
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<tr>
<td>CCD</td>
<td>Charge-coupled device</td>
</tr>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductors</td>
</tr>
<tr>
<td>COSHH</td>
<td>Control of Substances Hazardous to Health</td>
</tr>
<tr>
<td>CPD</td>
<td>Continuing Professional Development</td>
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<tr>
<td>CSAG</td>
<td>Clinical Standards Advisory Group</td>
</tr>
<tr>
<td>CT</td>
<td>Computed Tomography</td>
</tr>
<tr>
<td>DCP</td>
<td>Dental Care Professional</td>
</tr>
<tr>
<td>DRL</td>
<td>Diagnostic reference level</td>
</tr>
<tr>
<td>FDI</td>
<td>Federation Dentaire Internationale</td>
</tr>
<tr>
<td>FGDP(UK)</td>
<td>Faculty of General Dental Practice (United Kingdom)</td>
</tr>
<tr>
<td>FOV</td>
<td>Field of view</td>
</tr>
<tr>
<td>FSD</td>
<td>Focus to skin distance</td>
</tr>
<tr>
<td>GDC</td>
<td>General Dental Council</td>
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<tr>
<td>HMSO</td>
<td>Her Majesty’s Stationery Office</td>
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<td>HSC</td>
<td>Health Service Circular</td>
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<tr>
<td>HSE</td>
<td>Health and Safety Executive</td>
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<td>ICRP</td>
<td>International Committee on Radiological Protection</td>
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<tr>
<td>IRMER</td>
<td>Ionising Radiation (Medical Exposure) Regulations 2000</td>
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<tr>
<td>IRR</td>
<td>Ionising Radiations Regulations 1999</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
</tr>
<tr>
<td>NCIC</td>
<td>National Committee on Radiological Protection</td>
</tr>
<tr>
<td>NRES</td>
<td>National Research Ethics Service</td>
</tr>
<tr>
<td>NRPB</td>
<td>National Radiological Protection Board</td>
</tr>
<tr>
<td>PACS</td>
<td>Picture Archiving and Communication System</td>
</tr>
<tr>
<td>PSP</td>
<td>Photo-Stimulable Phosphor plate</td>
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<tr>
<td>QA</td>
<td>Quality Assurance</td>
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<td>Radiation Protection Advisor</td>
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<tr>
<td>SIGN</td>
<td>Scottish Intercollegiate Guidelines Network</td>
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<tr>
<td>TMD</td>
<td>Temporomandibular Joint Disorder</td>
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<tr>
<td>TMJ</td>
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<tr>
<td>WHO</td>
<td>World Health Organisation</td>
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