

GUIDELINES
FOR THE USE OF
RADIOGRAPHS IN
CLINICAL ORTHODONTICS



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FOREWORD

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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)¹ 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.²

CBCT imaging has a useful place in selected cases and European evidence-based guidelines for their use have been formulated by the SEDENTEXCT project.³ In this edition a new section on CBCT 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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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.

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for permission to reproduce material from Essentials of Dental Radiography and Radiology 5th Edition (2013), Whaites & Drage.

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

- 1. Health and Safety Legislation (2000)**
The Ionising Radiation (Medical Exposure) Regulations 2000. SI 2000 No 1059. London, the Stationery Office (IRMER)
<http://www.legislation.hmso.gov.uk/si/si2000/20001059.htm>
- 2. Larson BE (2012)**
Cone-beam computed tomography is the imaging technique of choice for comprehensive orthodontic assessment. *American Journal of Orthodontics and Dentofacial Orthopedics* 141, 402
- 3. European Commission (2012)**
Cone beam CT for dental and maxillofacial radiology (Evidence-based guidelines). Radiation Protection no 172. Luxembourg: Publications Office
http://www.sedentext.eu/files/radiation_protection_172.pdf

THE purpose of guidelines is to improve the effectiveness, and efficiency, of clinical care.⁴ 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.⁵ 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.⁶ They are recommended as current best practice and as selection criteria to comply with the requirements of IRMER.¹

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."⁷

"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."⁸

"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."⁹

"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."¹⁰

"The stated aims of this excellent booklet to assist the orthodontist to achieve sound clinical practice with desired outcomes are successfully met."¹¹

"The logical structure provides an easy expeditious read."¹²

"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 meaningful guidelines such as those in the United Kingdom."¹³

Awarded 'Highly Commended' in the British Medical Association Medical Book Competition 2009.

X-RAYS, and their ability to penetrate human tissue to create a visual image, were discovered by Wilhelm Röntgen in 1895. Within weeks of their discovery the first dental radiographic images were created. Within months medical diagnostic imaging had been revolutionised. These early images required high doses of radiation and very soon local side-effects such as skin reddening, hair loss and ulceration became apparent. Within only a few years it was realised that 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.¹⁴ UK law requires that *all radiographs must be clinically justified*. These guidelines are primarily designed to assist orthodontists in this 'justification' process.¹⁵

4. Scottish Intercollegiate Guidelines Network (SIGN) (2000) Getting validated guidelines into local practice. <http://www.sign.ac.uk/>

5. Jerrold L (2014) Seeing before doing *American Journal of Orthodontics and Dentofacial Orthopedics* 146, 530-3

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8. Turpin DL (Editor) (2008) British Orthodontic Society revises guidelines for clinical radiography *American Journal of Orthodontics and Dentofacial Orthopedics* 134, 597-8

9. Dreyer C (2008) Orthodontic radiographs Guidelines, 3rd edition *European Journal of Orthodontics* 30, 669-70

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11. Cameron J (2009) *Australian Orthodontic Journal* 25, 183

12. Williams G (2009) *British Dental Journal* 206, 3

13. Jerrold L (2015) Author's response *American Journal of Orthodontics and Dentofacial Orthopedics* 147, 296

14. Hawkes N (2007) Scan or scandal. *The Times (Times 2) June 14*, page 4

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THE DAMAGING EFFECTS OF IONISING RADIATION

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.

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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 Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment published by the Department of Health and the Health Protection Agency in 2001¹⁶
- The European Guidelines on Radiation Protection in Dental Radiology – the safe use of radiographs in dental practice in 2004¹⁷
- The third edition of Selection Criteria for Dental Radiography published by the Faculty of General Dental Practice (UK) 2013¹⁸
- The Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment by the Health Protection Agency in 2010¹⁹
- Radiation Protection: Cone beam CT for dental and maxillofacial radiology – guidelines published by the SEDENTEXT European Consortium in 2012.²⁰



16. Department of Health (2001) Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment

<https://www.gov.uk/government/publications/dental-practitioners-safe-use-of-x-ray-equipment>

17. European Commission (2004) European Guidelines on Radiation Protection in Dental Radiology. Radiation Protection 136. Luxembourg: Publications Office

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Chilton: Health Protection Agency

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http://www.sedentext.eu/files/radiation_protection_172.pdf

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)²¹ 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.²²

The European Commission has also published guidelines.¹⁷

The legal requirements of IRR 99 and IRMER 2000, together with 'good practice' advice were included in the 2001 Department of Health booklet Guidance Notes for Dental Practitioners on the Safe Use of X-ray equipment¹⁶ and in 2010 in the Health Protection Agency's booklet Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment.¹⁹

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.

21. Health and Safety Legislation (1999)
The Ionising Radiations Regulations 1999. SI 1999 No 3232. London, the Stationery Office (IRR 99)
<http://www.legislation.hmso.gov.uk/si/si1999/19993232.htm>

22. Health and Safety Legislation (2000)
The Ionising Radiation (Medical Exposure) Regulations 2000. SI 2000 No 1059. London, the Stationery Office (IRMER)
<http://www.legislation.hmso.gov.uk/si/si2000/20001059.htm>

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_R). 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_R) 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 (w_T), based on its radio-sensitivity. The sum of the individual tissue weighting factors represents the weighting factor for the whole body. The recommendations of the ICRP in 2007 for tissue weighting factors are shown in Table 1.²³

TABLE 1: Recommendations of the ICRP (2007) for tissue weighting factors²³

Tissue	2007 w_T	Tissue	2007 w_T
BONE MARROW	0.12	LIVER	0.04
BREAST	0.12	THYROID	0.04
COLON	0.12	BONE SURFACE	0.01
LUNG	0.12	BRAIN	0.01
STOMACH	0.12	KIDNEYS	0.01
BLADDER	0.04	SALIVARY GLANDS	0.01
OESOPHAGUS	0.04	SKIN	0.01
GONADS	0.08	REMAINDER TISSUES	0.12*

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

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

$$\text{Effective dose } (E) = \sum \text{Equivalent dose } (H_T) \text{ in each tissue} \times \text{relevant tissue weighting factor } (w_T)$$

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 μSv (micro sievert—one millionth of one sievert) or 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).^{23, 24}

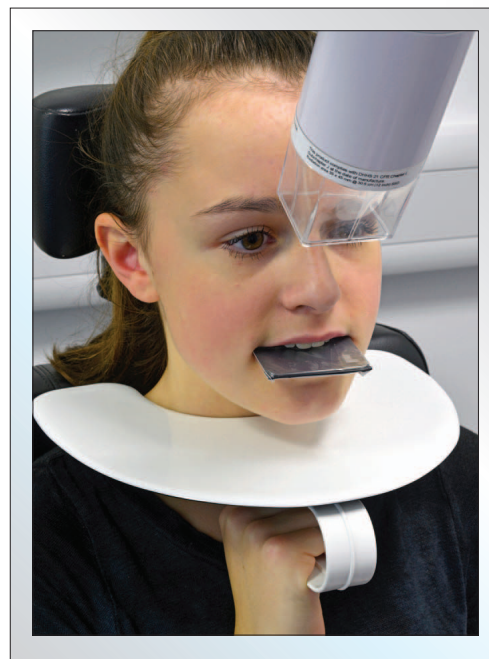


Figure 1. Use of a thyroid shield when taking an upper occlusal

EFFECTIVE DOSES AND RISKS FROM EXPOSURE TO X-RAYS IN ORTHODONTIC PRACTICE

Two publications, one from the Health Protection Agency²⁵ 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.

23. ICRP (2007)

The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. *Annals of the ICRP*, 37, 2-4

24. Svenson B, Sjöholm B, Jonsson, B (2004)

Radiation of absorbed doses to the thyroid gland in orthodontic treatment planning by reducing the area of irradiation. *Swedish Dental Journal* 28, 137-47

25. HPA Working Party on Dental Cone Beam CT Equipment (2010)

Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment. Health Protection Agency

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/340159/HPA-CRCE-010_for_website.pdf

26. European Commission (2012)

Cone beam CT for dental and maxillofacial radiology (Evidence-based guidelines). Radiation Protection no 172. Luxembourg: Publications Office. http://www.sedentext.eu/files/radiation_protection_172.pdf

TABLE 2: Frequency and collective dose for medical and dental X-ray examinations in the UK

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

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: Risks of cancer from diagnostic X-rays

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

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 Radiology²⁷ 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

AGE GROUP (year)	Multiplication factor for risk
< 10	x 3
10 – 20	x 2
20 – 30	x 1.5
30 – 50	x 0.5
50 – 80	x 0.3
80 +	Negligible

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).^{28, 29}

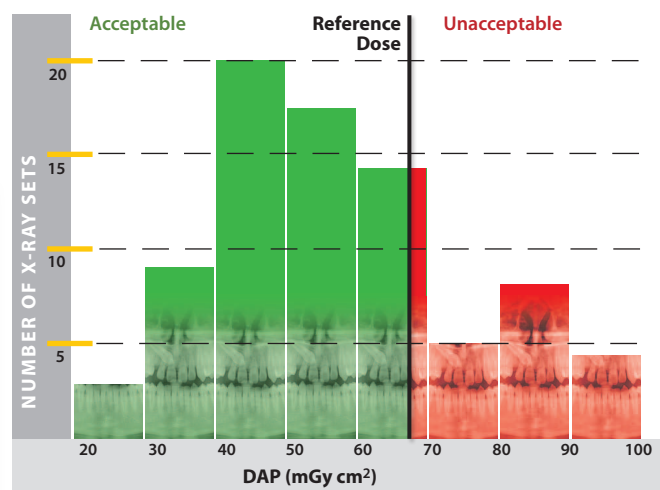


Figure 2. Surveys of panoramic X-ray units show a wide variation in dose for exposures in children. The National Reference ‘Dose-Area-Product’ level for this examination is 67mGy/cm². Exposures in excess of this value result in some children receiving a higher radiation dose than is needed to achieve an image of adequate quality²⁸

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27. European Commission (2004) European Guidelines on Radiation Protection in Dental Radiology. Radiation Protection 136. Luxembourg: Publications Office <https://ec.europa.eu/energy/sites/ener/files/documents/136.pdf>

28. Hart D, Hillier MC, Shrimpton PC (2010) Doses to Patients from Radiographic and Fluoroscopic X-ray Imaging procedures in the UK - 2010 review. HPA-CRCE-034. Health Protection Agency

29. Lecomber AR, Downes SL, Mokhtari M, Faulkner K (2000) Optimisation of patient doses in programmable dental panoramic radiography *Dentomaxillary Radiology* 29, 107-12

IMAGING EQUIPMENT AND TECHNIQUES AVAILABLE FOR ORTHODONTIC RADIOGRAPHY

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:³⁰

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).

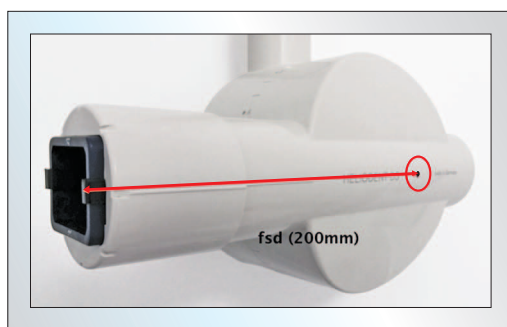


Figure 3.
X-ray tubehead showing focus to skin distance (fsd)

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.

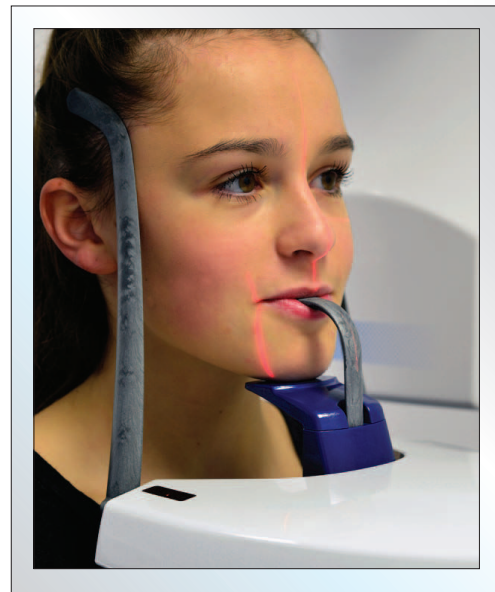


Figure 4.
Light beam markers to aid in patient positioning

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.

30. Department of Health (2001)

Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment
<https://www.gov.uk/government/publications/dental-practitioners-safe-use-of-x-ray-equipment>

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.

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.

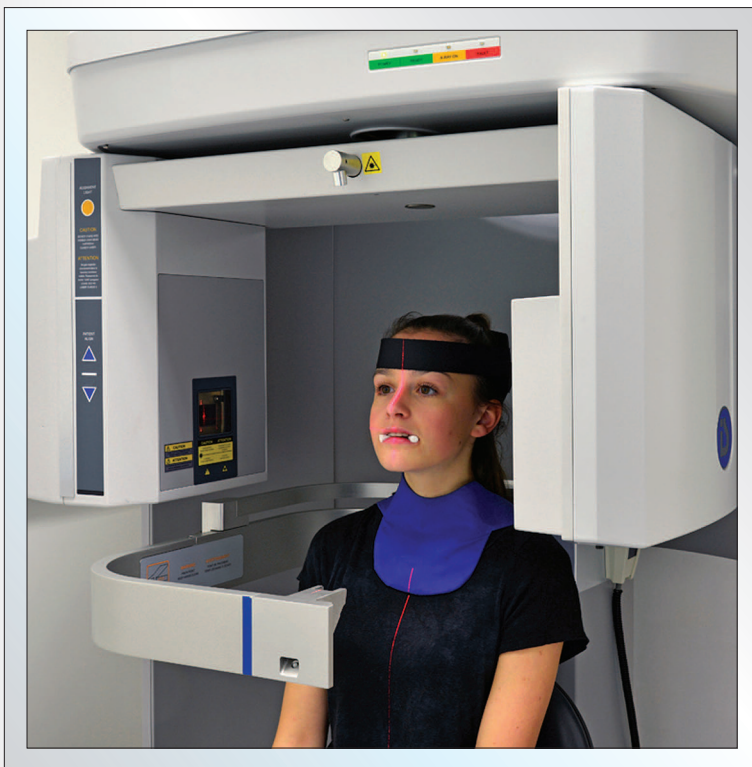


Figure 5.
Patient positioning
for CBCT showing
light markers, head
restraint and
thyroid collar

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 mm³ and 0.4 mm³) 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).

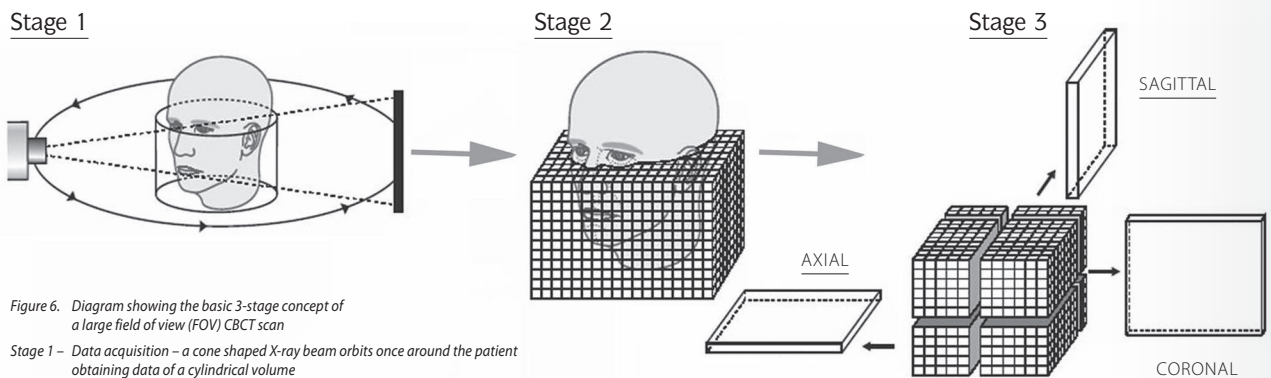


Figure 6. Diagram showing the basic 3-stage concept of a large field of view (FOV) CBCT scan
 Stage 1 – Data acquisition – a cone shaped X-ray beam orbits once around the patient obtaining data of a cylindrical volume
 Stage 2 – Primary reconstruction – the computer divides the cylindrical volume into tiny cubes or voxels
 Stage 3 – Secondary or multiplanar reconstruction – the computer creates separate images in the sagittal, coronal and axial anatomical planes (From Whites E and Drage N, *Essentials of Dental Radiography and Radiology* 5th Edition (2013), Elsevier/Churchill Livingstone)



Figure 7. Small FOV CBCT images of an unerupted right canine. The sagittal section shows resorption of the lateral incisor

9

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.³¹ 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 Equipment³² 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.

Employers are required to keep a register of staff and their training, as part of their overall quality assurance programme, including the following information:

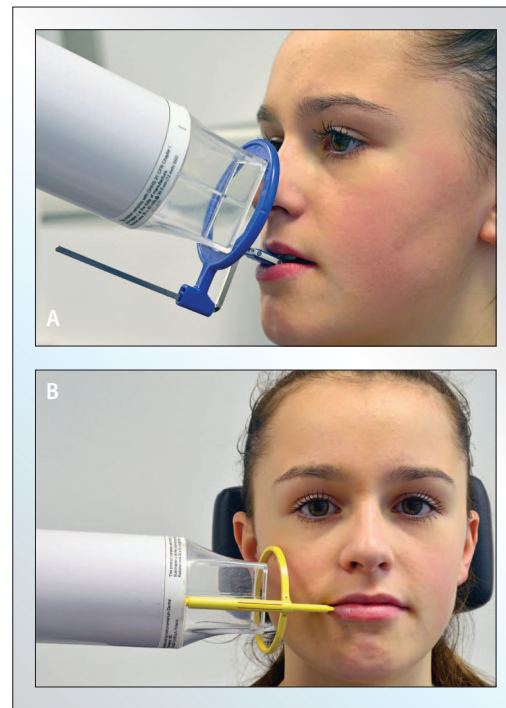
- Name
- Responsibility (*IRMER Referrer, Practitioner or Operator*)
- Date and form of training received
- Recommended date for a review of training needs.

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)



Figures 8a & 8b.
Patient positioning:
(a) Paralleling
technique periapical
(b) Bitewing

31. British Society of Dental and Maxillofacial Radiology (2015)
Core Curricula in Dental Radiography and Radiology for the Dental Team
www.bsdmfr.org.uk

32. Department of Health (2001)
Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment. London, the Stationery Office
<https://www.gov.uk/government/publications/dentalpractitioners-safe-use-of-x-ray-equipment>

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).



Figure 9. Patient positioning upper occlusal

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).



Figure 10. Patient positioning panoramic

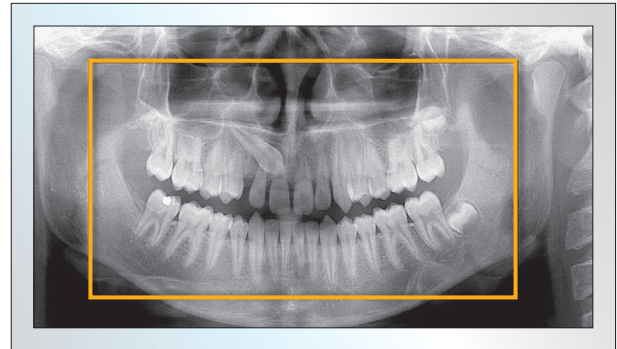


Figure 11. Panoramic radiograph showing the area marked in yellow that would result if field limitation 'dentition only' techniques were used

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/settings 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).

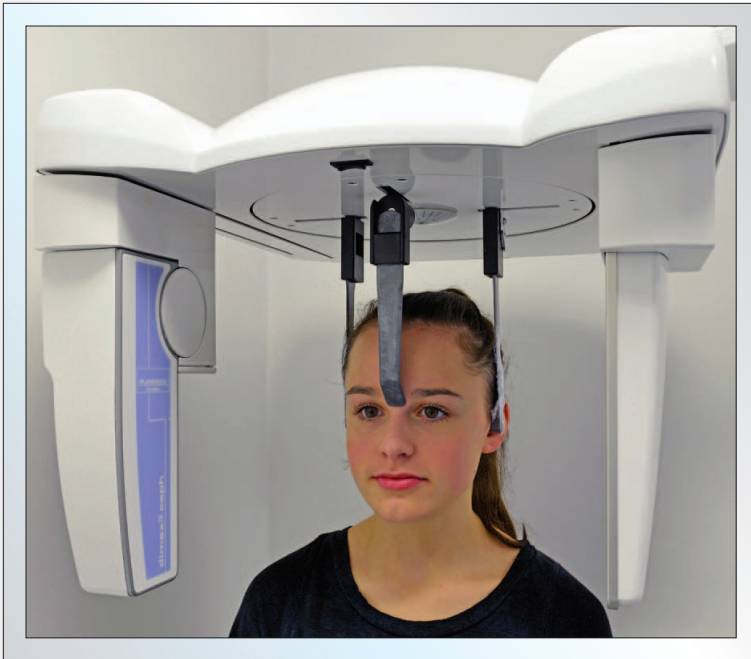


Figure 12.
Patient positioning.
Lateral cephalometric
radiograph in
horizontal scanning
direct digital unit

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.

33. World Health Organization (1982)
Quality Assurance in Diagnostic Radiology.
Macmillan/Procrom, Geneva
<http://whqlibdoc.who.int/publications/1982/9241541644.pdf>

34. Department of Health (2001)
Guidance Notes for Dental Practitioners on the
Safe Use of X-ray Equipment (Chapter 5).
London, the Stationery Office
<https://www.gov.uk/government/publications/dentalpractitioners-safe-use-of-x-ray-equipment>

SELECTION CRITERIA FOR THE USE OF RADIOGRAPHS IN ORTHODONTICS

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.³⁵ 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.³⁶

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).

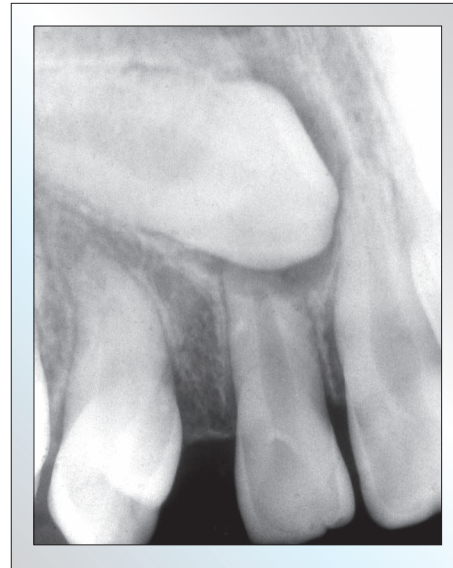


Figure 13.
An unerupted canine could not be palpated. A periapical radiograph shows the canine to be present and resorption of the lateral incisor root



Figures 14a & 14b.
a) The deciduous canines are retained and the unerupted canines could not be palpated buccally. The panoramic image shows that the maxillary canines are misplaced. The lower right second premolar is developmentally absent

b) Standard occlusal radiograph of the same patient demonstrates misplaced maxillary canines. Using vertical parallax, in conjunction with the panoramic image above, the canines are shown to be palatally placed

35. Health and Safety Legislation (2000)
The Ionising Radiation (Medical Exposure)
Regulations 2000. SI 2000 No 1059. London,
the Stationery Office (IRMER)
<http://www.legislation.hmso.gov.uk/si/si2000/20001059.htm>

36. Brucks A, Enberg K, Nordqvist I, Hansson AS, Jansson L and Svenson B (1999)
Radiographic examinations as an aid to orthodontic diagnosis and treatment planning
Swedish Dental Journal 23, 77-85



Figures 15a and 15b.

a) The permanent canines could not be palpated. The panoramic image shows a full complement of permanent teeth. The lower left deciduous canine is retained. The lower left canine is severely misplaced

b) The lateral cephalometric radiograph of the same patient shows the lower left canine labial to the lower incisors



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.³⁷

EXTRA-ORAL RADIOGRAPHS

Dental panoramic radiographs

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 Radiography³⁸ 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.³⁶

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.³⁹

37. European Commission (2004) European Guidelines on Radiation Protection in Dental Radiology, Radiation Protection 136. Luxembourg: Publications Office <https://ec.europa.eu/energy/sites/ener/files/documents/136.pdf>

38. Horner K, Eaton K (eds) (2013) Selection Criteria for Dental Radiography (3rd edition). Faculty of General Dental Practice (UK)

39. Houston WJB (1979) The current status of facial growth predictions: a review *British Journal of Orthodontics* 6, 11-17

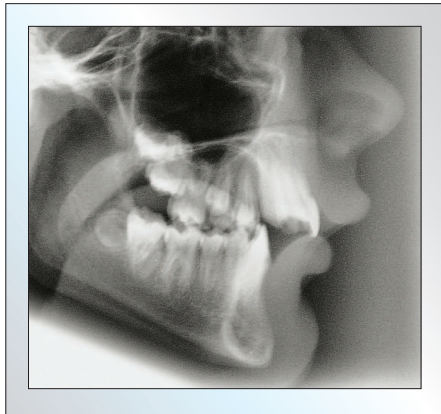


Figure 16. A patient with a Class II malocclusion on a marked skeletal base who will require complex treatment – a clear indication for a lateral cephalometric radiograph

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 spurts 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?	Repeat 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.

- | | | |
|--|--|--|
| <p>40. Jacob SC (2000)
Radiographic localization of unerupted teeth: Further findings about the vertical tube shift method and other localization techniques
<i>American Journal of Orthodontics and Dentofacial Orthopedics</i> 118, 439-47</p> | <p>43. Baccetti T, Franchi L, McNamara J (2002)
An improved version of the Cervical Vertebral Maturation (CVM) method for the assessment of mandibular growth
<i>Angle Orthodontist</i> 72, 316-25</p> | <p>46. Atchinson KA, Luke LS, White SC (1992)
An algorithm for ordering pre-treatment orthodontic radiographs
<i>American Journal of Orthodontics and Dentofacial Orthopedics</i> 102, 29-44</p> |
| <p>41. Houston WJB, Miller JC, Tanner JM (1979)
Prediction of the timing of the adolescent growth spurt from ossification events in hand-wrist films
<i>British Journal of Orthodontics</i> 6, 145-52</p> | <p>44. Mellion ZJ, Behrents RG, Johnston LE Jr (2013)
The pattern of facial skeletal growth and its relationship to various common indexes of maturation
<i>American Journal of Orthodontics and Dentofacial Orthopedics</i>, 143, 845-854</p> | <p>47. Brucks A, Enberg K, Nordqvist I, Hansson A S, Jansson L, Svenson B (1999)
Radiographic examinations as an aid to orthodontic diagnosis and treatment planning
<i>Swedish Dental Journal</i> 23, 77-85</p> |
| <p>42. Flores-Mir C, Nebbe B, Major PW (2004)
Use of skeletal maturation based on hand-wrist radiographic analysis as a predictor of facial growth: a systematic review
<i>Angle Orthodontist</i> 74, 118-24</p> | <p>45. Irish Institute of Radiography
Best practice guidelines
http://www.iirt.ie/about-us/best-practice-guidelines</p> | <p>48. Atchinson KA, Luke LS, White SC (1991)
Contribution of pre-treatment radiographs to orthodontists' decision making
<i>Oral Surgery Oral Medicine Oral Pathology</i> 71, 238-45</p> |

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.⁵⁰

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.⁵¹

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.^{52, 53} 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 1.2).

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

TABLE 5: Choice of view for radiographic examination

PROJECTION	FUNCTION
PANORAMIC RADIOGRAPH	<ul style="list-style-type: none"> • Identification of the developing dentition • Confirmation of the presence/absence of teeth
UPPER STANDARD OCCLUSAL	<ul style="list-style-type: none"> • Confirm the presence of unerupted teeth • Parallax localisation either with a panoramic or periapical • To identify supernumerary teeth • Identification of developmental anomalies
MANDIBULAR OCCLUSAL	<ul style="list-style-type: none"> • Localisation of unerupted teeth
PERIAPICALS	<ul style="list-style-type: none"> • Assess root morphology • Assess root resorption • Assess apical disease • In combination with a standard occlusal or second periapical to localise unerupted teeth by parallax
BITEWINGS	<ul style="list-style-type: none"> • Identification and assessment of severity of caries • Demonstration of periodontal bone levels (complementing a thorough clinical examination) • Assessment of existing restorations
LATERAL CEPHALOMETRIC RADIOGRAPH	<ul style="list-style-type: none"> • Assess skeletal pattern and labial segment angulation • Monitor the effects of treatment
CONE BEAM CT	<ul style="list-style-type: none"> • In selected cases to localise impacted teeth with particular reference to the position of adjacent teeth and possible resorption • To assess dental structural anomalies, e.g., gemination, fusion, supernumeraries • In some cases of dental trauma where there is suspected root fracture • For some complex cases of skeletal abnormality • Some cleft palate cases.

49. Han U, Vig KWL, Weintraub JA, Vig PS, Kowalski CJ (1991) Consistency of orthodontic treatment decisions relative to diagnostic records *American Journal of Orthodontics and Dentofacial Orthopedics* 100, 212-19
50. British Orthodontic Society (2005) Orthognathic Minimum Data Set Advice Sheet 22. London: British Orthodontic Society
51. Ericson S, Kuroi J (1988) Early treatment of palatally erupting maxillary canines by extraction of the primary canines *European Journal of Orthodontics* 10, 283-95
52. Segal GR, Schiffman PH, Tuncay OC (2004) Meta analysis of the treatment-related factors of external apical root resorption *Orthodontic Craniofacial Research* 7, 71-8
53. Roscoe MC, Meira JB, Cattaneo PM (2015) Association of orthodontic force system and root resorption: A systematic review *American Journal of Orthodontics and Dentofacial Orthopedics* 147, 610-26



Figure 17.

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

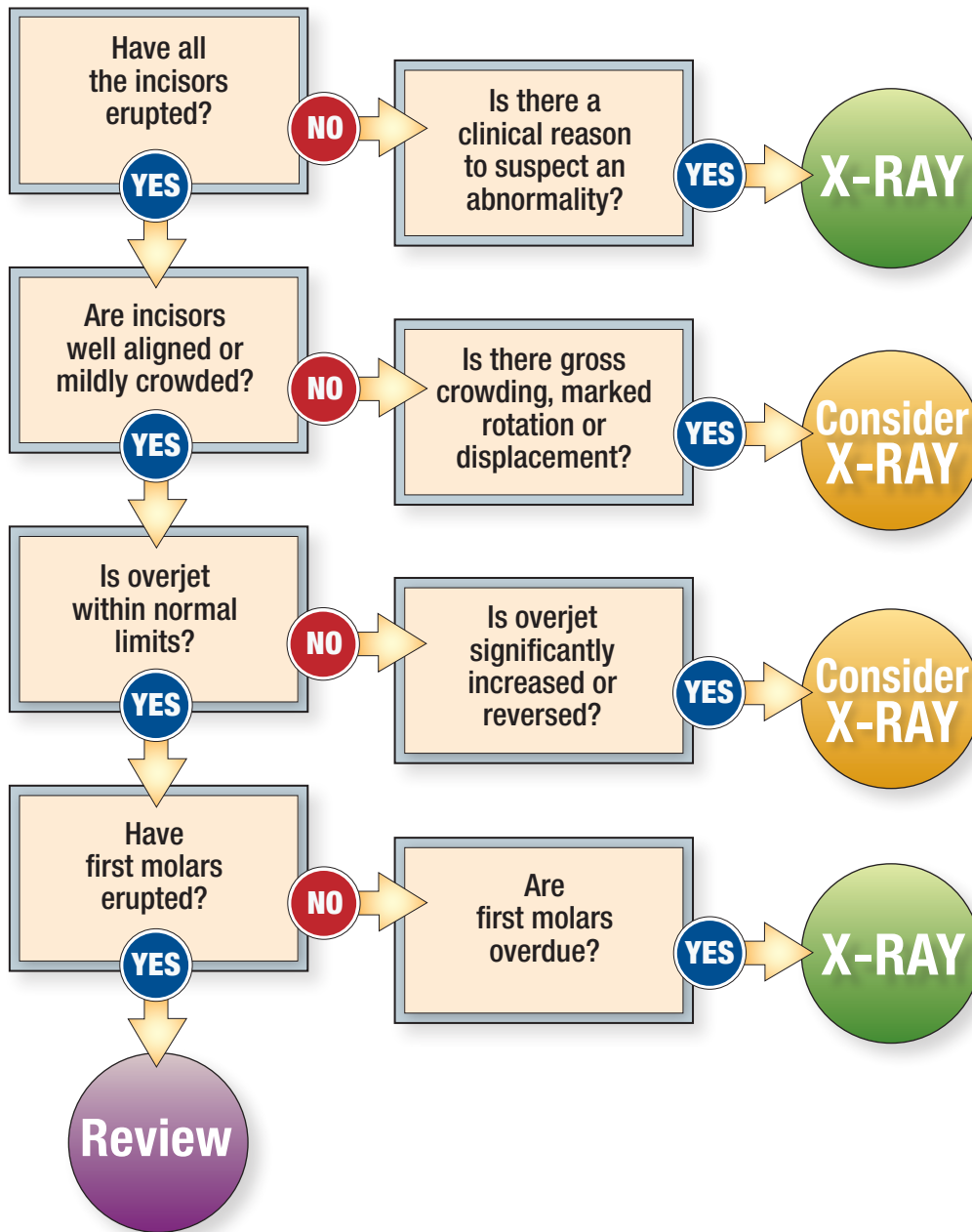




Figure 18.

INDICATIONS FOR RADIOGRAPHS – PATIENT OVER 10 YEARS OF AGE

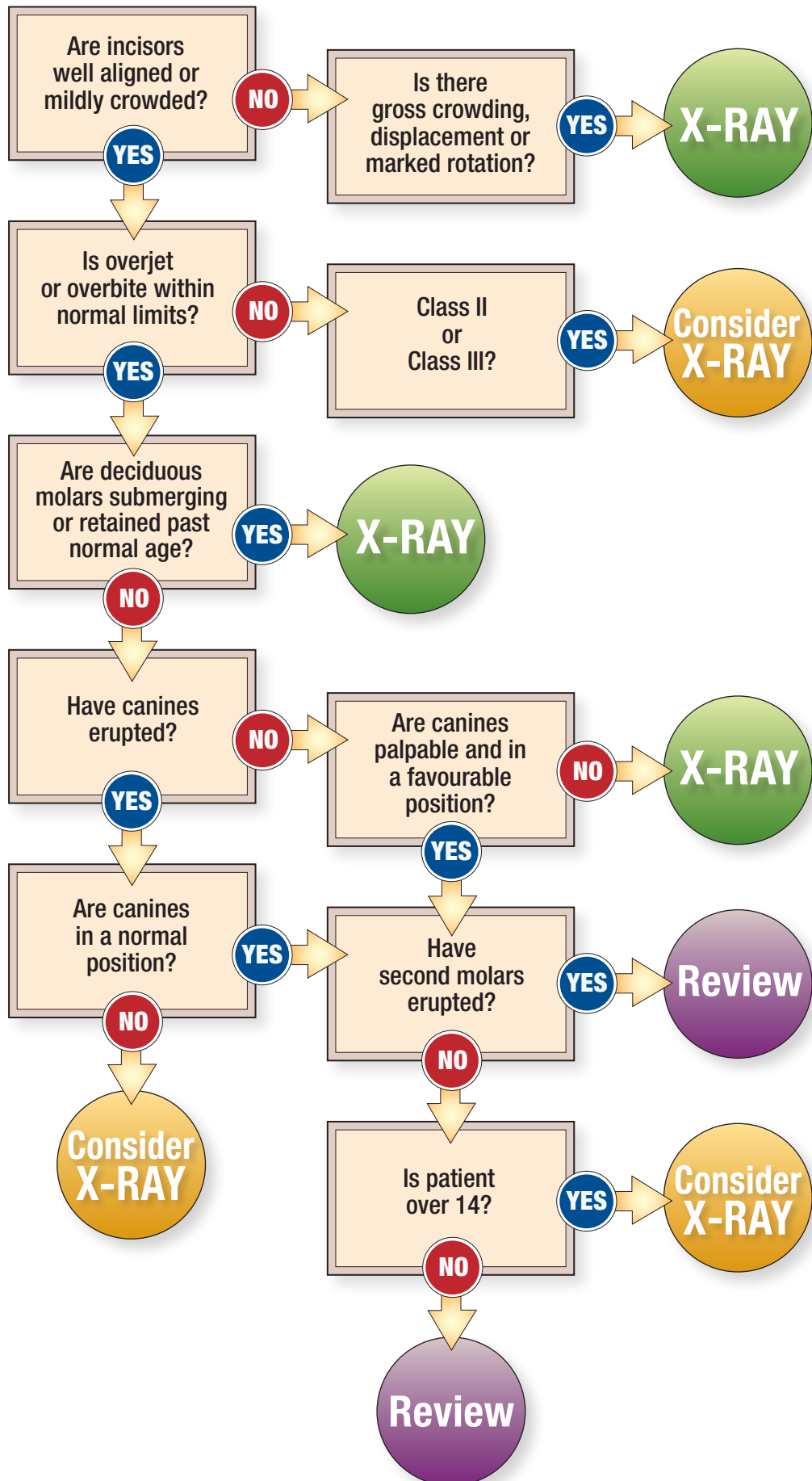




Figure 19.

IS A PRE-TREATMENT LATERAL CEPHALOMETRIC RADIOGRAPH INDICATED IN A PATIENT AGED 10–18?

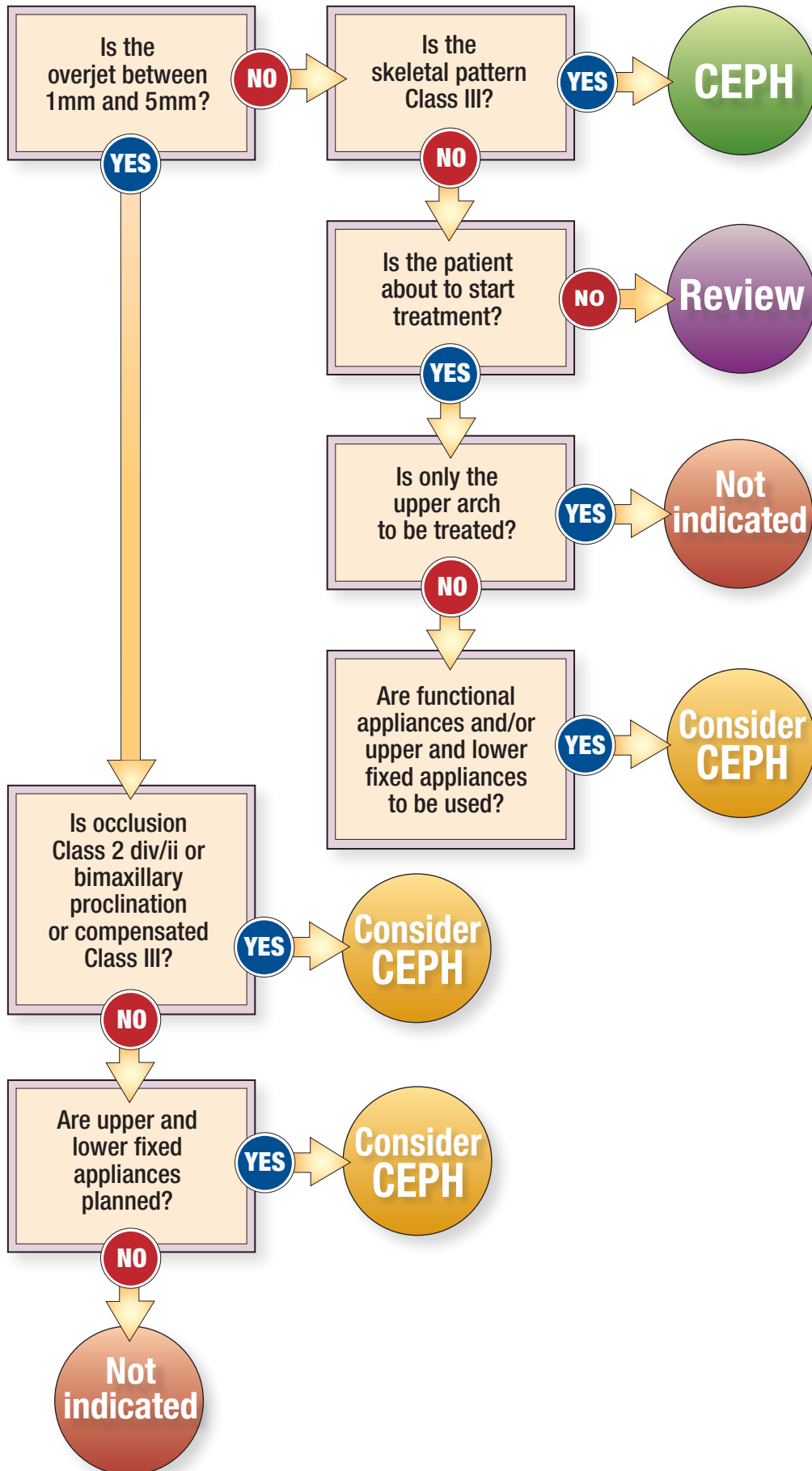
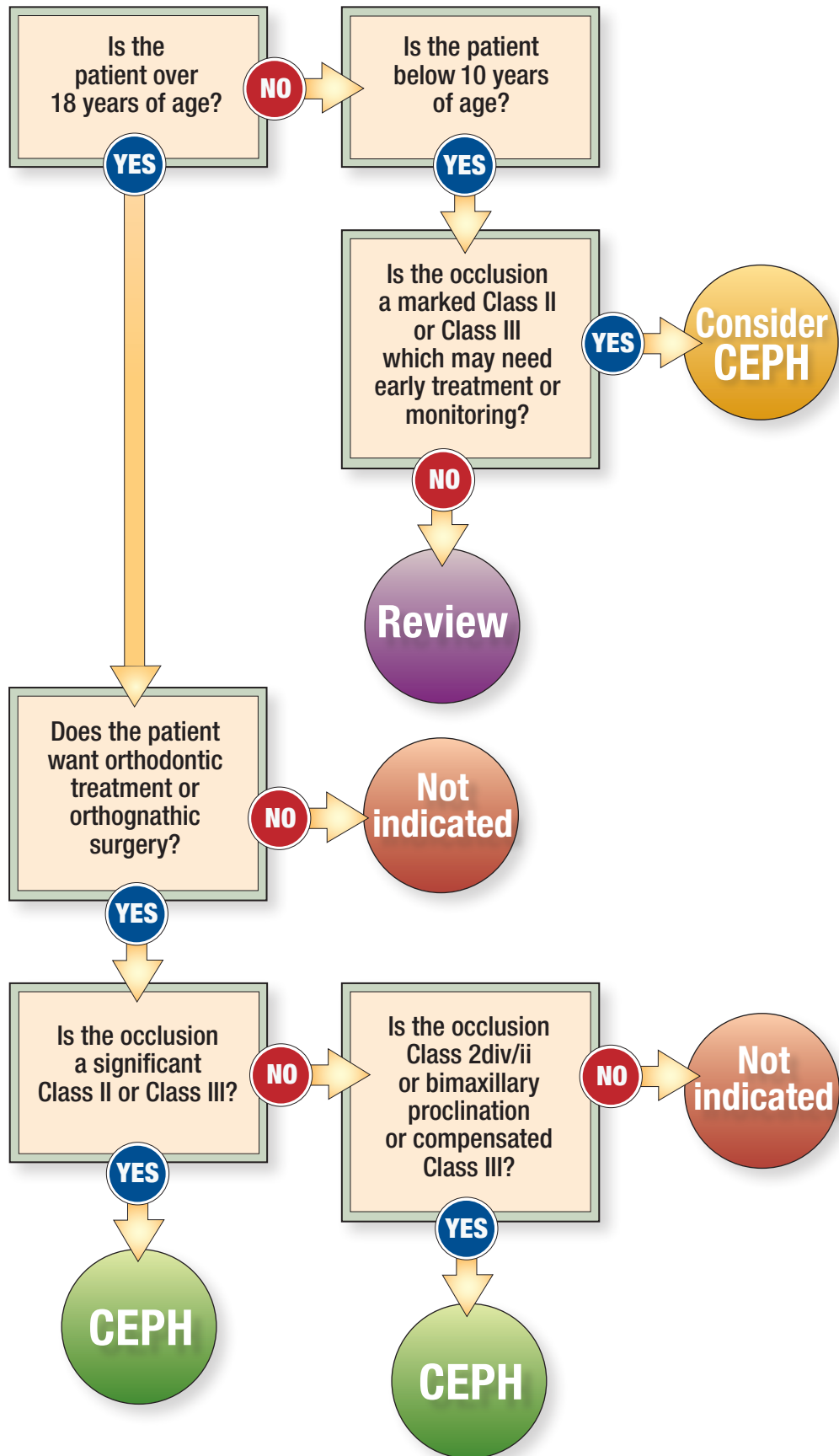




Figure 20.

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.'⁵⁴

USES OF SMALL FIELD OF VIEW (FOV) CBCT

Unrupted 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.⁵⁵ 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.^{56, 57}

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.^{56, 58, 59, 60, 61}

Previous UK and European guidelines⁶² 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.^{63, 64}

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. |

54. Abdelkarim AA (2015) Appropriate use of ionizing radiation in orthodontic practice and research *American Journal of Orthodontics and Dentofacial Orthopedics* 147, 166-8

55. Hidalgo-Rivas JA, Theodorakou C, Carmichael F, Murray B, Payne M, Horner K (2014) Use of cone beam CT in children and young people in three United Kingdom dental hospitals *International Journal of Paediatric Dentistry* 24, 336-48

56. Alqerban A, Jacobs R, Souza PC, Willems G (2009) In-vitro comparison of two cone-beam computer tomography systems and panoramic imaging for detected simulated canine impaction-induced external root resorption in maxillary lateral incisors *American Journal of Orthodontics and Dentofacial Orthopedics* 136, 764, e1-11; discussion 764-5

57. Pittayapat P, Willems G, Alqerban A, Coucke W, Ribeiro-Rotta RF, Souza PC, Westphalen FH, Jacobs R (2014) Agreement between cone beam computed tomography images and panoramic radiographs for initial orthodontic evaluation *Oral Surgery Oral Medicine Oral Pathology Oral Radiology* 117, 111-9

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.⁶⁵ As described in a recent review,⁶⁶ 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.

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. Many 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*.^{54, 67}

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 angulation and position of teeth is shown more accurately by CBCT than on panoramic radiography.^{68, 69} 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)⁷⁰ studied cases where treatment plans were made with conventional radiographs and study models

58. Haney E, Gansky SA, Lee JS, Johnson E, Maki K, Miller AJ, Huang JC (2010) Comparative analysis of traditional radiographs and cone-beam computed tomography volumetric images in the diagnosis and treatment planning of maxillary impacted canines *American Journal of Orthodontics and Dentofacial Orthopedics* 137, 590-7

59. Botticelli S, Verna C, Cattaneo PM, Heidmann J, Melsen B (2011) Two-versus three-dimensional imaging in subjects with unerupted maxillary canines *European Journal of Orthodontics* 33, 344-9

60. Wriedt S, Jaklin J, Al-Nawas B, Wehrbein H (2012) Impacted upper canines: examination and treatment proposal based on 3D versus 2D diagnosis *Journal of Orofacial Orthopedics* 73, 28-40

61. Alqerban A, Jacobs R, Fleuws S, Willems G (2015) Radiographic predictors for maxillary canine impaction. *American Journal of Orthodontics and Dentofacial Orthopedics* 147, 345-54

62. HPA Working Party on Dental Cone Beam CT Equipment (2010) Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment. Chilton: Health Protection Agency https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/340159/HPA-CRCE-D10_for_website.pdf

63. Naoumova J, Kuroj J, Kjellberg H (2015) Extraction of the deciduous canine as an interceptive treatment in children with palatal displaced canines – part I: shall we extract the deciduous canine or not? *European Journal of Orthodontics* 37, 209-18

64. Naoumova J, Kuroj J, Kjellberg H (2015) Extraction of the deciduous canine as an interceptive treatment in children with palatal displaced canines – part II: possible predictors of success and cut-off points for a spontaneous eruption *European Journal of Orthodontics* 37, 219-29

65. European Commission (2012) Cone beam CT for dental and maxillofacial radiology (Evidence-based guidelines). Radiation Protection no 172. Luxembourg: Publications Office http://www.sdentext.eu/files/radiation_protection_172.pdf

66. Kapila SD, Nervina JM (2015) CBCT in orthodontics: assessment of treatment outcomes and indications for its use *Dentomaxillofacial Radiology* 44, 20140282

67. Isaacson K (2013) Cone beam CT and orthodontic diagnosis – a personal view *Journal of Orthodontics* 40, 3-4

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.⁷¹ 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 guidelines⁶⁵ 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.⁷²

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 periapical 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,^{65, 73} 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.⁷³

ADULTS			
European Commission (2012) ⁶⁵	Field of view height (cm)		
	<10cm 11-674 (61*)	>10cm 30-1073 (87*)	
Ludlow et al (2015) ⁷³	<10cm 5-652 (84+)	10-15cm 9-560 (177+)	>15cm 46-1073 (212+)
CHILD			
European Commission (2012) ⁶⁵	<10cm 16-214 (43*)	>10cm 114-282 (186*)	
Ludlow et al (2015) ⁷³	<10cm 7-521 (103+)	>10cm 13-769 (175+)	

The values in this table are those reported in two systematic reviews, grouped by field of view height. All effective dose figures are in microsieverts (µSv). Figures in parentheses are either *median or +mean values.

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	Use the smallest FOV consistent with the diagnostic needs
● Tube operating potential (kV) and tube current exposure time product (mAs)	The combination of the lowest kV and lowest mAs settings consistent with an adequate image quality should be selected
● 'Resolution' settings	The lowest resolution consistent with the diagnostic needs should be chosen
● Shielding	The use of thyroid shields containing suitable X-ray absorbing material should be considered

While a few CBCT machines have a single fixed FOV, most new machines will offer a choice.⁷⁴ There is a correlation between the size of the FOV and the effective dose, so this is a straightforward means of optimisation.⁶⁵ As well as its radiation protection advantages, a smaller FOV will require a shorter time to perform 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 basis images). 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.^{75, 76, 77} 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

68. Van Elslande D, Heo G, Flores-Mir C, Carey J, Major PW (2010) Accuracy of mesiodistal root angulation projected by cone-beam computed tomographic panoramic-like images. *American Journal of Orthodontics and Dentofacial Orthopedics* 137 (4 Suppl), S94-9

69. Bouwens DG, Cevidanes L, Ludlow JB, Phillips C (2011) Comparison of mesiodistal root angulation with post treatment panoramic radiographs and cone-beam computed tomography 139, 126-32.

70. Hodges RJ, Atchison KA, White SC (2013) Impact of cone-beam computed tomography on orthodontic diagnosis and treatment planning. *American Journal of Orthodontics and Dentofacial Orthopedics* 143, 665-74

71. Pittayapat P, Limchichana-Bolstad N, Willem G, Jacobs R (2014) Three-dimensional cephalometric analysis in orthodontics: a systematic review. *Orthodontic & Craniofacial Research* 17, 69-91

72. Holroyd JR, Gulson AD (2009) The radiation protection implications of the use of dental cone beam Computed Tomography (CBCT) in Dentistry - What you need to know. Chilton: Health Protection Agency https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/421884/The_Radiation_Protection_Implications_of_the_Use_of_Cone_Beam_Computed_Tomography_in_Dentistry_for_website.pdf

73. Ludlow JB, Timothy R, Walker C, Hunter R, Benavides E, Samuelson DB, Scheske MJ (2015) Effective dose of dental CBCT - a meta analysis of published data and additional data for nine CBCT units. *Dentomaxillofacial Radiology* 44, 20140197

74. Nemtoi A, Czink C, Haba D, Gahleitner A (2013) Cone beam CT: a current overview of devices. *Dentomaxillofacial Radiology* 42, 20120443

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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.⁷⁸

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 ($\text{mGy}\cdot\text{cm}^2$), 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.⁷⁸

TABLE 9: Strategy for optimisation: low dose protocol

When planning a CBCT examination:
<ul style="list-style-type: none"> • Assess patient size and be prepared to adjust exposure factors accordingly • Select the smallest field of view consistent with the diagnostic task • Consider the diagnostic task in question and whether there is a need for high levels of detail
Make a final choice on exposure factors

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.⁷⁸ Curricula for further training for dentists undertaking radiological interpretation of CBCT have been established.^{78,79} 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.^{78,79,80,81} 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.⁷⁸

THE use of radiographs in research is incorporated in IRMER.⁸²

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.⁸³

In a formal orthodontic postgraduate training programme appropriate records for teaching and research are needed. Lateral 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,⁸⁴ or conform to nationally agreed standards, for example the Clinical Standards Advisory Group (CSAG) protocols for the long term follow up of patients with cleft lip and palate.⁸⁵

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 reference⁸²), full details of which are available.⁸⁶

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.

75. Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakis CJ (2005) Dose reduction in maxillofacial imaging using low dose Cone Beam CT. *European Journal of Radiology* 56, 413-7
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79. European Commission (2012) Cone beam CT for dental and maxillofacial radiology (Evidence-based guidelines). Radiation Protection no 172. Luxembourg: Publications Office http://www.sedentext.eu/files/radiation_protection_172.pdf
80. Horner K, Islam M, Flygare L, Tsiklakis K, Whaites E (2009) Basic principles for use of dental cone beam computed tomography: consensus guidelines of the European Academy of Dental and Maxillofacial Radiology. *Dentomaxillofacial Radiology* 38, 187-95
81. Brown J, Jacobs R, Levring Jäghagen E, Lindh C, Baksi G, Schulze D, Schulze R (2014) European Academy of DentoMaxillofacial Radiology. Basic training requirements for the use of dental CBCT by dentists: a position paper prepared by the European Academy of DentoMaxillofacial Radiology. *Dentomaxillofacial Radiology* 43, 2013029182.
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83. National Research Ethics Service <http://www.hra.nhs.uk/about-the-hra/our-committees/nres/>
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85. Clinical Standards Advisory Group (1998) Report of a CSAG Committee on cleft lip and/or palate. The Stationery Office, London
86. Central Office for Research Ethics Committees <http://www.corec.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.⁸⁷ 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



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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.¹⁰³

The Consumer Protection Act (1987)¹⁰⁴

- 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 Protection¹⁰⁶ 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 refuting 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.



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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**



GLOSSARY

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