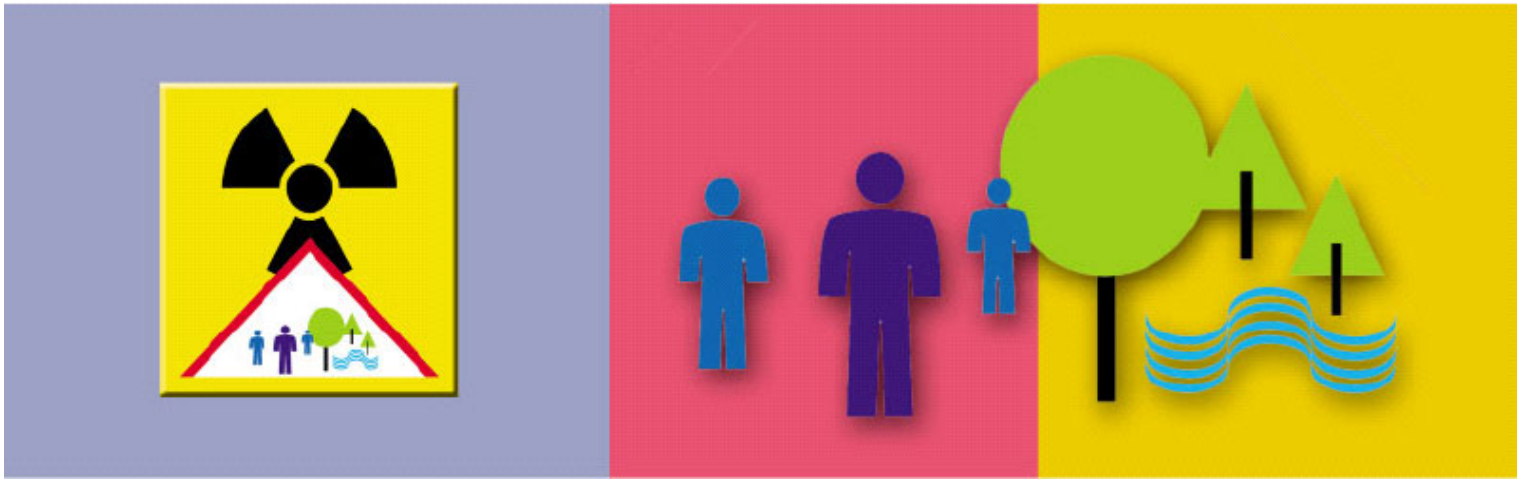
RADIATION PROTECTION



European guidelines
on radiation protection in dental radiology

The safe use of radiographs
in dental practice

Issue N° 136

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The safe use of radiographs in dental practice

Directorate-General for Energy and Transport
Directorate H — Nuclear Safety and Safeguards
Unit H.4 — Radiation Protection

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PREFACE

The aim of this study is to provide a practical guide to radiation protection for professional groups of dentists and their assistants, based upon the two relevant Council Directives of the European Union:

- Directive 96/29/Euratom, of 13 May 1996, laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation
- Directive 97/43/Euratom of 30 June 1997, on health protection of individuals against the dangers of ionising radiation in relation to medical exposure (Medical Exposures Directive).

The 1996 Basic Safety Standards Directive mentioned above ensures the protection of workers exposed to ionising radiation, including dentists and their assistants, and of members of the public.

Directive 97/43/Euratom provides for a high level of health protection to ionising radiation in medical exposure. All the measures adopted in the Directive are concerned not only with avoiding unnecessary or excessive exposure to radiation but also with improving the quality and effectiveness of medical uses of radiation.

No exposure to X-rays can be considered completely free of risk, so the use of radiation by dentists and their assistants implies a responsibility to ensure appropriate protection.

In order to help Member States to implement the Directives**,** the Commission decided to update and extend the technical guidelines in Radiation Protection 81 (Radiation protection and quality assurance in dental radiology: "The safe use of radiographs in dental practice" (1995)). A contract was awarded to the University of Manchester, UK, to carry out the study "European Guidelines on Radiation Protection in Dental Radiology".

The project was designed to give clear and comprehensive information on dental radiological practices, taking into account relevant knowledge and available technology, and give guidance on the application of radiation protection principles in dental radiology to all individuals, including the patient and the personnel.

This document provides general guidelines on the safe use of radiographs in dental practice. Guidelines are not a rigid constraint on clinical practice. Local variations may be required according to healthcare practice and provision.

I am confident that the results of the study will be of help to professional groups of dentists and their assistants, and will contribute to optimising the use of ionising radiation in dentistry.

A. JANSSENS

Acting Head of Unit

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Foreword

The radiation protection activities of the Commission of the European Union in the medical field are based on two Council Directives:

- Directive 96/29/Euratom, of 13 May 1996, laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation (European Basic Safety Standards); and
- Directive 97/43/Euratom of 30 June 1997, on health protection of individuals against the dangers of ionising radiation in relation to medical exposure (Medical Exposures Directive).

Although doses incurred during dental examinations are in general relatively low, dental radiology accounts for nearly one third (1)of the total number of radiological examinations in the European Union and therefore merits specific attention with regard to radiation protection.

Article 7 of the 'Medical Exposures Directive' stipulates that dental practitioners must have adequate theoretical and practical training for the purpose of radiological practices as well as relevant competence in radiation protection. Article 7 also requires continuing education and training after qualification.

To facilitate the implementation of this article by Member States, the Commission decided to develop the present document, updating and extending the technical guide Radiation Protection 81 (2) in order that it takes into account the technological developments and the new requirements of the two Council Directives. It is designed to give clear and comprehensive information on dental radiological practices, taking into account relevant knowledge and technology available, and give guidance on the application of the radiation protection principles in dental radiology for all individuals, including both the patient and the personnel.

It is our hope that this handbook will be of help to professional groups of dentists and their assistants, and that it will contribute to optimise the use of ionising radiation in dentistry.

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References

1. 2001. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR Report to the General Assembly with Scientific Annex.
2. **van der Stelt, P. F.** 1995. Radiation protection and quality assurance in dental radiography. The safe use of radiographs in dental practice. Office for Official Pulications of the European Communities, Luxemborg.

1. Introduction

The aim of this book is to provide a practical guide to radiation protection for dentists working in a primary care setting, based upon the two relevant Council Directives of the European Union (EU).

- **Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation.**
- **Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure.**

Laws derived from these Directives exist within individual EU States that impose specific enforceable requirements upon dentists. This document sets general guidelines on good practice in the use of X-rays by dentists.

Guidelines are systematically developed statements to assist practitioner and patient in decisions about appropriate health care for certain specific clinical circumstances (1). As this implies, guidelines are not a rigid constraint on clinical practice, but a concept of good practice against which the needs of the individual patient can be considered(2).

1.1. Why radiographs in dentistry?

Radiographs are essential to dentists for:

- Diagnosis
- Treatment planning
- Monitoring treatment or lesion development

However, an integral part of radiography is exposure of patients and, potentially, clinical staff to X-rays. No exposure to X-rays can be considered completely free of risk, so the use of radiation by dentists is accompanied by a responsibility to ensure appropriate protection.

1.2. Guideline development

There is now widespread acceptance in medicine and dentistry that clinical practice should be as ‘evidence-based’ as possible. This document was developed using such an approach. The project team collected and analysed relevant published literature, guidelines that have proved effective in the past to arrive at recommendations that will contribute to optimisation of the use of ionising radiation in dentistry. Details of the methodology used in identifying relevant literature and the appraisal process are given in Table 1.1 and Appendix 1.

It should be clearly understood that the approach adopted for different sections within this document has not been uniform. This is because the volume of evidence available for review varies. Some sections have involved more comprehensive sifting of the evidence, while others rely heavily on expert opinion and conventional literature review.

Table 1.1 Criteria used to grade recommendations

Symbol used	Criteria used to assign grading to reviewed literature
ED	**Article or other requirement of the EURATOM Directive(s) that must be applied.**
A	**Meta-analyses/systematic reviews of randomised control trials (RCTs) or laboratory studies with low risk of bias.** *or* **RCTs.**
B	**Meta analyses/ systematic reviews of case-control or cohort studies with high risk of bias.** *or* **Case-control, cohort studies with a low risk of confounding, bias or chance and a moderate probability that the relationship is causal.** *or* **Good quality laboratory studies with little or no evidence of bias/experimental error.**
C	**Non-analytic studies (e.g. case reports, case series, cross-sectional surveys).** *or* **Laboratory studies with risk of bias/experimental error.** *or* **Expert opinion/non-systematic review article.**
NR	**National Recommendations in some Member States. In some cases, however, National requirements will differ from the recommendations made in this document and will overrule these.**

1.3 References

1. 1998. Making the best Use of a Department of Clinical Radiology: Guidelines for Doctors. 4th ed. Royal College of Radiologists, London.
2. 1990. Medical Audit in Radiodiagnosis. Royal College of Radiologists, London.

2 Radiation dose and risk

The aim of this section is to describe the:

- **The nature of X-rays**
- **The nature of radiation damage**
- **Radiation dose**
- **Radiation risk**
- **Dental radiography doses and risks in a life context**

2.1 X-rays

X-rays are a type of electromagnetic (EM) radiation. EM radiation also includes visible light, radio waves, microwaves, cosmic radiation, and several other varieties of 'rays'. All can be considered as 'packets' of energy, called *photons,* which have wave properties, most importantly a wavelength and frequency. X-rays are short wavelength, high frequency EM radiation. The importance of this is that high frequency means high energy. When X-rays hit atoms this energy can be transferred, producing ionisation of atoms.

2.2 Radiation damage

When patients undergo X-ray examinations, millions of photons pass through their bodies. These can damage any molecule by ionisation, but damage to the DNA in the chromosomes is of particular importance. Most DNA damage is repaired immediately, but rarely a portion of a chromosome may be permanently altered (a mutation). This may lead ultimately to the formation of a tumour. The latent period between exposure to X-rays and the clinical diagnosis of a tumour may be many years. The risk of a tumour being produced by a particular X-ray dose can be estimated; therefore, knowledge of the doses received by radiological techniques is important. While doses and risks for dental radiology are small, a number of epidemiological studies have provided evidence of an increased risk of brain (19, 22) , salivary gland (16, 22) and thyroid(15, 27) tumours for dental radiography.

The effects described above are believed to have no threshold radiation dose below which they will not occur(2). They can be considered as 'chance' (*stochastic*) effects, where the magnitude of the risk is proportional to the radiation dose. There are other known damaging effects of radiation, such as cataract formation, skin erythema and effects on fertility, that definitely have threshold doses below which they will not occur. These threshold doses vary in size, but all are of a magnitude far greater than those given in dental radiography. Thus, except in extraordinary circumstances, these *deterministic* effects are given no further consideration.

2.3 Radiation dose

The terms 'dose' and 'exposure' are widely used but often misunderstood. 'Doses' may be measured for particular tissues or organs (e.g. skin, eye, bone marrow) or for the whole body, while 'exposure' usually refers to equipment settings (time, mA, kV). A commonly used measure of dose in surveys is 'entrance dose', measured in milligrays (mGy).This has an advantage of being fairly easily measured by placing dosemeters on the patient's skin. Diagnostic

reference levels (DRLs), based upon entrance dose surveys, may be set as standards against which X-ray equipment can be assessed as part of quality assurance (see Chapter 5 Section 5.4 for a discussion of DRLs in dental radiography).

In this chapter, however, radiation dose is expressed as ***effective dose*** (refer to Glossary for definition), measured in units of energy absorption per unit mass (Joules / kg) called the Sievert (more usually the microSievert, μSv, representing one millionth of a Sievert). In practice, effective dose is calculated for any X-ray technique by measuring the energy absorption in a number of 'key' organs in the body, so that the final figure is a representation of 'whole body' detriment. While effective dose is an impossible quantity to measure *in vivo*, it is possible to determine it from laboratory studies or computer modelling. This can then be used to estimate radiation risk.

Many studies have measured doses of radiation for dental radiography, but only a few have estimated effective dose. There are still a number of radiographic techniques for which no published data are available and some for which very different results have been reported. In many cases this reflects controversy about whether salivary glands should be given special weighting in calculation of dose. Furthermore, variation in the technical parameters of the X-ray sets and image receptors used in studies means that care should be taken when comparing dose estimations from different studies.

2.4 The risks

Radiation detriment can be considered as the total harm experienced by an irradiated individual. In terms of stochastic effects, this includes the lifetime risk of fatal cancer, non-fatal cancer and hereditary effects. The probability of radiation-induced stochastic effects for the whole population is $7.3 \times 10^{-2} Sv^{-1}$. Table 2.1 (derived from (3)) gives the breakdown of this summed figure into its constituent elements. Hereditary effects are believed to be negligible in dental radiography (26).

Table 2.1 Nominal lifetime probability coefficients for stochastic effects

Detriment (10^{-2} Sv^{-1})	
Fatal cancer	5.0
Non-fatal cancer*	1.0
Severe hereditary effects	1.3
Total	7.3

*The lifetime probability co-efficient for non-fatal cancer represents detriment rather then true incidence, which would be significantly greater.

Risk is age-dependent, being highest for the young and least for the elderly. Here, risks are given for the adult patient at 30 years of age. These should be modified using the multiplication factors given in Table 2.2 (derived from (3)). These represent averages for the two sexes; at all ages risks for females are slightly higher and those for males slightly lower.

Table 2.2 Risk in relation to age

These data are derived from (3) and represent relative attributable lifetime risk based upon a relative risk of 1 at age 30 (population average risk). It assumes the multiplicative risk projection model, averaged for the two sexes. In fact, risk for females is always relatively higher than for males.

Age Group (years)	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 risk

Beyond 80 years of age, the risk becomes negligible because the latent period between X-ray exposure and the clinical presentation of a tumour will probably exceed the life span of a patient. In contrast, the tissues of younger people are more radiosensitive and their prospective life span is likely to exceed the latent period.

Table 2.3 gives doses and risks for the dental radiographic techniques likely to be used in dentistry. However, care should be taken to adjust the risk estimates according to the age of patients using Table 2.2.

As mentioned above, a particular problem arises from the inclusion or exclusion of the salivary glands in the calculation of dose. The salivary glands are not specifically included as an organ in effective dose calculations as described by the International Commission on Radiation Protection (3), leading to an underestimation of risk. However, in view of the apparent relationship between dental radiography and increased risk of salivary gland tumours, many researchers have applied a special weighting factor so that salivary gland doses, that would otherwise be excluded, are incorporated into dose calculation. By following this practice, effective doses and risks are increased.

Table 2.3 Effective doses and risks of stochastic effects – tabular summary of literature review.

The paper by White (26) represented a recalculation of largely pre-ICRP 60 publications. Only papers subsequent to 1990 are specifically referenced, in addition to White. The use of E-speed film and rare-earth intensifying screens has been assumed for intraoral and panoramic radiography, respectively. Round (60 mm diameter) collimation is assumed for intraoral radiography.

X-ray technique	Effective dose (μSv)	Risk of fatal cancer (per million)	References
Intraoral radiograph (bitewing/periapical)	1 - 8.3	0.02 - 0.6	(5, 6, 9, 13, 21, 24, 26)
Anterior maxillary occlusal	8	0.4	(9)
Panoramic	3.85 - 30	0.21 - 1.9	(7, 9, 11, 14, 17, 18, 21, 26)
Lateral cephalometric radiograph	2-3	0.34[#]	(12, 14, 20, 21, 25)
Cross-sectional tomography (single slice)	1 - 189	1 - 14	(8, 9, 11, 23)
CT scan (mandible)	364 -1202	18.2 - 88	(9, 10, 23)
CT scan (maxilla)	100 - 3324	8 - 242	(9, 10, 23)

(5): Data derived for single intraoral film by halving figures to allow for E-speed film and by dividing original data for full mouth survey by 19. No adjustment made for high kV (90) used in this study.
(6): Data derived for single intraoral film by halving figures to allow for E-speed film and by dividing original data for full mouth survey by 19. No adjustment made for high kV (90) used in this study.
(26): White excluded salivary glands from consideration in dose and risk estimations, accounting for lower figures. His data for intraoral radiography are derived by halving figures to allow for E-speed film and by dividing original data for full mouth survey by 20.
[#]Based upon risks to brain, salivary glands and thyroid gland only.

Despite their principal use in hospital practice, doses for cross-sectional tomography and CT are given because of their increasing use for implant treatment planning by dentists.

From the figures presented above, it can be seen that conventional dental radiography is associated with low doses and risks for the individual patient. However, while dental radiography is generally ‘low dose’, it is a high volume procedure, with many millions of radiographs taken annually in the European Union (Table 2.4).

Table 2.4 Estimated annual numbers of dental radiographs in EU countries for which data are available (4).

EU Country	Annual number of radiographs x 10^3 (One radiograph means one exposure)	Annual number of radiographs per 1,000 population*
Denmark	2,400	449
Germany	22,520	274
Spain	5,515	138
Luxembourg	191	433
Netherlands	2,700	169
Portugal	986	96
Finland	1,484	286
Sweden	15,000 **	1,660**
United Kingdom	12,500	209

*Based on population figures for 2001

** Personal Communication from Article 31 Group – error in original report (4)

2.5 Doses and risks in context

Life is a risky business. Among the many risks to which we are prone, we are all constantly exposed to normal background radiation, which averages about 2400 µSv (2) each year (average world figures). Medical exposures (including dental) add substantially to this figure, with wide variation from country to country. With this in mind, a panoramic radiograph may be associated with an effective dose the same as 1-5 days' additional background radiation, while two bitewing radiographs would be equivalent to about one day. For comparative purposes, a chest X-ray (20 µSv) would be equivalent to around three days of additional background radiation. Comparisons can be made between radiation doses in dental radiography associated with increased exposure to cosmic rays (another high energy form of EM radiation). For example, a long haul flight from Brussels to Singapore is estimated to lead to an additional effective dose of 30 µSv, while a short flight from Brussels to Athens incurs an estimated dose of about 10 µSv (1).

Dental radiography doses and risks are minimal, comparable in most cases (with the exception of CT and multiple cross-sectional tomography) with exposure to a few days of natural background radiation.

Statement 2.A

Individual doses in basic dental radiography (intra-oral, panoramic and cephalometric) are low, being equivalent to those associated with a few days of background radiation. Individual doses from more complex imaging (CT scans and multiple slice cross-sectional tomography) can be substantially higher.

A

Statement 2.B

Individual risks in dental radiography are small but are greater in the younger age groups (below 30 years) in which (in many Member States) dental radiography is most frequently performed.

2.6 References

1. 1997. European Commission. Radiation Protection 88. Recommendations for the implementation of Title VII of the European Basic Safety Standards (BSS) Directive concerning significant increase in exposure due to natural radiation sources. Office for Official Publications of the EC.
2. 2001. European Commission. Radiation Protection 125: Low dose ionizing radiation and cancer risk. Office for Official Publications of the EC,Luxembourg. http://europa.eu.int/comm/environment/radprot/publications.
3. 1990. ICRP Publication 60. Recommendations of the International Commission on Radiatiological Protection. Annal of the ICRP **21**.
4. 2001. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR Report to the General Assembly with Scientific Annex.
5. **Avendanio, B., N. L. Frederiksen, B. W. Benson, and T. W. Sokolowski.** 1996. Effective dose and risk assessment from detailed narrow beam radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **82:**713-9.
6. **Cederberg, R. A., N. L. Frederiksen, B. W. Benson, and T. W. Sokolowski.** 1997. Effect of the geometry of the intraoral position-indicating device on effective dose. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **84:**101-9.
7. **Danforth, R. A., and D. E. Clark.** 2000. Effective dose from radiation absorbed during a panoramic examination with a new generation machine. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **89:**236-243.
8. **Dula, K., R. Mini, J. T. Lambrecht, P. F. van der Stelt, P. Schneeberger, G. Clemens, H. Sanderink, and D. Buser.** 1997. Hypothetical mortality risk associated with spiral tomography of the maxilla and mandible prior to endosseous implant treatment. Eur J Oral Sciences **105:**123-9.
9. **Dula, K., R. Mini, P. F. van der Stelt, and D. Buser.** 2001. The radiographic assessment of implant patients: decision-making criteria. Int J Oral Maxillofac Implants **16:**80-9.
10. **Frederiksen, N. L., B. W. Benson, and T. W. Sokolowski.** 1995. Effective dose and risk assessment from computed tomography of the maxillofacial complex. Dentomaxillofac Radiol **24:**55-8.
11. **Frederiksen, N. L., B. W. Benson, and T. W. Sokolowski.** 1994. Effective dose and risk assessment from film tomography used for dental implant diagnostics. Dentomaxillofac Radiol **23:**123-7.
12. **Gijbels, F., C. Bou Serhal, G. Willems, H. Bosmans, G. Sanderink, M. Persoons, and R. Jacobs.** 2001. Diagnostic yield of conventional and digital cephalometric images: a human cadaver study. Dentomaxillofac Radiol **30:**101-5.
13. **Gijbels, F., R. Jacobs, G. Sanderink, E. De Smet, B. Nowak, J. Van Dam, and D. Van Steenberghe.** 2002. A comparison of the effective dose from scanography with periapical radiography. Dentomaxillofac Radiol **31:**159-63.
14. **Gori, C., F. Rossi, A. Stecco, N. Villari, and G. Zatelli.** 2000. Dose evaluation and quality criteria in dental radiology. Radiat Prot Dosimetry **90:**225-227.
15. **Hallquist, A., L. Hardell, A. Degerman, G. Wingren, and L. Boquist.** 1994. Medical diagnostic and therapeutic ionizing radiation and the risk for thyroid cancer: a case-control study. Eur J Cancer Prevention **3:**259-67.
16. **Horn-Ross, P. L., B. M. Ljung, and M. Morrow.** 1997. Environmental factors and the risk of salivary gland cancer. Epidemiology **8:**414-9.
17. **Lecomber, A. R., S. L. Downes, M. Mokhtari, and K. Faulkner.** 2000. Optimisation of patient doses in programmable dental panoramic radiography. Dentomaxillofac Radiol **29:**107-12.
18. **Lecomber, A. R., and K. Faulkner.** 1998. Conference Proceeding: Dose and risk in Dental Radiography, Luxembourg 1997. *Reference Doses and Quality in Medical Imaging: What the referring practitioner and directing medical staff should know*. Radiat Prot Dosimetry **80:**23-25.
19. **Longstreth, W. T., Jr., L. K. Dennis, V. M. McGuire, M. T. Drangsholt, and T. D. Koepsell.** 1993. Epidemiology of intracranial meningioma. Cancer **72:**639-48.
20. **Maillie, H. D., and J. E. Gilda.** 1993. Radiation-induced cancer risk in radiographic cephalometry. Oral Surg Oral Med Oral Pathol **75:**631-7.
21. **Pasler, F. A., and H. Visser.** 1999. Zahnmedizinische Radiologies, Vol. 5. Georg Thieme, Auflage.
22. **Preston-Martin, S., and S. C. White.** 1990. Brain and salivary gland tumors related to prior dental radiography: implications for current practice. J Am Dent Assoc **120:**151-8.
23. **Scaf, G., A. G. Lurie, K. M. Mosier, M. L. Kantor, G. R. Ramsby, and M. L. Freedman.** 1997. Dosimetry and cost of imaging osseointegrated implants with film-based and computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **83:**41-8.

24. **Velders, X. L., J. van Aken, and P. F. van der Stelt.** 1991. Risk assessment from bitewing radiography. Dentomaxillofac Radiol **20:**209-13.
25. **Visser, H., T. Rodig, and K. P. Hermann.** 2001. Dose reduction by direct-digital cephalometric radiography. Angle Orthodontist **71:**159-63.
26. **White, S. C.** 1992. Assessment of radiation risk from dental radiography. Dentomaxillofac Radiol **21:**118-26.
27. **Wingren, G., A. Hallquist, and L. Hardell.** 1997. Diagnostic X-ray exposure and female papillary thyroid cancer: a pooled analysis of two Swedish studies. Eur J Cancer Prevention **6:**550-6.

3 Justification: referral criteria

The aim of this section is to:

- **Explain the concept of radiographic justification**
- **To provide specific guidelines for a range of clinical conditions commonly encountered in general dental practice**

Any X-ray exposure entails a risk to the patient. Under normal circumstances the risk from dental radiography is very low. Nonetheless, it is essential that any X-ray examination should show a net benefit to the patient, weighing the total potential diagnostic benefits it produces against the individual detriment that the exposure might cause. The efficacy, benefits and risk of available alternative techniques having the same objective but involving no or less exposure to X-rays should be taken into account.

Recommendation 3 A

All X-ray examinations must be justified on an individual patient basis by demonstrating that the benefits to the patient outweigh the potential detriment.

The anticipated benefits are that the X-ray examination would add new information to aid the patient's management.

ED

In order that the justification process can be carried out, it is essential that selection of appropriate radiography is based on the individual patient's history and a clinical examination. The 'routine' use of radiography on patients based on a generalised approach rather than individual prescription is unacceptable. A 'routine' or 'screening' examination is defined as one in which a radiograph is taken regardless of the presence or absence of clinical signs and symptoms.

Recommendation 3 B

No radiographs should be selected unless a history and clinical examination have been performed.

'Routine' radiography is unacceptable practice.

ED*

* The statement/recommendation although not specifically stated in the European Directive is intrinsic to the process of justification as defined by the Directive. There are no randomised controlled trials to support the recommendation; such a study design would neither be possible nor ethical to perform.

Choosing the appropriate radiographic examination should also be based upon consideration of the prevalence of diseases, their rates of progression and the diagnostic accuracy of the imaging techniques in question.

Consulting guidelines facilitates the process of selecting radiographs. Such guidelines, called 'referral criteria' or 'selection criteria' exist for both medical and dental radiography. Radiographic Referral Criteria have been defined as "*descriptions of clinical conditions derived from patient signs, symptoms and history that identify patients who are likely to benefit from a particular radiographic technique".* As with any guideline, these are not intended to be rigid constraints on clinical practice, but a concept of good practice against which the needs of the individual patient can be considered.

The term 'referral criteria' is appropriate for medical practitioners, where radiography is usually arranged by referral to a specialist in radiology. However, some dentists may refer patients for radiography to hospitals or dental colleagues where they do not have the necessary equipment in their own practices. When acting as a referrer, the dentist should ensure that adequate clinical information about the patient is provided to the person taking responsibility for the exposure.

Recommendation 3 C

When referring a patient for a radiographic examination, the dentist should supply sufficient clinical information (based upon a history and clinical examination) to allow the practitioner taking clinical responsibility for the X-ray exposure to perform the justification process.

ED

Evidence-based guidelines (9) have been devised for selection of dental radiography. The following parts of this section are a representation of selected guidelines from that document. In isolated cases guidelines have been adjusted to take into account evidence in a European context.

3.1 Dental caries diagnosis

Caries risk must be assessed for all new patients and then subsequently at recall appointment as risk factors may change in the intervening period. By identifying patients who are at the greatest risk of dental decay, clinicians can effectively implement prevention techniques to maintain low caries risk status.

Caries is a multifactorial disease requiring a wide-ranging assessment of categories of risk. The important categories identified during the systematic review (9) were:

- Clinical evidence of previous disease
- Dietary habits
- Social history
- Use of fluoride
- Plaque control
- Saliva
- Medical history

When combined with the clinical judgement of the dentist, the use of these factors have been found to be an extremely efficient predictor of caries risk (6, 7). Table 3.1 expands on each of the categories by sub-dividing them into high and low risk. Obviously, the moderate risk patient will lie in between the two levels.

3.1.1. Children

The early enamel lesion progresses at a relatively slow rate taking at least two years to progress into dentine, although progression is not inevitable (6). Early diagnosis of these enamel lesions is important, as with intervention lesion progression can be slowed or reversed (6).

Posterior bitewing radiographs are an essential adjunct to clinical examination(9). The initial clinical examination must include an assessment of caries risk (as high, medium or low). As outlined previously, the assessment of risk is relevant in determining when to take radiographs and therefore must be carried out at each subsequent recall examination ensuring that the time interval for radiography becomes patient-specific. It is feasible that adoption of the following recommendation may lead to more radiographs being taken. However, this is justified as it will result in better patient care.

Recommendation 3 D

Prescription of bitewing radiographs for caries diagnosis should be based upon caries risk assessment.

Intervals between subsequent bitewing radiographic examinations must be reassessed for each new period, as individuals can move in and out of caries risk categories with time.

Table 3.1: Caries Risk Factors (9)

Risk Factors	Risk Category	
	High Risk	**Low Risk**
Clinical Evidence	• New lesions • Premature extractions • Anterior caries or restorations • Multiple restorations • No fissure sealants • Fixed appliance orthodontics • Partial dentures	• No new lesions • No extractions • Sound anterior teeth • None or few restorations • Restorations inserted years ago • Fissure sealed teeth • No appliance • No dentures
Dietary Habits	• Frequent sugar intake	• Infrequent sugar intake
Use Of Fluoride	• Drinking water not fluoridated • No fluoride supplements • No fluoride toothpaste	• Drinking water fluoridated • Fluoride supplements • Fluoride toothpaste used
Social History	• Socially deprived • High caries rate in siblings • Low knowledge of dental disease • Irregular attender • Ready availability of snacks • Low dental aspirations	• Socially advantaged • Low caries in siblings • Dentally aware • Regular attender • Limited access to snacks • High dental aspirations
Plaque Control	• Infrequent ineffective cleaning • Poor manual control	• Frequent effective cleaning • Good manual control
Saliva	• Low flow rate • Low buffering capacity • High *S Mutans* and *Lactobacillus* counts	• Normal flow rate • High buffering capacity • Low *S. Mutans* and *Lactobacillus* counts
Medical History	• Medically compromised • Handicapped • Xerostomia • Long term cariogenic medicine	• No medical problem • No physical problem • Normal salivary flow • No long term medication

In high caries risk children there is good evidence to support taking posterior bitewing radiographs at the initial examination, even in the absence of clinically detectable decay. The benefit is reported as being between 167% and 800% of the diagnostic yield from clinical diagnosis with or without fibre optic transillumination assistance. Where a child is classified as high caries risk the subsequent bitewing examination should be after 6 months. Bitewing radiographs should not be taken more frequently than this and it is imperative to reassess caries risk in order to justify using this interval again. Evidence of no new or active lesions would be an indicator that the child had entered the moderate or low risk category.

Recommendation 3 E

It is recommended that when children are designated as high caries risk they should have six-monthly posterior bitewing radiographs taken. This should continue until no new or active lesions are apparent and the individual has entered a lower risk category.

B

In moderate caries risk children the evidence also supports the diagnostic use of bitewing radiographs. Many authors report significant addition to the diagnostic yield from the use of bitewing radiographs, varying from 150% to 270% of the yield from clinical examination alone. Where a child is classified as moderate caries risk the subsequent bitewing examination should be after 12 months. Evidence of no new or active lesions would be an indicator that the child had entered the low risk category.

Recommendation 3 F

It is recommended that when children are designated as moderate caries risk they should have annual posterior bitewing radiographs. This should continue until no new or active lesions are apparent and the individual has entered a lower risk category.

B

In low caries risk children there is less good evidence to support the taking of posterior bitewing radiographs: diagnostic yield is lower than that with higher risk groups. Nevertheless, radiographs reveal 2-3 times more caries lesions than clinical examination alone. In low caries prevalence populations, it is suggested that selective radiography should be conducted of surfaces suspected clinically as being carious. Where caries population prevalence is not low, but a child is classified as low caries risk, the subsequent bitewing examination should be after 12-18 months in the deciduous dentition and 24 months in the permanent dentition. More extended recall intervals may be employed if there is explicit evidence of continuing low caries risk. Selective radiography of suspect surfaces may be appropriate as an alternative to bitewing radiography where caries prevalence is low.

Recommendation 3 G

Radiography for caries diagnosis in low caries risk children should take into account population prevalence of caries.
Intervals of 12-18 months (deciduous dentition) or 24 months (permanent dentition) may be used, although longer intervals may be appropriate where there is continuing low caries risk.

C

There is comparatively little evidence evaluating the diagnostic yield of radiographs for caries in adults. Therefore, in the absence of research data guidelines have been devised by extrapolation of studies in children and young adults.

Recommendation 3 H

It is recommended that adults designated as high caries risk have six-monthly posterior bitewing radiographs taken until no new or active lesions are apparent and the individual has entered another risk category.

C

Recommendation 3 I

It is recommended that adults designated as moderate caries risk have annual posterior bitewing radiographs taken until no new or active lesions are apparent and the individual has entered another risk category.

C

Recommendation 3 J

It is recommended that adults designated as low caries risk have posterior bitewing radiographs taken at approximately 24-month intervals. More extended intervals may be used where there is continuing low caries risk.

C

3.1.3. Alternative methods to radiography for caries diagnosis

Clinicians have recommended flossing teeth and the temporary separation of teeth, using orthodontic separators or wooden wedges, to assist in caries diagnosis during the clinical examination.

Alternative methods to ionising radiation with which to diagnose caries have also been developed. These include established techniques such as fibreoptic transillumination (FOTI) and electrical conductance measurements (ECM). Other newer emerging technologies include Quantitative Light-induced Fluorescence (QLF), Infrared Laser Fluorescence (DIAGNOdent) and Digital Imaging Fiber Optic Transillumination (DIFOTI).
Some of these techniques have limitations that affect their diagnostic or commercial availability and in some cases, their practicality within the dental

surgery. Others require further *in vivo* research and validation. However, several of these techniques have shown promise and may well become an accepted part of the routine diagnostic armamentarium of the practicing clinician in the future(12, 27, 44).

Recommendation 3 K

Alternative methods to using ionising radiation in caries diagnosis should be considered once their diagnostic validity has been clearly established.

C

3.2 Radiographs in the management of the developing dentition

Many children seek orthodontic treatment. When such treatment is clinically required, most children are appropriately treated at around 12-13 years of age and will require radiographs to confirm the presence and condition of all teeth. Occasionally, there will be a need for a radiographic examination at an earlier age where there is a serious departure from normal dental development or when a child attends in pain or after trauma.

Children are subject to higher risks from X-ray exposure than are adults. Consequently the importance of justification for radiography is underlined. Basic information on radiography for orthodontics is available on the following pages and Table 3.2. For further details, refer to the literature (29).

Usually the radiographic examination will consist of a panoramic radiograph (or right and left oblique lateral radiographs). Upper anterior occlusal radiographs are invariably required to supplement oblique lateral radiographs, but this is not the case for panoramic radiographs. Such films only provide additional information to the panoramic film in a minority of cases (25, 29). Therefore they should be prescribed only after being justified by examining the panoramic radiograph.

3.2.1. Orthodontic radiographs

Radiography is needed following clinical examination in a proportion of orthodontic patients. In addition, a patient in the mixed dentition stage may well require radiography to determine if interceptive treatment is appropriate. When previous radiographs are available, these may already contain all the information that the clinician needs for further management.

A clinical examination is necessary to ensure that the radiographs requested will be appropriate for the patient's specific orthodontic problem. Similarly, the need for radiography to monitor treatment progress is dependent upon a careful clinical assessment. Table 3.2 gives a broad overview of the function of the various radiographic projections used in orthodontic practice.

Various studies have confirmed that a clinical examination supplemented by study models is often sufficient for treatment planning (26). Furthermore research using algorithms (14) and clinical indicators (28), has shown that a marked reduction in the numbers of orthodontic films is possible without compromising patient treatment. From these studies, the effect of radiographs on changing orthodontic diagnosis and treatment plans is limited ranging from 16% to 37% and 4% to 20% respectively (13-15, 20).

Cephalometric radiography is often requested for selected patients undergoing orthodontic treatment. The flow chart in Table 3.3 gives a very simplified overview of those cases that require lateral cephalometry. In addition, a cephalogram should be taken at:

- The end of functional appliance treatment to see the position to which the lowers anterior teeth have been proclined.
- The end of presurgical treatment for orthognathic cases.
- Just prior to the end of active fixed appliance treatment to assess the position of the lower incisors.

When assessing the position of the lower incisors, the lateral cephalogram is recommended only if the information is going to change the orthodontist's decision on their finishing mechanics or retention regime.

3.2.2 Other views

The posteroanterior (PA) view of the face/head has been advocated in cases of patients who present with facial asymmetry. The value of hand or wrist radiography in clinical orthodontics has been questioned, as these views lack the reliability to predict growth spurts. Similarly, radiography for temporomandibular joint dysfunction cannot be justified (22, 29) and films taken for this reason have been shown to have no impact on treatment planning (34). A more detailed description of the frequency and use of all types of orthodontic films can be obtained from published guidelines (29).

Recommendation 3 L

Specialist guidelines on orthodontic radiography should be consulted as an aid to justification in the management of the developing dentition in children.

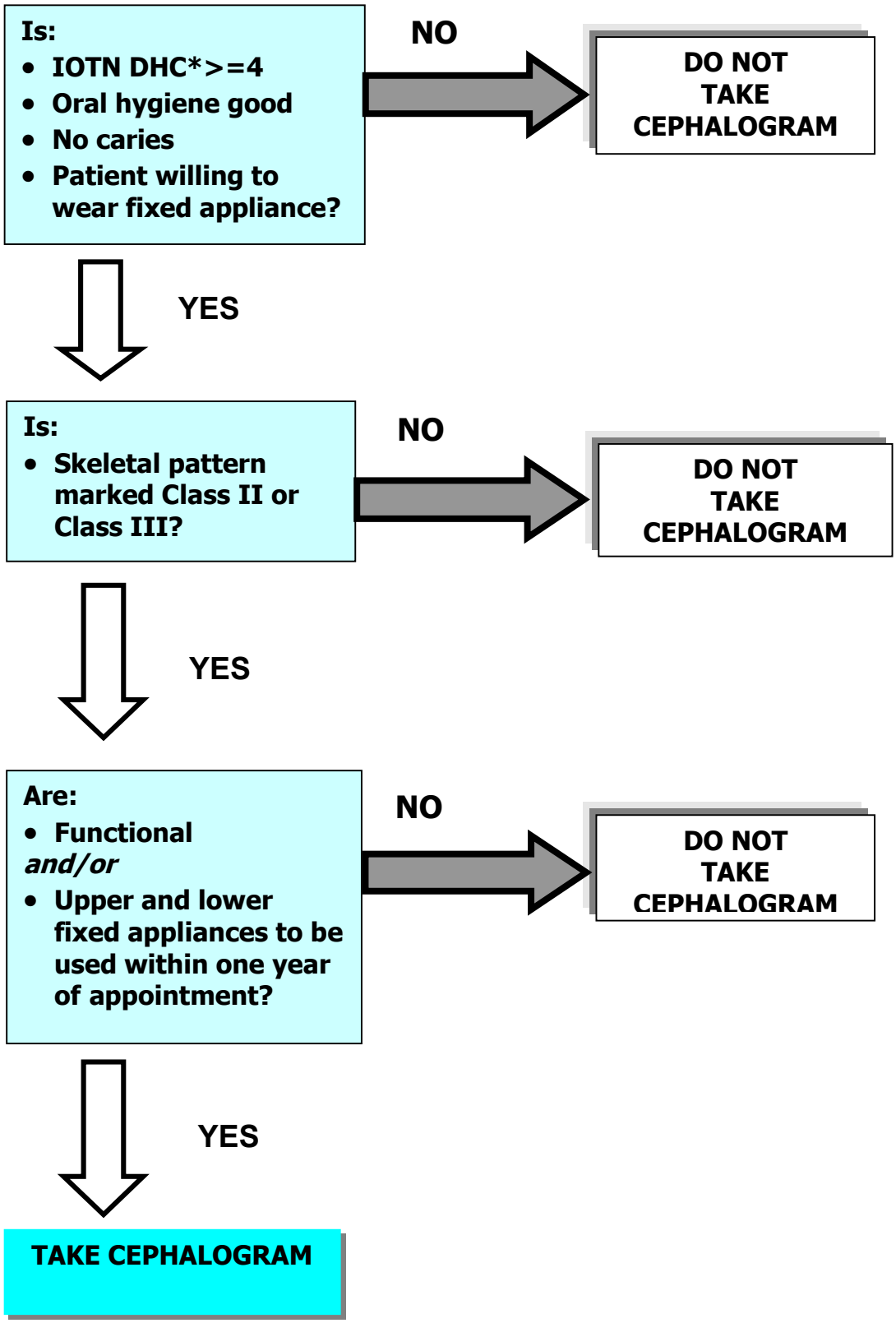
Table 3.2: Various radiographic views and their function in orthodontic practice. (Modified from (29))

Projection	Function
Panoramic radiograph or lateral oblique views	• Identification of the developing dentition. • Confirmation of the presence/absence of teeth.
Lateral cephalometric view	• To assess skeletal pattern and labial segment angulation. • Assessment of unerupted teeth.
Occlusal views generally Anterior oblique occlusal of maxilla (standard occlusal) and mandibular anterior oblique occlusal	• Identification of abnormality/ potential pathology and to localise unerupted teeth. • To obtain views of incisor region when lateral oblique films have been taken.

Occlusal views specifically:
1. Anterior oblique occlusal of maxilla (standard occlusal)
 	
2. True occlusal of the mandible
	• Localization of tooth/teeth by vertical parallax involving:
	  • Anterior oblique occlusal in combination with panoramic film.
	  or
	  • Anterior oblique occlusal in combination with a periapical film.
	
	• Localization of unerupted teeth.

Periapicals	• To assess root morphology and angulation. • To assess root resorption. • To assess apical pathology. • In combination with an oblique occlusal or second periapical, to localise unerupted teeth by parallax.
Bitewings	• To assess teeth of doubtful prognosis. • Caries identification and assessment of periodontal bone levels.
Posteroanterior view	• Occasionally needed in patients with facial asymmetry and certain jaw anomalies.

Table 3.3: A simplified flow chart to determine whether a pre-treatment cephalogram is needed.



*IOTN DHC - Index of orthodontic treatment need dental health component (38, 42).

3.3 Radiography in periodontal assessment

The diagnosis of periodontal diseases depends on a clinical examination. This maybe supplemented by radiographs if they provide additional information, which could potentially change patient management and prognosis. However, there is no clear evidence to support any robust recommendations on selection of radiographs (45).

The posterior bitewing projection offers both optimal geometry and the fine detail of intraoral radiography for patients with small amounts of uniform bone loss (36). Bitewings have the additional advantage in that they may have already been indicated for caries assessment, providing information about bone levels without the need for an additional radiation dose. More complex or extensive bone loss would require different imaging. Vertical bitewing, periapical and panoramic radiographs all have uses, either alone or in combination. Where periapical radiographs are used, the paralleling technique is indicated as this gives a better geometrical perspective on the periodontal bone than the bisecting angle technique.

Recommendation 3 M

Radiographs should be used in the management of periodontal disease if they are likely to provide additional information that could potentially change patient management and prognosis.

C

Recommendation 3 N

There is insufficient evidence to propose robust guidelines on choice of radiography for periodontal diagnosis and treatment, but existing radiographs e.g. bitewing radiographs taken for caries diagnosis should be used in the first instance.

C

3.4 Radiography in endodontics

Radiographs are essential for many aspects of endodontic treatment. It is appropriate to consider their role at the different stages of treatment(1).

3.4.1. Pre-operative

A periapical radiograph provides essential information about pulp and root canal anatomy that cannot be obtained in any other way (30). In addition it provides information about periradicular anatomy that may contribute to treatment planning or be essential if surgical endodontic treatment is being considered.

3.4.2. Working length estimation

Some types of electronic apex locators are reliable at identifying the apical constriction and are useful for locating perforations. However, using these devices in certain clinical situations can result in a degree of inaccuracy. In view of this, periapical radiography is often still required during working length estimation. It may be necessary to take two (or more) radiographs in order to determine the length of all the root canals in multi-rooted teeth (23).

3.4.3. Pre-condensation

If there is doubt about the integrity of the apical constriction, a check radiograph should be taken of the master gutta-percha cone before final condensation/obturation.

3.4.4. Post-operative

A periapical radiograph should be taken immediately following obturation as this gives a basic assessment of the quality of the root filling and a reference image of the periapical condition for subsequent review.

3.4.5. Review

The peak incidence of healing and the peak incidence of emerging chronic apical periodontitis are seen at 1 year after treatment, with a high proportion (89%) of endodontically treated teeth demonstrating signs of healing at one year (35). This suggests that a one-year follow-up radiography may be sufficient for small asymptomatic apical lesions. Teeth that remain symptomatic and those with large periapical lesions may require additional radiographic review to assess the treatment options.

Recommendation 3 O

It is recommended that radiographic examinations are carried out at the following stages of endodontic treatment:

1. Pre-operative assessment	B
2. Working length estimation*	B
3. Post-operative	B
4. At 1-year review or if symptomatic	C

* For those practitioners without access to electronic apex locators, a working length estimation will be required.

3.5 New adult patients

Many dentists follow a routine practice of examining new adult patients using panoramic or full-mouth intraoral radiography. As discussed above, such 'routine' practices are not acceptable (39-41).

Most evidence shows that conventional panoramic radiography has lower diagnostic accuracy for the common dental radiographic diagnostic tasks (caries diagnosis, periapical diagnosis) than intraoral (bitewing and periapical) radiography. Over and above these common tasks, routine panoramic radiography in search of asymptomatic bony lesions without clinical signs is not justified because of the low prevalence of such abnormalities. There is no justification for review panoramic radiography at arbitrary time intervals.

Full-mouth periapical radiography can be criticised in the same way as routine panoramic radiography. 'Routine' radiography will inevitably lead to unnecessary X-ray exposure. Selected periapical radiography of new adult patients will improve the relative risk/benefit for patients (17, 37). Taking periapical radiographs of teeth with clinical symptoms, and of those with a history of endodontic therapy and deep caries as shown on bitewing radiographs, revealed 90% of periapical lesions in one research study (11). Others have also reported (19) the effectiveness of selection criteria for identification of periapical pathosis. Table 3.4 shows a flow chart (43) for the selection of radiography for new adult patients.

Recommendation 3 P

For a new adult dentate patient, the choice of radiography should be based upon history, clinical examination and an individualised prescription as illustrated in Table 3.4.

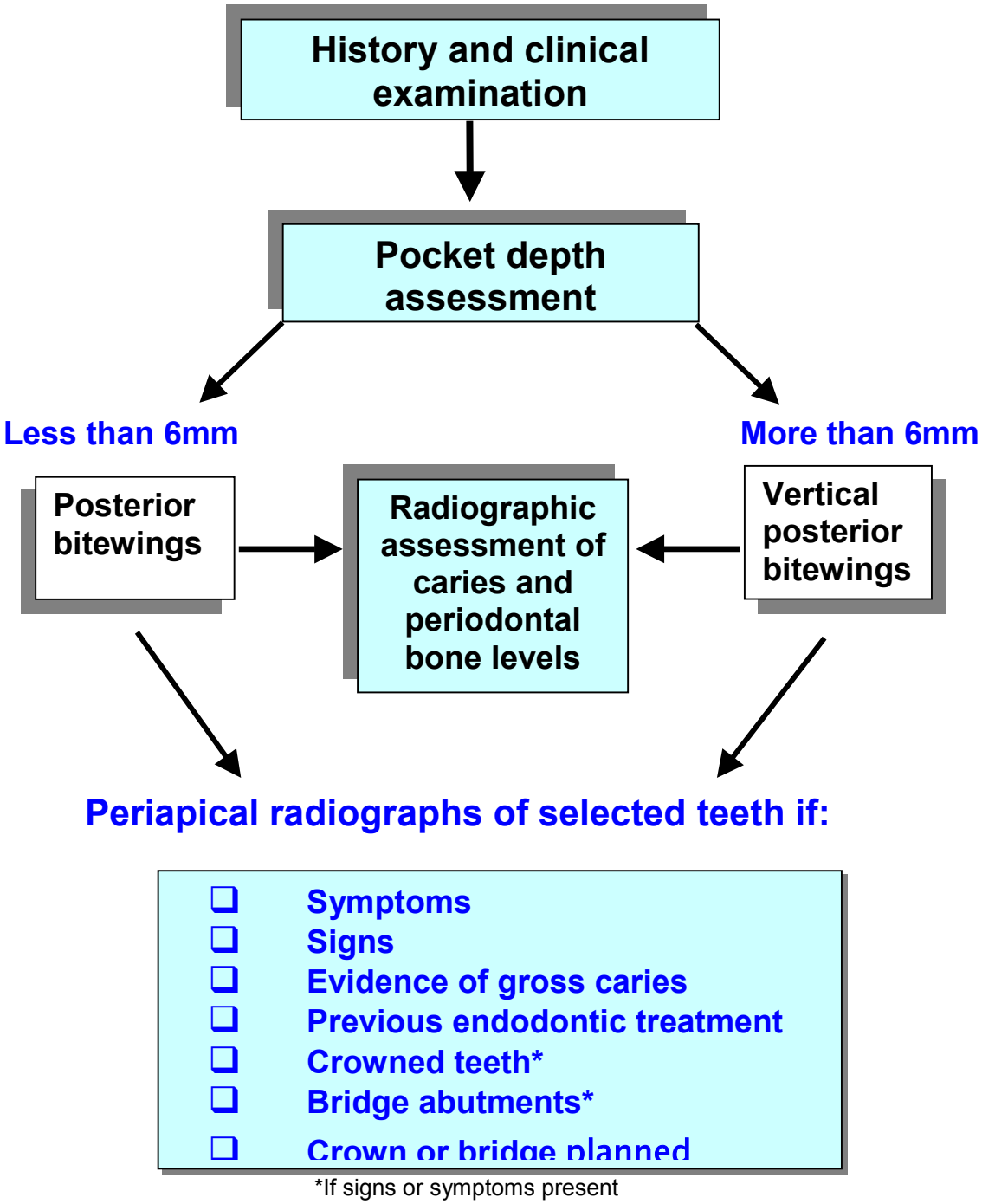
C

Recommendation 3 Q

For a new adult dentate patient, panoramic radiography may be indicated in a limited number of dental treatments, notably orthodontic assessment and certain oral surgical procedures (i.e. lower third molars).

C

Table 3.4 Flow chart of radiographic management of dentate patients. **(**Modified from (43)).



*If signs or symptoms present

This flow chart will not apply in every case. For example, the patient who has few remaining teeth due to advanced periodontal disease may not need a radiographic examination to plan treatment. The history and examination is therefore crucial and prescription of radiographs should be planned on this basis.

3.6. The edentulous patient

In the absence of any clinical signs or symptoms, there is no justification for any radiographic examination (18, 31, 32). The obvious exception is if implant treatment is planned, although if treatment is extensive other more advanced imaging (cross-sectional imaging) may well be appropriate. Where clinical examination identifies the possible presence of an abnormality, such as a possible retained root, then an intraoral radiograph of the site is the appropriate radiographic examination.

Recommendation 3 R

There is no justification for radiography of edentulous patients without a specific indication such as implant treatment or clinical signs or symptoms.

B

3.7. Radiography in implantology

Imaging is essential in implantology. In treatment planning, radiographs provide information on the quantity and quality of bone in the proposed site of implant placement. Following treatment, imaging is used to assess implant osteointegration, bone healing and to periodically review the fixture.

The review of the literature displays a paucity of evidence-based guidelines on radiography for implantology. Evidence has, in the main, been derived from expert opinion and review papers (24, 33). An assessment of these papers revealed inconsistencies and little reliable information on the frequency of follow-up radiography.

The imaging modality chosen is often a function of the treatment phase and a reflection of the number of proposed implants and their position in the oral cavity. Table 3.5 gives a broad overview of the advantages and disadvantages of the various radiographic projections used in implantology.

3.7.1. Pre-operative planning

In evaluating a pre-operative site, the clinician requires information on:

- The quality and quantity of bone
- The bucco-lingual width and height of available bone
- The inclination of bony contours
- The presence of osseous undercuts
- Evidence of atypical anatomy such as enlarged marrow spaces
- Presence of pathology
- Exact location of certain anatomic structures (i.e. the maxillary antrum, inferior alveolar canal, the mental foramen etc)

Table 3.5: Summary of radiographic techniques for implantology

IMAGING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Periapical radiography	• Availability • High resolution image • Optimum and reproducible geometry if paralleling technique used • Low dose technique • Low cost	• No bucco-lingual dimension • Limited reproducibility unless stents and paralleling technique used • Difficulties encountered in edentulous patients • Limited reproducibility with bisecting angle technique and image distortion apparent • Limited area imaged
Occlusal radiography	• Possible aid in demonstrating course of the inferior alveolar canal	• No role in maxillary implantology • Only permits gross bucco-lingual bone assessment
Panoramic radiography	• Large area imaged	• High inherent magnification (20-30%) • Geometric distortion both vertically and horizontally • Lingually positioned objects cast superiorly reducing accuracy • Technical errors common reducing measurement accuracy • No bucco-lingual measurement possible • Reduced resolution • Localisation of anatomy may be difficult
Lateral cephalometric radiography	• May be useful in anterior jaw regions. • Cross-sectional image of mid-line of jaws gives information on: • Tooth inclination • Bone quantity • Image has known magnification	• Images of structures not in mid-line are superimposed
Cross-sectional tomography	• Well defined image without superimposition • Bucco-lingual width recorded • Uniform magnification • Accurate measurement	• Limited availability • High dose techniques • Time consuming • Technical errors occur • Film interpretation requires further training • Long acquisition time
Computed tomography	• Allows multiple sites to be assessed • Well defined image layer without superimposition • Multiplanar views and 3-D reconstruction possible. • Uniform magnification (1:1) • Accurate measurement • Bone densitometry possible	• Limited availability • Film interpretation requires further training • High cost • High dose

With the exception of reformatted computed tomography (CT), all radiographic projections are magnified. The magnification factor must be derived and any assessments of available bone height must be calculated having taken this factor into consideration. Magnification factors can be derived by use of a reference object in the same plane as the alveolus.

Periapical radiographs taken for single tooth replacement require the use of film holders and the paralleling technique for optimum geometry. Optimum geometry is often difficult to achieve in the edentulous jaw. The magnification factor in panoramic radiography is particularly variable and the consensus of one expert committee (47) was to recommend that the panoramic film should be augmented by tomography, either conventional or computed, in order to provide the information necessary for optimum implant placement.

When imaging using either conventional or computed tomography to generate cross-sectional images, proposed implants sites and/or tomographic landmarks should be identified using surgical stents consisting of metal rods, balls or radiopaque markers.

Conventional tomography is obtained either from dedicated software incorporated into panoramic equipment or from specifically designed X-ray machines for implantology. The latter comprises multimodal systems using narrow beam radiography and spiral tomography. In the past CT scanning has been restricted to general hospital facilities, however smaller dedicated head and neck CT imaging equipment is becoming more commonplace. Spiral CT techniques benefit from shorter scanning times and improved accuracy.

3.7.2. Choice of radiographic techniques

The number of implants and their proposed position in the oral cavity are often the main factors dictating the choice of imaging technique. A proportion of patients need advanced imaging especially in cases involving bone grafts and in those in which there are multiple potential implant sites. In these cases CT has been recommended (47). Table 3.6 details the range of imaging methods for pre-operative planning in various parts of the oral cavity.

3.7.3. During Surgery

If any radiography is needed then periapical radiographs are readily available and use of digital imaging should be considered which offers the benefits of 'real-time' imaging.

3.7.4. Postoperative assessment

Radiography has been recommended to evaluate the implant post-operatively. The frequency and timing of review radiographs appears to be purely subjective. During the healing phase, radiography would obviously needed if the patient has clinical symptoms. If not, the next radiographic review should occur at 12 months and is considered essential to assess marginal bone levels. Subsequent review intervals range from annual reviews to once every three years. More frequent radiography is obviously needed if the patient is symptomatic.

Table 3.6: Appropriate imaging techniques for pre-operative planning.
Cross-sectional imaging refers to either CT or specialised tomography equipment.

Implant number	Location	Technique	Complicating factors	Supplementary techniques
Single implant	Anterior maxilla and mandible	Intra-oral technique using paralleling technique	• Extensive bone resorption • Enlarged incisive foramen	Combinations of lateral cephalometric and panoramic radiography
			• Pronounced buccal concavity • Pronounced sub-lingual fossa	Cross-sectional tomography
	Premolar maxilla	Combinations of periapical and panoramic radiographs	• Extensive bone resorption • Close relationship of antral floor	Cross-sectional tomography
	Premolar mandible	Combinations of periapical, occlusals and panoramic radiographs	• Extensive bone resorption • Close relationship of neuro-vascular structures	Cross-sectional tomography
	Molar Maxilla	Combinations of periapical and panoramic radiographs	• Extensive bone resorption • Close relationship of antral floor	Cross-sectional tomography
	Molar Mandible	Combinations of periapical, occlusals and panoramic radiographs	• Extensive bone resorption • Close relationship of neuro-vascular structures	Cross-sectional tomography
Multiple implants	Cross-sectional imaging is often beneficial			

A paralleling technique intraoral radiograph will provide a precise high-resolution image of bone height. The use of identical standardized intraoral radiographs enables the clinician to monitor longitudinally the fixture and adjacent bone levels. In screw-shaped implants, use can be made of the inter-thread distance to monitor mesial and distal bone loss. In the Brånemark technique the inter-thread distance is 0.6mm. The angulation of the X-ray beam must be within 9° (24) of the long axis of the fixture to open the threads and permit these measurements. Digital radiography can be used to assess bone density, allow manipulation of the image and permit subtraction of two radiographs.

Recommendation 3 S

Imaging is essential in implantology in pre-operative planning and to review the fixture.

C

3.8. Radiography prior to oral surgery and tooth extraction

In the case of third molars (5 , 8), if clinical guidelines for removal have been met, a panoramic radiograph (or alternatively oblique lateral views) is the most appropriate radiographic examination. The panoramic radiograph or oblique lateral views will provide information about the distance to the lower border of the mandible and the course and relationship of the mandibular canal.

In other surgical situations, such as apicectomy, root removal or enucleation of small cysts, an intraoral radiograph may be all that is required for treatment planning.

There is no convincing evidence to support the need for routine radiography prior to extraction of teeth (3). However, where a radiograph already exists, this should be referred to before commencing the procedure. The appropriate radiograph (with the exception of third molars) would normally be a periapical film.

Recommendation 3 T

Pre-extraction radiography may be indicated in the following situations:

- A history of previous difficult extractions
- A clinical suspicion of unusual anatomy
- A medical history placing the patient at special risk if complications were encountered
- Prior to orthodontic extractions
- Extraction of teeth or roots that are impacted, buried or likely to have a close relationship to anatomical structures (i.e. mental/inferior dental nerve, the maxillary antrum and/or tuberosity and the lower border of the mandible).

C

3.9. Radiography of pregnant patients

As the dose, and therefore the risk to the developing fetus is so low (4), there is no contraindication to radiography of women who are or may be pregnant providing that it is clinically justified. There is no need to use a lead protective apron (4, 48) (See Section 4.5.1). However, the use of a lead apron

continues to be recommended (or advised) in some nation-states on the grounds it may reassure the patient.

Recommendation 3 U

There is no evidence that normal selection criteria for dental radiography need be altered if a patient is or may be pregnant.

C NR

3.10. Consent in radiography

The dentist usually seeks either verbal or implied consent. The latter relies upon a patient not actively refusing the radiograph. Implied consent is not satisfactory, as it does not allow for the gathering of information that might influence whether the radiograph is necessary (e.g. if a radiograph has recently been taken elsewhere) (21).

There is an increasing emphasis on the need to obtain informed consent for all aspects of medical and dental practice and not merely for high-risk procedures such as interventional radiology or irreversible treatments such as tooth extraction. Informed consent is mandatory in some nation states. The basic information needed for patients undergoing dental radiography is outlined in Section 3.11 below. Written consent is no more than an indication that the process of informed consent has been satisfactorily completed. There are two situations in dental radiography when written consent is specifically required: first, for patients recruited to research projects which must have received approval by an Ethics Committee first and second, for patients undergoing a medico-legal exposure which has no direct health benefit.

Recommendation 3 V

Informed consent should be obtained from patients prior to radiography in accordance with national requirements.

ED

3.11. Previous radiographs and reports

Both the prescriber and practitioner are required under the Directive (2) to obtain where practicable previous diagnostic information such as radiographs and/or reports in order to avoid unnecessary repeat examinations.

Previous films may:

- Eliminate the need for new radiographs if they answer the current clinical need
- Facilitate monitoring of a disease process e.g. caries progression and regression
- Allow an assessment of healing e.g. of a periapical lesion

No evidence about the value of previous radiographs and reports was obtained from the dental literature. However, a few good quality research studies in medical (10, 16, 46) radiology confirmed their value, particularly for previous radiographs, in increasing diagnostic confidence and establishing a patient history.

There should be no barrier to the loan of radiographs and/or reports from a patient's previous dentist on the clear understanding that they are returned. The provision of a clinical evaluation of the outcome of each dental radiograph is a mandatory requirement in some nation states.

Recommendation 3 W

Access to previous radiographs will avoid unnecessary exposures and aid patient management.

ED

3.12. Information for patients

An explanation of the risks of dental radiography should emphasise the potential benefit to the patient's management and prognosis against very low risk of adverse consequences. Two points should be stressed.

- Dental radiography is a very low risk procedure (refer to Table 2.3).
- Without the radiograph(s), the patient's treatment will be compromised.

Furthermore, assuming adherence to recommendations in this document, the dentists can inform patients that they employ state of the art techniques to minimise the risk and has a quality assurance programme in place to optimise image quality.

With regard to the radiography of patients who are, or maybe, pregnant, the same three points can be emphasised, explaining that the risks from dental radiography are no different whether the patient is or is not pregnant.

Recommendation 3 X

Information given to patients prior to dental radiography should stress the very low risk set against the potential benefits for their treatment.

C

3.13. References

1. 1994. Consensus report of the European Society of Endodontology on quality guidelines for endodontic treatment. Int Endod J **27:**115-124.
2. Council Directive 97/43/Euratom on health protection of individuals against the dangers of ionising radiation in relation to medical exposure 1997. Official Journal of the European Communities **No L 180/22**.
3. 1999. Dental Protection. The whole tooth- and nothing but the tooth! Dental News **20:**7-8.
4. 1994. Guidelines on Radiological standards for primary dental care. Volume 5 Number 3. Royal College of Radiologists and National Radiological Protection Board.
5. 2000. National Institute for Clinical Excellence. Technology Appraisals Guidance- No. 1. Guidance on the removal of wisdom teeth. National Institute for Clinical Excellence.
6. Preventing Dental Caries in children at High Caries Risk. A National Clinical guideline. www.sign.ac.uk. SIGN Publication Number 47. SIGN Executive, Royal College of Physicians, 9, Queen Street, Edinburgh EH2 1JQ.
7. 1988. Review of methods of identification of high caries risk groups and individuals. Federation Dentaire International Technical - Report no 31. Int Dent J, **38:**177-89.
8. May 2002. Scottish Intercollegiate Guidelines Network (SIGN). A guideline developers' handbook. Report No.: SIGN 50.
9. 1998. Selection Criteria for Dental Radiography. Faculty of General Dental Practitioners, Royal College of Surgeons of England, London.
10. **Aideyan, U. O., K. Berbaum, and W. L. Smith.** 1995. Influence of prior radiologic information on the interpretation of radiographic examinations. Acad Radiol **2:**205-8.
11. **Akerblom, A., M. Rohlin, and G. Hasselgren.** 1988. Individualised restricted intraoral radiography versus full-mouth radiography in the detection of periradicular lesions. Swed Dent J **12:**151-159.
12. **Angmar-Månsson, B. E., and S. Al-Khateeb.** 1998. Caries Diagnosis. J Dent Educ **62:**771-79.
13. **Atchinson, K. A.** 1986. Radiographic examinations of orthodontic educators and practitioners. J Dent Educ **50:**651-55.
14. **Atchinson, K. A., L. S. Luke, and S. C. White.** 1992. An algorithm for ordering pretreatment orthodontic radiographs. Am J Orthodont Dentofac Orthoped **102:**29-44.
15. **Atchinson, K. A., L. S. Luke, and S. C. White.** 1991. Contribution of pretreatment radiographs to orthodontists' decision making. Oral Surg Oral Med Oral Pathol **71:**238-45.
16. **Berbaum, K. S., and W. L. Smith.** 1998. Use of reports of previous radiologic studies. Acad Radiol **5:**111-4.
17. **Bohay, R. N.** 2000. The sensitivity, specificity, and reliability of radiographic periapical diagnosis of posterior teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **89:**639-642.
18. **Bohay, R. N., R. G. Stephens, and S. L. Kogon.** 1998. A study of the impact of screening or selective radiography on the treatment and postdelivery outcome for edentulous patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **86:**353-9.
19. **Brooks, S. L., and S. Y. Cho.** 1993. Validation of a specific selection criterion for dental periapical radiography. Oral Surg Oral Med Oral Pathol **75:**383-6.
20. **Bruks, A., K. Enberg, I. Nordqvist, A. S. Hansson, L. Jansson, and B. Svenson.** 1999. Radiographic examinations as an aid to orthodontic diagnosis and treatment planning. Swed Dent J **23:**77-85.
21. **Dimond, B. C.** 2002. Legal aspects of radiography and radiology. Blackwell Science Ltd, Oxford.
22. **Eliason, S., and G. Isacsson.** 1992. Radiographic signs of temporomandibular disorders to predict outcome of treatment. J Craniomandib Disord **6:**281-87.
23. **Fava, L. R. D., and P. M. H. Dummer.** 1997. Periapical radiographic techniques during endodontic diagnosis and treatment. Int Endod J **30:**250-261.
24. **Frederiksen, N. L.** 1995. Diagnostic imaging in dental implantology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **80:**540-54.
25. **Giles, S. A., and N. G. Taylor.** 1997. Are anterior occulsal radiographs still indicated for orthodontic assessment? Br Dent J **183:**325-328.
26. **Han, U. K., K. W. L. Vig, J. A. Weintraud, P. S. Vig, and C. J. Kowalski.** 1991. Consistency of orthodontic treatment decisions relative to diagnostic records. Am J Orthodont Dentofac Orthoped **100:**212-219.
27. **Hintze, H., A. Wenzel, B. Danielson, and B. Nyvad.** 1998. Reliability of visual examination, fibre-optic transillumination and bitewing radiography, and reproducibility of direct visual examination following tooth separation for the identification of cavitated carious lesions in contacting approximal surfaces. 1998; 32: 204-9. Caries Res, **32:**204-9.
28. **Hintze, H., A. Wenzel, and S. Williams.** 1990. Diagnostic value of clinical examination for the identification of children in need of orthodontic treatment compared with clinical examination and screening pantomography. Eur J Orth **12:**385-388.
29. **Isaacson, K. G., and A. R. Thom (ed.).** 2001. Guidelines for the use of radiographs in clinical Orthodontics, 2nd ed. British Orthodontic Society, London.
30. **Klein, R. M. F., S. A. Blake, B. R. Nattress, and P. N. Hirchmann.** 1997. Evaluation of x-ray beam angulation for successful twin canal identification in mandibular incisors. Int Endod J **30:**58-63.
31. **Kogon, S. L., D. H. Charles, and R. G. Stephens.** 1991. A clinical study of radiographic selection criteria for edentulous patients. J Can Dent Assoc **57:**794-8.
32. **Kogon, S. L., R. G. Stephens, and R. N. Bohay.** 1997. An analysis of the scientific basis for the radiographic guideline for new edentulous patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **83:**619-23.
33. **Lekholm, U., and G. A. Zarb.** 1985. Patient selection and preparation. *In* P. I. Brånemark, G. A. Zarb, and T. Albrektsson (ed.), Tissue integrated prosthesis. Osteointegration in Clinical Dentistry.Quintessence, Berlin.
34. **Luke, L. S., P. Lee, K. A. Atchison, and S. C. White.** 1997. Orthodontic residents' indications for use of the lateral TMJ tomogram and the posteroanterior cephalogram. J Dent Educ **61:**29-36.

35. **Orstavik, D.** 1996. Time-course and risk analyses of the development and healing of chronic apical periodontitis in man. Int Endod J **29:**150-155.
36. **Pepelassi, E. A., and A. Diamanti-Kipioti.** 1997. Selection of the most accurate method of conventional radiography for the assessment of periodontal osseous destruction. J Clin Periodontol **24:**557-567.
37. **Richardson, P. S.** 1997. Selective periapical radiology compared to panoramic screening. Prim Dent Care **4:**95-9.
38. **Richmond, S., K. O'Brien, A. Buchanan, and D. Burden.** 1992. An introduction to occlusal indices. ORTHO-CARE (UK) Ltd., Bradford, UK.
39. **Rushton, V. E., K. Horner, and H. M. Worthington.** 2002. Screening panoramic radiography of new adult patients in general dental practice: diagnostic yield when combined with bitewing radiography and identification of selection criteria. Br Dent J **192:**275-279.
40. **Rushton, V. E., K. Horner, and H. V. Worthington.** 1999. Aspects of panoramic radiography in general dental practice. Br Dent J **186:**342-4.
41. **Rushton, V. E., K. Horner, and H. V. Worthington.** 2001. Screening panoramic radiology of adults in general dental practice: radiological findings. Br Dent J **190:**495-501.
42. **Shaw, W. C., K. O'Brien, and S. Richmond.** 1991. Indices of orthodontic treatment need and treatment standards. Br Dent J **170:**107-112.
43. **Shelley, A.** 2000. The Bridge. BUPA Dental Cover **19:**4.
44. **Stookey, G. K., and C. González-Cabezas.** 2001. Emerging methods of caries diagnosis. J Dent Educ **65:**1001-06.
45. **Tugnait, A., V. Clerehugh, and P. N. Hirschmann.** 2000. The usefulness of radiographs in diagnosis and management of periodontal diseases: a review. J Dent **28:**219-226.
46. **White, K., K. Berbaum, and W. L. Smith.** 1994. The role of previous radiographs and reports in the interpretation of current radiographs. Invest Radiol **29:**263-5.
47. **White, S. C., E. W. Heslop, L. G. Hollender, K. M. Mosier, A. Ruprecht, M. K. Shrout, and American Academy of Oral Maxillofacial Radiology ad hoc Committee on Parameters of Care.** 2001. Parameters of radiologic care: An official report of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **91:**498-511.
48. **Wood, R. E., A. M. P. Harris, E. J. van der Merwe, and C. J. Nortje.** 1991. The leaded apron revisited:Does it reduce gonadal radiation dose in dental radiology? Oral Surg Oral Med Oral Pathol **71:**642-46.

4 Equipment factors in reduction of radiation doses to patients

The aim of this section is to:

- **Describe the ways in which radiation dose is influenced by selection of equipment and materials**
- **Derive recommendations on equipment and materials**

In Section 2, review of the literature demonstrated that individual doses and risks to patients in dental radiography were low. However, these figures are based upon laboratory studies using phantoms rather than 'real life'. Dose surveys have revealed wide variations in doses given to patients for the same examination. Such variations reflect the variability in performance of different X-ray equipment and materials. In this section the importance of selection of appropriate equipment and materials in limiting doses (and hence risk) is reviewed.

4.1 X-ray generation and kilovoltage

The kilovoltage of an X-ray machine is the potential difference that exists across the X-ray tube during use. Kilovoltage controls the mean and peak X-ray energies in the X-ray beam. Low kilovoltages, giving lower energy X-rays, leads to higher skin doses for patients(22). They also necessitate longer exposure times than would be needed for a higher kilovoltage X-ray set (milliamperage assumed to be equal). These factors have led to lower limits to be set for kilovoltage in legislation from various countries, usually in the 50 to 60 kV region. Higher kilovoltages reduce skin dose, but lead to higher 'depth' dose(18) and more scatter of X-rays. In the case of dental (intraoral) X-ray sets, kilovoltage is usually either fixed or minimally variable.

An important consideration with dental (intraoral) radiography is the X-ray spectral sensitivity of dental X-ray film and the image quality at different kilovoltages. Increasing the kilovoltage much beyond 70 kV would result in a spectrum ill-matched to the optimal sensitivity of dental film (22). 'Low' kilovoltages produce images of higher contrast than do higher kilovoltages. This reflects the different types of attenuation of low and high energy radiation. There is debate about the optimal kilovoltage for dental work, with some authorities recommending higher values, particularly in the USA.

A kilovoltage of around 60-70 kV for intraoral radiography is considered to be a reasonable compromise choice in terms of limiting dose and all-round diagnostic efficacy (22).

Recommendation 4 A

65 to 70 kV is recommended as the kilovoltage of choice for dental (intraoral) X-ray sets using AC equipment, with 60kV for those using DC X-ray sets.

Unlike intraoral radiography, kilovoltage is used as the principle means of exposure control for panoramic radiography. Thus most panoramic X-ray machines offer a wide range of kilovoltages to the operator. Choice of kilovoltage is principally governed by the need to control X-ray intensity and by the energy sensitivity of the film/screen combination.

Constant potential ('direct current') X-ray generation is a modern alternative to traditional pulsating kilovoltage for both dental (intraoral) and panoramic /cephalometric equipment. Such a method of X-ray generation produces proportionately fewer low energy X-rays(22, 34, 41) and hence gives reductions in skin dose for patients. The mean X-ray energy from a constant potential (DC) X-ray set is higher than that from an alternating potential (AC) X-ray set at the same operating kilovoltage. It has been demonstrated that for a constant potential set a kilovoltage setting of 5-8 kV lower is needed to maintain radiographic contrast (19). Thus 60 kV is recommended as the optimal operating potential for intraoral work. Constant potential equipment provides more predictable and accurate X-ray output and is therefore a better choice for use with digital receptor systems.

Recommendation 4B

Constant potential ('DC') X-ray equipment is recommended when purchasing new X-ray equipment, especially when digital image receptors systems are chosen.

C

4.2 Filtration

Filtration of the X-ray beam preferentially removes lower energy X-ray photons from the beam. Thus it is invaluable as a means of reducing skin doses to patients. Filtration using aluminium is an established component of dental X-ray equipment. Such filtration is fitted at manufacture and is therefore a factor that is not readily under the control of the dentist.

Recommendation 4 C

Filtration by aluminium is a key method of reducing skin dose to patients.

B

Additional filtration using materials (K-edge filters) other than aluminium, such as rare-earth materials, have been investigated as means of dose reduction in intraoral dental radiography by a number of researchers (22, 25, 30, 31, 33, 46, 52, 54). The underlying reason for their use is that they 'shape' the X-ray spectrum and more closely match the spectral sensitivity of dental film. The evidence appears to be that all offer reductions in dose (22, 25, 30, 31, 33, 46, 54), but that this must be balanced against cost (54), effects on image

quality(46) and the likely increase in exposure times associated with their use. Dose reduction has also been demonstrated for panoramic radiography (24). Rare-earth filtration offers some dose reduction in intraoral radiography, but it should only be adopted after advice from a medical physics expert on setting new exposure factors.

4.3 Collimation, field-size trimming

Reducing the size of the X-ray beam to the minimum size needed to image the object of interest is an obvious means of limiting dose to patients. Limiting beam area on the skin surface also limits the volume of the patient that is irradiated. As well as 'field size' on the patient's skin being important, the X-ray source to skin distance plays a role in limiting doses. Because of the divergence of the X-ray beam, increasing this distance reduces the divergence within the patient and therefore reduces the volume irradiated.

4.3.1 Intraoral radiography

On dental X-ray sets for intraoral radiography field size is constrained by collimation of the beam. Visualisation of the field size is facilitated by the 'position indicating device' (PID).

Short pointed PIDs were once favored because the conical shape allowed a less obstructed view of film/teeth relationship and provided a visual indication of the central ray (9). However, in the last 20 years most dental intraoral sets have been manufactured with an open-ended PID of 60 mm diameter. A circular beam of this size is 135% larger in area than a conventional dental film (30 x 40 mm), indicating an obvious way of reducing patient dose(22). Various investigators have estimated that rectangular collimation can achieve dose reductions exceeding 60% in dental radiography(9, 13, 18). Cederberg and associates (9) calculated and compared the effective dose and also estimated the risk from the use of short and long, round and rectangular open-end PIDs and a short pointed closed-end PID. They reported that both long and short rectangular collimation resulted in the lowest effective doses, with values 3.5 to 5 times less than round collimation. They also demonstrated that the use of pointed closed-end PIDs equates to a risk of 5.6 times that of a long rectangular PID.

The adoption of rectangular collimation (30 x 40 mm beam) has been recommended in both UK (21, 36) and USA (2, 55). However, it is important to remember that use of rectangular collimation requires the use of film holding devices with a beam alignment guide to prevent cone cuts. Rectangular collimation can be achieved by replacing the round PID with a rectangular one, attaching a special rectangular collimating plate to the end of the round PID or using a film holder that incorporates a metal shield to block radiation beyond the edges of the film (2). These possibilities mean that existing equipment can easily be adapted to allow rectangular collimation (36).

Recommendation 4 D

Rectangular collimation is a highly effective means of dose reduction in intraoral dental radiography. It should be used in combination with film holders incorporating beam-aiming devices. In those cases where film holders are not possible, rectangular collimation should still be considered.

Where circular X-ray beams continue to be used, the beam diameter must not exceed 60 mm. Beam collimators/directors should be open ended and provide a minimum focus-to-skin distance (FSD) of 200 mm.

4.3.2 Panoramic radiography

Panoramic radiography was designed originally as a means of examining the jaws and the teeth. However, the radiographed area is frequently far in excess of that of diagnostic interest. Dentists had no facility for reducing the area irradiated. However, several machines now offer programmed field-size trimming as a means of reducing patient dose. Field limitation can significantly reduce patient exposure when specific diagnostic information is required. New equipment should be provided with automatic selection of beam limitation, although manual selection is acceptable (36). The beam height at the receiving slit or secondary collimator should be restricted to no greater than that required to expose the area of diagnostic interest and certainly no greater than the film (should normally be 120 or 150 mm). The beam width should normally be no greater than 5 mm(36).

Some new panoramic machines have a ‘child-imaging mode’, which reduces the exposed area by 27 to 45% (22). Some also offer more sophisticated programmes to permit imaging of individual jaw segments and temporomandibular joints. In a study, Lecomber and Faulkner(27) reported that by using a field size programme on the Orthophos X-ray unit limited to the tooth bearing regions of the jaws, effective dose could be reduced by more than 50%. Such facilities offer a simple way of reducing dose and the purchase of machines with these facilities should be encouraged.

Recommendation 4 E

If available, limitation of field size to the area required for diagnosis should be used for panoramic radiography.

4.3.3 Cephalometric radiography

Cephalometry (also known as teleradiography) traditionally produces images of the entire head and much of the cervical spine. However, the area of interest to orthodontists usually stops at the level of the base of the skull. A British Orthodontic Society working party supported the concept of reduction of lateral cephalogram dosage by the use of modified wedge collimation to remove part of the skull from diagnostic area (22, 32). This viewpoint is supported in other publications(49, 55). Although such collimation should significant reduce patient dose, manufactures of cephalometric equipment have not yet included this form of collimation as standard. Further collimation of the lateral cephalogram to show the maxilla and mandible only is a viable alternative for measuring cephalometric values during treatment(32).

Recommendation 4 F

Where possible, lateral cephalograms should be collimated to limit the field to the area required for diagnosis. Manufacturers must incorporate this feature into the design of cephalographic equipment.

Soft tissue profile using wedge filters is usual on lateral cephalometric radiographs. Some dose reduction can be included by placing the filter between the patient and the X-ray source rather than between the patient and the cassette (22, 55).

4.4 Choice of image receptor

4.4.1 Intraoral radiography

Until 1980, the fastest intraoral film commercially available was film of group D. In 1981, E-speed films became available, capable of reducing the amount of radiation by approximately 50%. However, this fast film had a lower inherent contrast, was very sensitive to aged and depleted solutions and lost its high speed at higher densities (48). This was probably the main reason that only a few dentists adopted this type of film(6, 8, 20, 38, 42, 45).

Subsequent developments in film technology by various manufacturers have delivered improved E-speed emulsions (44, 56) and films that fall into the ISO speed group F. One brand of F-speed film that is widely available has been shown to offer dose reductions of 20-25% compared with the same manufacturer's E-speed film(14, 29, 43).

In conclusion, for intraoral radiography the fastest available films consistent with satisfactory diagnostic results should be used. Intraoral films of ISO speed groups E or F are recommended because they reduce the radiation dose more than 50% compared with group D-speed films. The use of instant

process film, which have slower speeds and limitations in image quality (10), should be limited to specific essential situations, as in endodontics or pre-extraction cases during out-of-hours care.

Recommendation 4 G

For intraoral radiography, only the fastest available (Group E or faster) films should be used, as they significantly reduce patient dose.

4.4.2 Extraoral radiography

For panoramic, cephalometric and other extraoral radiographs, the fastest available film-intensifying screen combination consistent with satisfactory diagnostic results should be used. The film screen combination should be at least 400 and the light sensitivity of the film should be correctly matched with the intensifying screens. The introduction of rare-earth intensifying screen/film combination has been shown to give dose reduction of around 50% for panoramic and cephalometric radiology (22).

Manufacturers generally emphasize the use of matched combinations of orthochromatic film and rare-earth screens because such combinations more efficiently convert radiation energy to light in comparison with orthochromatic film combined with calcium tungstate screens (53). Since rare-earth phosphor screens were introduced in 1972, manufacturers have tried to develop such combinations in order to improve speed and to increase sharpness of the radiographic images

A number of studies have been carried out to evaluate the sensitometric properties of these film-screen combinations (47, 51, 53). Wide latitude films perform better for panoramic radiography than higher contrast films.

Recommendation 4 H

For extraoral radiography the fastest available rare-earth intensifying screen/film combination consistent with satisfactory diagnostic results should be used. The speed of the system should be at least 400.

4.4.3 Digital receptors

Recently, several digital imaging systems have been introduced as alternatives to conventional radiographic techniques. The digital images are supposed to achieve images of high diagnostic quality, at least equal to that of

conventional radiographic film. Furthermore, the images are displayed immediately on the computer monitor and no processing chemicals or equipment are necessary.

Two types of intraoral digital systems are currently available. The first type involves those systems that they are using imaging sensors based on charge-coupled devices (CCD). The first system for direct digital intraoral radiography was introduced in 1989 and was based on a CCD sensor sensitive to visible light. CCD systems convert radiation into visible light by using a scintillation screen. The light is transferred to the CCD via fibre optic coupling or optical lenses. The pattern of light is detected and converted to an electronic signal that is passed to the computer for conversion into an image. The number of CCD systems available for intraoral radiography has increased rapidly. Today, most sensors use a scintillation layer to improve the quantum efficiency of the system. Improvements in pixel size, in the active area of the sensor, in spatial resolution, noise and image manipulation have been made by manufacturers in recent years. Recently some sensors have been developed with smaller pixel size and with the use of the so-called Active Pixel Sensor (APS) and Complementary Metal-Oxide Semiconductor (CMOS) technologies. Several studies have evaluated the physical and clinical performance of the majority of the intraoral digital systems(3, 4, 12, 17, 26, 35, 37).

The second type of digital intraoral system uses photostimulable storage phosphor (PSP) image plates. The plates consist of a polyester base coated with a crystalline halide composed of europium-activated barium fluorohalide compounds. When the image plate is irradiated, the absorbed X-ray energy is stored as a latent image within the phosphor crystals. In a scanner, a narrow laser beam causes the release of the stored energy as visible blue light that is turned into an analog electronic signal and thereafter digitized. Scanning is accomplished in about 25 seconds and the resulting image is displayed on the computer monitor. In contrast to CCD systems, storage phosphor systems are cordless.

Each of these two types of intraoral digital systems has advantages and disadvantages. Because image acquisition is more rapid with CCD systems than with PSP, the former may be more useful when ‘instant’ radiographs are desirable. In contrast, PSP systems are wireless and use a larger size image plate, approximately the size of a No.2 periapical film. One of the most important advantages of digital radiography is the reduction of radiation dose. Various studies have shown that the amount of radiation needed to create an image for both types of intraoral system is lower than with film.

One study demonstrated that the optimal exposure time for all systems was approximately half that needed for conventional film and that digital images had to be modified by adjusting the contrast and brightness to optimize the visibility of the region of interest(37). Another study(39) reported that a CCD system provided reduction in average skin entrance dose of 31-34% when compared with E-speed film; with added niobium filtration the reduction was found to be 51-60%. PSP systems have a wide exposure latitude and Borg

and Grondahl (7) found that reliable endodontic measurements could be obtained even at very low exposure settings.

Although digital radiography offers a significant dose reduction, the number of retakes (essentially due to bad positioning of the bulky CCD with its' encumbering wire) may result in increased dose for the patient. Furthermore, due to smaller sensor sizes, more than one exposure may be required to cover the anatomical area imaged using a single conventional film. Problems with positioning sensors have been reported as leading to high reject rate (23).

Recommendation 4 I

Intraoral digital radiography offers a potential dose reduction. A medical physics expert should be consulted to achieve dose reduction optimisation.

B

For panoramic and cephalometric radiography, the same two types of digital systems are also available. For CCD systems, conventional film is replaced by a long vertical CCD. The same sensor is used in cephalometric radiography, where the CCD is mounted on the cephalostat behind the patient's head. The patient's head is scanned in lines with a flat, fan shaped X-ray beam. During the scanning process, which takes about 15 seconds, the patient must stay motionless. The second type of digital panoramic and cephalometric system uses a PSP plate in place of the conventional film cassette.

Panoramic and cephalometric digital radiography have the same clinical advantages as intraoral digital radiography, although dose reduction is not expected to be as effective as with intraoral systems. The exposure settings of CCD type panoramic units require exposures that are almost equal to those of machines using film/screen combinations. There will be no dose reduction. Some papers however, report that, depending on the diagnostic task, a lower exposure of the radiograph could be sufficient when density and contrast can be adjusted from the software features(11, 15, 16, 28, 50). This is one of the benefits of digital radiography where the density and contrast of an image can be optimized after the image has been taken. This is different to conventional radiography, where the contrast and density cannot be changed after the image is taken.

Recommendation 4 J

It is unlikely that digital panoramic and cephalometric radiography can routinely offer dose reduction compared with conventional screen/film combinations. A medical physics expert should be consulted to achieve dose reduction optimisation.

C

4.5.1 Leaded aprons

Lead aprons do not protect against scattered radiation internally within the body and in the case of panoramic radiography, they may physically interfere with the procedure and degrade the final image (21). Despite the extremely low gonadal dose associated with dental radiography, the use of a lead apron has been recommended in the past in order to allay patient anxiety. However, it has been shown that gonadal doses are not significantly different in dental radiography with and without a lead apron (22). UK Guidance Notes for dental practitioners on the safe use of X-ray equipment (36), clearly state that there is no justification for the routine use of lead aprons for patients in dental radiography. An official report of the American Academy of Oral and Maxillofacial Radiology (55), pointed out that the value of leaded aprons is minimal compared with the benefits of the use of E-speed films and rectangular collimation. It was concluded that their use could be considered optional except when required by law. See Section 3.8 for comments on radiography in pregnant patients.

Recommendation 4 K

There is no evidence to justify routine use of abdominal (gonadal) lead protection for dental radiography.

4.5.2 Thyroid collar

The thyroid gland is one of the more radiosensitive organs in the head and neck region. It is frequently exposed to scattered radiation and occasionally to primary beam during dental radiography. Because people under age 30 are at greater risk of radiation induced thyroid cancer than older individuals, some have argued that thyroid collars should be used when intraoral radiographic examinations are made on this population(55). However, it is probable that rectangular collimation for intraoral radiography offers similar level of thyroid protection to lead shielding, in addition to its other dose reducing effects (21, 22, 40). Thyroid shielding is inappropriate for panoramic radiography as it may interfere with the primary beam. In cephalometric radiography lead thyroid protection is necessary if the beam collimation does not exclude the thyroid gland. Thyroid shielding was found to reduce radiation doses of 45% during CT of the head and is strongly recommended, especially in younger age groups (5).

Recommendation 4 L

Lead shielding of the thyroid gland should be used in those cases where the thyroid is in line of, or very close to, the primary beam.

C

Patient doses should be kept as low as reasonably achievable. In dental radiography, patient dose limitation involves consideration of the X-ray equipment, the beam size, the image receptor and, occasionally, the use of lead protection. Optimizations of each of these acts synergistically to substantially reduce doses.

For intraoral radiography the effect of altering the various equipment factors is demonstrated in Table 4.1. It is possible to see that a shift from the baseline equipment to a constant potential set, rectangular collimation and F-speed film would lead to a dose reduction of about two thirds of the original level.

Table 4.1: The effect upon dose of equipment modification when compared with a baseline of a 70 kV AC dental X-ray set with a 60 mm cylindrical beam used with E-speed film.

Equipment factors	Multiplication factor upon dose
Digital systems (Phosphor plate or CCD)	x 0.5 – 0.75
Rectangular collimation (30 x 40 mm)	x 0.5
F-speed film	x 0.8
'DC' constant potential set	x 0.8
'Short cone' (100 mm source to skin distance)	x 1.5
50 kV set	x 2.0
D-speed film	x 2.0

The multiplication factors indicate the effects upon dose. *Table adapted from (1)*

Similar modifications can be made for other types of dental radiography (panoramic, cephalometric).

Some dose limitations can only be achieved by purchase of new equipment. However, some entail minimal (e.g. rectangular collimation) or no (e.g. F-speed film) additional costs to the dentist. Such low cost options should be adopted as a priority.

4.7 References

1. 1998. Selection Criteria for Dental Radiography. Faculty of General Dental Practitioners, Royal College of Surgeons of England, London.
2. **ADA.** 2001. Council on Scientific affairs - An update on radiographic practices: information and recommendations. J Am Dent Assoc **132:**234-238.

3. **Attaelmanan, A. G., E. Borg, and H. G. Grondahl.** 1999. Assessments of the physical performance of 2 generations of 2 direct digital intraoral sensors. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **88:**517-23.
4. **Attaelmanan, A. G., E. Borg, and H. G. Grondahl.** 2001. Signal-to-noise ratios of 6 intraoral digital sensors. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **91:**611-5.
5. **Beaconsfield, T., R. Nicholson, A. Thornton, and A. Al-Kutoubi.** 1998. Would thyroid and breast shielding be beneficial in CT of the head? Eur Radiol **8:**664-7.
6. **Bohay, R. N., S. L. Kogon, and R. G. Stephens.** 1994. A survey of radiographic techniques and equipment used by a sample of general dental practitioners. Oral Surg Oral Med Oral Pathol **78:**806-10.
7. **Borg, E., and H. G. Grondahl.** 1996. Endodontic measurements in digital radiographs acquired by a photostimulable, storage phosphor system. Endod Dent Traumatol **12:**20-4.
8. **Button, T. M., W. C. Moore, and A. D. Goren.** 1999. Causes of excessive bitewing exposure: results of a survey regarding radiographic equipment in New York. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **87:**513-7.
9. **Cederberg, R. A., N. L. Frederiksen, B. W. Benson, and T. W. Sokolowski.** 1997. Effect of the geometry of the intraoral position-indicating device on effective dose. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **84:**101-9.
10. **Czajka, J., V. E. Rushton, A. C. Shearer, and K. Horner.** 1996. Sensitometric and image quality performance of "rapid" intraoral film processing techniques. Br J Radiol **69:**49-58.
11. **Dula, K., G. Sanderink, P. F. van der Stelt, R. Mini, and D. Buser.** 1998. Effects of dose reduction on the detectability of standardized radiolucent lesions in digital panoramic radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **86:**227-33.
12. **Farman, A. G., W. C. Scarfe, D. B. Schick, and P. M. Rumack.** 1995. Computed dental radiography: evaluation of a new charge coupled device- based intraoral radiographic system. Quintessence Int **26:**399-404.
13. **Freeman, J. P., and J. W. Brand.** 1994. Radiation doses of commonly used dental radiographic surveys. Oral Surg Oral Med Oral Pathol **77:**285-9.
14. **Geist, J. R., and J. W. Brand.** 2001. Sensitometric comparison of speed group E and F dental radiographic films. Dentomaxillofac Radiol **30:**147-52.
15. **Gijbels, F., C. Bou Serhal, G. Willems, H. Bosmans, G. Sanderink, M. Persoons, and R. Jacobs.** 2001. Diagnostic yield of conventional and digital cephalometric images: a human cadaver study. Dentomaxillofac Radiol **30:**101-5.
16. **Hagemann, K., D. Vollmer, T. Niegel, U. Ehmer, and I. Reuter.** 2000. Prospective study on the reproducibility of cephalometric landmarks on conventional and digital lateral headfilms. J Orofacial Orthopedics **61:**91-9.
17. **Harada, T., K. Nishikawa, H. Shibuya, Y. Hayakawa, and K. Kuroyanagi.** 1995. Sens-A-Ray characteristics with variations in beam quality. Oral Surg Oral Med Oral Pathol Oral Radiol Endond **80:**120-123.
18. **Hayakawa, Y., H. Fujimori, and K. Kuroyanagi.** 1993. Absorbed doses with intraoral radiography. Function of various technical parameters. Oral Surg Oral Med Oral Pathol **76:**519-24.
19. **Helmrot, E., G. A. Carlsson, and O. Eckerdal.** 1994. Effects of contrast equalization on energy imparted to the patient: a comparison of two dental generators and two types of intraoral film. Dentomaxillofac Radiol **23:**83-90.
20. **Hintze, H.** 1993. Radiographic screening examination: frequency, equipment, and film in general dental practice in Denmark. Scand J Dent Res **101:**52-6.
21. **Hirschmann, P. N.** 1995. Guidelines on radiology standards for primary dental care: a resume. Royal College of Radiologists and the National Radiological Protection Board. Br Dent J **178:**165-7.
22. **Horner, K.** 1994. Review article: radiation protection in dental radiology. Br J Radiol **67:**1041-9.
23. **Horner, K., A. C. Shearer, A. Walker, and N. H. F. Wilson.** 1990. Radiovisiography: an initial evaluation. Br Dent J **168:**244-248.
24. **Kapa, S. F., and D. A. Tyndall.** 1989. A clinical comparison of image quality and patient exposure reduction in panoramic radiology with heavy metal filtration. Oral Surg Oral Med Oral Pathol **67:**750-759.
25. **Kapa, S. F., D. A. Tyndall, and T. E. Ouellette.** 1990. The application of added beam filtration to intraoral radiography. Dentomaxillofac Radiol **19:**67-74.
26. **Kunzell, A., and C. Benz.** 1997. Noise in digital dental radiographs. Dentomaxillofac Radiol **26:**261-285.
27. **Lecomber, A. R., and K. Faulkner.** 1993. Dose reduction in panoramic radiography. Dentomaxillofac Radiol **22:**69-73.
28. **Lim, K. F., and K. W. Foong.** 1997. Phosphor-stimulated computed cephalometry: reliability of landmark identification. Br J Orthodont **24:**301-8.
29. **Ludlow, J. B., E. Platin, and A. Mol.** 2001. Characteristics of Kodak Insight, an F-speed intraoral film. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **91:**120-9.
30. **MacDonald-Jankowski, D. S., and C. P. Lawinski.** 1992. The effect of thin K-edge filters on radiation dose in dental radiology. Br J Radiol **65:**990-995.
31. **MacDonald-Jankowski, D. S., and C. P. Lawinski.** 1991. The reduction in radiation dose for intraoral radiographs by the use of thin K-edge filters. Br J Radiol **64:**524-528.
32. **Mandall, N. A., K. D. O'Brien, and H. V. Worthington.** 1999. Radiation reduction using a modified collimated lateral skull radiograph during orthodontic treatment. Clin Orthodont Res **2:**179-85.
33. **Mauriello, S. M., V. P. Overman, and G. B. Mann.** 1996. Clinical evaluation of a samarium compound filter and E-speed film. Quintessence Int **27:**769-73.
34. **McDavid, W. D., U. Welander, B. K. Pillai, and C. R. Morris.** 1982. The Intrex: a constant potential x-ray unit for periapical dental radiography. Oral Surg Oral Med Oral Pathol **53:**433-436.
35. **Molteni, R.** 1992. Visualix, a new system for direct dental X-ray imaging: a preliminary report. Dentomaxillofac Radiol **21:**222-223.
36. **National Radiological Protection Board.** 2001. Guidance notes for dental practitioners on the safe use of x-ray equipment. Department of Health, London.

37. **Pfeiffer, P., P. Schmage, I. Nergiz, and U. Platzer.** 2000. Effects of different exposure values on diagnostic accuracy of digital images. Quintessence Int **31:**257-60.
38. **Platin, E., A. Janhom, and D. Tyndall.** 1998. A quantitative analysis of dental radiography quality assurance practices among North Carolina dentists. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **86:**115-20.
39. **Scarfe, W. C., A. G. Farman, J. W. Brand, and M. S. Kelly.** 1997. Tissue radiation dosages using the RVG-S with and without niobium filtration. Aust Dent J **42:**335-42.
40. **Schmidt, K., X. L. Velders, F. C. van Ginkel, and P. F. van der Stelt.** 1998. Het gebruik van een loodkraag bij intraorale rontgenopnamen. Ned Tijdschr Tandheelkd **105:**209-212.
41. **Stenstrom, B., P. Julin, and L. Karlsson.** 1987. Comparison between panoramic radiographic techniques. Part IV: Absorbed doses and energy imparted from the Orthopantomograph model OP10. Dentomaxillofac Radiol **16:**11-15.
42. **Svenson, B., and A. Petersson.** 1995. Questionnaire survey on the use of dental X-ray film and equipment among general practitioners in the Swedish Public Dental Health Service. Acta Odontol Scand **53:**230-5.
43. **Syriopoulos, K., X. L. Velders, G. C. Sanderink, and P. F. van Der Stelt.** 2001. Sensitometric and clinical evaluation of a new F-speed dental X-ray film. Dentomaxillofac Radiol **30:**40-4.
44. **Syriopoulos, K., X. L. Velders, G. C. Sanderink, F. C. van Ginkel, and P. F. van der Stelt.** 1999. Sensitometric evaluation of four dental X-ray films using five processing solutions. Dentomaxillofac Radiol **28:**73-9.
45. **Syriopoulos, K., X. L. Velders, P. F. van der Stelt, F. C. van Ginkel, and K. Tsiklakis.** 1998. Mail survey of dental radiographic techniques and radiation doses in Greece. Dentomaxillofac Radiol **27:**321-8.
46. **Tetradis, S., G. Scaf, A. G. Lurie, and M. L. Freedman.** 1995. Niobium filtration of conventional and high-frequency x-ray generator beams for intraoral radiography. Effects on absorbed doses, image density and contrast, and photon spectra. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **80:**232-41.
47. **Thunthy, K. H., and R. Weinberg.** 1997. Film-screen systems: sensitometric comparison of Kodak Ektavision system to Kodak T-Mat/RA system. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **83:**288-92.
48. **Thunthy, K. H., and R. Weinberg.** 1995. Sensitometric comparison of Kodak EKTASPEED Plus, Ektaspeed, and Ultra-speed Dental Films. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **79:**114-6.
49. **Tsiklakis, K., C. Donta-Bakoyanni, M. Tassopoulou, and V. Kamenopoulou.** 2000. Absorbed radiation dose during lateral cephalometric radiography: comparison of screen-film systems and field-size combinations. J Clin Pediat Dent **24:**117-21.
50. **Visser, H., T. Rodig, and K. P. Hermann.** 2001. Dose reduction by direct-digital cephalometric radiography. Angle Orthodontist **71:**159-63.
51. **Wakoh, M., A. G. Farman, H. Kitagawa, K. Nishikawa, and K. Kuroyanagi.** 1998. A sensitometric comparison of Kodak Ektavision and Fuji Super HR-S panoramic radiographic films. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **86:**249-53.
52. **Wakoh, M., A. G. Farman, W. C. Scarfe, M. S. Kelly, and K. Kuroyanagi.** 1995. Perceptibility of defects in an aluminum test object: a comparison of the RVG-S and first generation VIXA systems with and without added niobium filtration. Dentomaxillofac Radiol **24:**211-4.
53. **Wakoh, M., K. Nishikawa, N. Kobayashi, A. G. Farman, and K. Kuroyanagi.** 2001. Sensitometric properties of Agfa Dentus OrthoLux, Agfa Dentus ST8G, and Kodak Ektavision panoramic radiographic film. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **91:**244-51.
54. **White, S. C., and B. M. Gratt.** 1991. Evaluation of Niobi-X filtration in intraoral radiology. Oral Surg Oral Med Oral Pathol **72:**746-755.
55. **White, S. C., E. W. Heslop, L. G. Hollender, K. M. Mosier, A. Ruprecht, M. K. Shrout, and American Academy of Oral Maxillofacial Radiology ad hoc Committee on Parameters of Care.** 2001. Parameters of radiologic care. An official report of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod **91:**498-511.
56. **White, S. C., and D. C. Yoon.** 2000. Comparison of sensitometric and diagnostic performance of two films. Compendium of Continuing Education in Dentistry (Jamesburg, NJ) **21:**530-2, 534, 536 passim.

5 Quality standards and quality assurance

The aim of this section is to demonstrate the key role of quality assurance in radiation protection.

The objectives are to describe:

- **The concept of a quality assurance programme**
- **Quality standards and quality targets**
- **Diagnostic reference levels for patient dose**
- **Maintenance and testing of X-ray equipment**
- **Quality control of image receptors and processing of images**
- **Common problems in dental radiography**

The purpose of Quality Assurance (QA) in dental radiology is to ensure consistently adequate diagnostic information, while radiation doses are controlled to be as low as reasonably achievable.

5.1 Quality assurance programme

A well-designed QA programme should be comprehensive but inexpensive to operate and maintain for the dentist and staff.

QA should address the following:

- Image quality assessment
- Practical radiographic technique
- Patient dose and X-ray equipment
- Darkroom, film, cassettes and processing

The QA programme should entail surveys and checks that are performed according to a regular timetable. A written log of this programme should be maintained by staff to ensure adherence to the programme and to raise its importance among staff. A specific person should be named as leader for the QA programme.

Recommendation 5 A

A radiological QA programme should be implemented by the Holder of the dental facility

ED

5.2 Image quality assessment

Ensuring radiographs of consistently acceptable quality is obviously of benefit to patient and dentist alike. However there is ample research evidence (refer to Tables 5.1.and 5.2) showing that image quality is often less than ideal in primary dental care (33, 42, 56, 66).

Table 5.1 Film fault frequency for intraoral radiography carried out within general dental practice.
References are cited in parentheses.

Type of films assessed (Total no.of films assessed within published studies)	No. of unacceptable films (% value and range if available)	Film faults (% frequency and range if available from published studies)							
		Apex missing	Apex obscured	Incorrect vertical angulation	Incorrect horizontal angulation	Film bending	Cone cutting	Positioning errors	Inadequate density and contrast
Bitewing radiographs (696)	45.2%(33)	N/A	N/A	1.8%(56)-4.3%(55)	2.0%(41).-8.0%(56)	1.8%(56)	1.4%(33)-41.3%(55)	2.0%(41).-54.3%(55)	3.0%(41)-54.3%(55)
Periapical radiographs (6849)	9.5%(35)-56.4%(41).	12.1%(33)-59.9%(35)	2.6%(26).-13.3%(50)	5.7%(56)-43.2%(55)	3.3%(33)-16.6%(56)	1.9%(55)-13.3%(50)	0.9%(50)-35.1%(55)	6.1%(50)-23%(26, 41).	10.3%(33)-32%(35)

Table 5.2 Film fault frequency within panoramic radiographs taken in general dental practice.
References are cited in parentheses.

Research studies Total no. of films assessed within published studies	No of unacceptable films and range of faults (%) from published studies	Film faults (% frequency and range if available from published studies)							
		Anterior / posterior positioning errors	Faults in density and contrast	Incorrect sagittal plane	Occlusal plan errors	Slumped patient position	Screen artefacts	Film fog	Foreign objects/ ghost shadows Poor film/ screen contact
2641	18.2%(30) - 33.0%)(52)	54.1%(52)	13.0%(25) - 40.2%(52)	24.0%(52)	21.9%(52)	9.0%(52)	5.2%(52)	3.8%(52) - 7% (25)	3.5%(52) 1.5%(25, 52)

Section 5.9 shows some common problems that may occur in dental radiography. It is essential that image quality be monitored on a regular basis. This should be done in two ways. First, the dentist at the chair side can be vigilant in examining radiographs as and when they are produced. To facilitate this, reference images of good quality can be kept available for comparative purposes. Second, the dentist and staff can conduct periodic audits of image quality. Clinical audit requires assessment against a clearly defined set of Quality Standards.

Image quality can be simply assessed as 'Excellent' (no faults), 'Acceptable' (some faults but not affecting image interpretation) and 'Unacceptable' (faults leading to the radiograph being unsuitable for interpretation). However, simply logging the proportions of radiographs in each category will not help in improving quality. An important step is to record the reasons for grading a radiograph as being of unacceptable quality. The Quality Standards given in Tables 5.3 to 5.6 provide a means of comparing radiographs against an ideal. Other standards, analogous to those described in EUR 16260 (7) may also have been developed. Audit may reveal errors that are recurring frequently and thus point towards essential changes in practice.

5.2.1 Targets for radiographic quality

Using the criteria given for film quality, the practitioner can implement a 'reject film analysis'. Assessment of rejected films allows the dentist to identify the cause of poor images.

Unacceptable films are those in which film quality departs significantly from the accepted Quality Standard, thereby, compromising or preventing diagnosis and, in more extreme cases, negating the purpose for which the film was taken.

There can be no tolerable level of 'unacceptable' radiographs. However, in the UK, a non-evidence based level 'not greater than 10%' for unacceptable films has been recommended as an achievable audit standard for primary dental care. This is an achievable target as rates of unacceptable films in hospital departments can be much lower (47). Obviously, as there will be wide inter-practitioner variation in the level of unacceptable films in primary dental care, a more realistic and achievable standard would be for each dentist to achieve a 50% reduction in unacceptable films at each subsequent audit session (46).

Recommendation 5B

As a minimum target, no greater than 10% of radiographs should be of unacceptable quality. The aim should be to reduce the proportion of unacceptable radiographs by 50% at each successive audit cycle.

C

Table 5.3 Quality standards for bitewing radiography

A: Evidence of optimal image geometry • There should be no evidence of bending of the image of the teeth. • There should be no foreshortening or elongation of the teeth. • Ideally, there should be **no horizontal overlap**. If overlap is present, it should not obscure more than one half the enamel thickness. This may be unavoidable due to anatomical factors (i.e. overcrowding, shape of dental arch) requiring an additional bitewing or a periapical radiograph.
B: Correct anatomical coverage • The film should cover the distal surfaces of the canine teeth and the mesial surfaces of the most posterior erupted teeth. • The periodontal bone level should be visible and equally imaged in the maxilla/mandible, confirming ideal centring.
C: Good density and contrast • There should be good density and adequate contrast between the enamel and the dentine.
D: Adequate number of films • When the third molars are erupted or partially erupted and impacted and all the other teeth are present, two films may be needed on each side to evaluate the dentition. • Extreme curvature of the arch may impact on the number of films required.
E: Adequate processing and darkroom techniques • No pressure marks on film, no emulsion scratches. • No roller marks (automatic processing only). • No evidence of film fog. • No chemical streaks/splashes/contamination. • No evidence of inadequate fixation/washing.
F: Other • If the patient clinically exhibits periodontal bone loss of >6 mm, two vertically positioned films (i.e. with the narrower length positioned parallel to the floor of the mouth) are required to enable the bone of the periodontium to be imaged. • Access to previous radiographs may reveal the need for vertical bitewings.

Table 5.4 Quality standards for periapical radiography

A: Evidence of optimal image geometry • There should be no evidence of bending of the teeth and the periapical region of interest on the image. • There should be no foreshortening or elongation of the teeth. • Ideally, there should be **no horizontal overlap**. If overlap is present, it must not obscure pulp/root canals.
B: Correct anatomical coverage • The film should demonstrate all the tooth/teeth of interest (i.e. crown and root[s]). • There should be 2-3 mm of periapical bone visible to enable an assessment of apical anatomy.
C: Good density and contrast • There should be good density and adequate contrast between the enamel and the dentine.
D: Adequate number of films • In endodontic treatment, it may be necessary to separate superimposed root canals using two radiographs at different horizontal angles. Obtain one 'normal' film and one with a 20° oblique horizontal beam angle for all molars and maxillary first premolars. • Assessment of some horizontally impacted mandibular third molars may require two films to image the apex. Obtain one 'normal' film and one with a more posterior 20° oblique horizontal beam angle.
E: Adequate processing and darkroom techniques • No pressure marks on film, no emulsion scratches. • No roller marks (automatic processing only). • No evidence of film fog. • No chemical streaks/splashes/contamination. • No evidence of inadequate fixation/washing.

Table 5.5 Quality standards for panoramic radiography

A: Patient preparation/ instruction adequate • Edge to edge incisors. • No removable metallic foreign bodies (e.g. earrings, spectacles, dentures). • No motion artefacts. • Tongue against roof of mouth. • Minimisation of spine shadow.
B: No patient positioning errors • No antero-posterior positioning errors (equal vertical and horizontal magnification). • No mid sagittal plane positioning errors (symmetrical magnification). • No occlusal plane positioning errors. • Correct positioning of spinal column.
C: Correct anatomical coverage • Appropriate coverage depending upon the clinical application. Field size limitation should have been used (if available) to exclude structures irrelevant to clinical needs (e.g. limitation of field to teeth and alveolar bone for everyday dental use).
D: Good density and contrast • There should be good density and adequate contrast between the enamel and the dentine.
E: No cassette/ screen problems • No light leaks. • Good film/screen contact. • Clean screens.
F: Adequate processing and darkroom techniques • No pressure marks on film, no emulsion scratches. • No roller marks (automatic processing only). • No evidence of film fog. • No chemical streaks/splashes/contamination. • No evidence of inadequate fixation/washing. • Name/date/left or right marker all legible.

Table 5.6: Quality standards for cephalometric radiography

A: Patient preparation/ instruction adequate • Frankfort plane perpendicular to film. • No sagittal plane positioning errors. • No occlusal plane positioning errors • Teeth in centric occlusion (stable and natural intercuspation). • Lips relaxed.
B: No patient positioning errors • No antero-posterior positioning errors. • No mid sagittal plane positioning errors. • No occlusal plane positioning errors. • Exact matching of external auditory meati with positioning devices.
C: Correct anatomical coverage • Visibility of all cephalometric tracing points required for the analysis. • Visibility of all anterior skeletal and soft tissue structures.
D: Good density and contrast
E: No cassette/ screen problems • No light leaks. • Good film/screen contact. • Clean screens.
F: Adequate processing and darkroom techniques • No evidence of film fog. • No evidence of chemical streaks/contamination. • No evidence of inadequate fixation /washing. • No evidence of screen damage/artifacts. • No roller marks/pressure marks. • Name and date legible.

5.3 Practical radiographic technique

5.3.1 Intraoral radiography

Section 6.9 shows some common problems in intraoral radiography. A parallel X-ray beam directed perpendicular to both the object being examined and the film provides the best imaging geometry. This can be achieved for the common intraoral radiographic projections using:

- X-ray set with a 'long' open-ended PID
- Film holder with a beam-aiming device

The X-ray focus to skin distance should be at least 200 mm. This means that the X-ray beam is closer to parallelism than was seen with older X-ray sets using shorter distances. The film holder itself should incorporate three key components:

- Bite block
- Rigid backing to support the film
- Extra-oral beam aiming device

The bite block helps to maintain correct film position relative to the teeth. The rigid backing limits the risk of film bending and resultant image distortion. The beam-aiming device ensures the ideal of a beam that is perpendicular to the film.

5.3.2 The paralleling technique

The paralleling technique requires that the X-ray film is positioned parallel with the long axes of the teeth. The central ray of the X-ray beam passes at right angles, i.e. perpendicular, to the tooth being imaged.
In order to minimize magnification of the image and subsequent loss of image sharpness, the technique uses an increased focal spot-to-object distance ensuring a more parallel X-ray beam is incident to the object and image receptor.

5.3.2.1 Advantages of the paralleling technique

Adopting the paralleling technique has many benefits for both the operator and patient:

- Minimal elongation/foreshortening/distortion
- An increased FSD reduces surface dose
- An increased FSD improves image quality by reducing the penumbra effect
- Reduction in distortional effects due to bending of the film/image receptor

The use of the paralleling technique along with film holding beam alignment instruments allows the operator to obtain images that have reproducibility and standardisation. This allows the clinician to study longitudinal disease progression and to assess accurately treatment outcomes (50).

Recommendation 5 C

Film holders incorporating beam-aiming devices using the paralleling technique and facilitating rectangular collimation should be used for intraoral radiography wherever possible.

5.3.3 Panoramic radiography

Research shows that patient positioning errors are frequent in carrying out panoramic radiography in primary dental care (25, 30, 52).

It is extremely important that dentists understand how their panoramic equipment works and that they can effectively 'trouble-shoot' problems. Section 5.9 shows some common errors of positioning and technique in panoramic radiography. Technique is facilitated when equipment incorporates patient positioning aids and uses light beams.

Recommendation 5 D

Accurate positioning in panoramic radiography can be facilitated by using all available positioning aids correctly and by adequate training of users. When buying new equipment it is important to ensure that light beam positioning aids are included.

5.3.4 Cephalometric radiography

It is intrinsic to the purposes of cephalometric radiography that images are reproducible. This requires a fixed X-ray source/patient/image receptor relationship. It is unacceptable to perform cephalometric radiography without a cephalostat to fix head position. Most dentists working in primary dental care would use an integrated panoramic/cephalometric radiographic system. However, some may use a dental X-ray set as the source. The large distance of patient to X-ray source required in cephalometry, is such that using an unmodified dental X-ray set would lead to an unacceptably large X-ray field and excessive radiation dose. Therefore, dental X-ray equipment must be suitably modified to ensure correct collimation and alignment bydirect involvement of a medical physics expert.

Recommendation 5 E

A cephalostat and a fixed X-ray source/patient/image receptor relationship should be used for cephalometric radiography.

Visualisation of the soft tissue profile is needed on cephalometric radiographs. This can be done either by using a suitable wedge filter in front of the patient (preferred option from a dose reduction standpoint) or cassette, or by fitting graduated intensifying screens within the film cassette.

5.4 Patient dose and X-ray equipment - Diagnostic Reference Levels

An objective of the QA programme is to ensure doses are kept as low as reasonably achievable. It is, therefore necessary to ensure that patient doses are monitored on a regular basis.

Diagnostic Reference Levels (DRLs) are patient dose levels for medical diagnostic exposure that can be used as investigation levels as part of this optimisation process. The International Commission on Radiological Protection (ICRP) first introduced the term diagnostic reference level in 1996 (13) and has produced further advice (15). The requirement for DRLs has been included within the European Medical Exposures Directive (3) and the EC has produced further guidance on the setting of DRLs (5).

Essentially, the aim of DRLs is to provide reference levels of easily measurable patient dose quantities for facilities to compare their average doses against. DRLs are not intended to be applied to individual exposures of individual patients (5). They can be set at a range of levels, i.e. European, national, regional, or local level. The intention is to indicate an upper level of acceptability for current normal radiological practice. The use of DRLs is *"a simple means of identifying those situations well away from the optimum where corrective action is most urgently needed"* (61).

Having an average dose below a relevant DRL gives some confirmation that patient doses in a particular facility are reasonably in line with other facilities. It does not necessarily indicate that dose is optimised. However, doses consistently above a DRL would definitely indicate that patient dose is not in line with the ALARA principle and that action should be taken to reduce dose.

The concept of DRLs is now well established within general hospital radiology. The most usual method of setting a DRL is to base it on the third quartile of field measurements performed in a large number of establishments (5, 21, 62). Consequently, DRLs are based on current practice across a wide range of different establishment, not on results from a select group of facilities with a high level of equipment and expertise.

European wide DRLs have not, so far, been promulgated for dental projections, although some European countries have established national dental DRLs (or equivalent) (22, 36, 45).

5.4.1 Intraoral

5.4.1.1 Dose quantities

The majority of surveys of patient dose in intraoral film radiography have measured the dose in air or tissue at the end of the spacer cone (usually referred to as entrance surface dose (ESD) although often it is an

underestimate as backscatter from within the head is not always included). This is a relatively simple measure, readily performed by a medical physics expert (MPE). The MPE might visit the practice to perform the measurement using some form of electronic dosemeter, alternatively either a film or thermoluminescent device dosemeter (TLD) package can be provided by post for exposure by the dental practice staff. Germany (36) currently requires the measurement of dose at depth. Whilst being a better indicator of effective dose than entrance dose, this will not pick up the significant difference in skin dose caused by using low kV equipment.

5.4.1.2 European data

A summary of dose surveys and current national DRLs for European and North American data is given in table 5.7. It is evident that a wide variation in dose exists from practice to practice, with many surveys recording ESD at individual practices above 20 mGy. The distributions of the results tend to be skewed with just a few outliers at the higher doses (31, 37, 45).

It can be seen that the mean levels tend to be lower for the most recently performed surveys, probably reflecting the change from D- to E-speed film and the greater use of 60-70 kV X-ray equipment.

5.4.1.3 Suggested values

The majority of patient intraoral dose surveys have been in terms of cone end dose, measured in air, for average adult settings. Unfortunately, a range of projections has been chosen. The UK data is by far the most comprehensive survey of actual practice in Europe and the recommended DRL has been based on this. At this stage it is not suggested that the lower value currently being promoted within the UK be adopted as it is clear that within Europe there is significant variation in practice; for example the Danish, Greek and Portuguese surveys also encompassed a significant number of X-ray sets and indicate higher levels within these countries.

Recommendation 5 F

The Medical Directive requires the establishment of DRLs.
The working party recommends a DRL of 4 mGy absorbed dose in air measured at the end of the spacer cone for a standard maxillary molar projection.

5.4.2 Digital equipment

Intraoral digital detectors are generally capable of operating optimally at lower doses compared with film (see Section 4.4.3.) DRLs derived from survey of practices using film will be higher than those achievable using digital radiography. When individual practices using digital sensors compare doses to European or national DRLs, the expected difference between film and digital sensor should be borne in mind.

Digital detectors, in particular phosphor plate systems, have very large latitude. Higher doses than necessary may be used without the operator being warned by a dark image (29). For this reason, it is of particular

Table 5.7: Summary of surveys of intraoral dose quantities and DRLs.

Country/ date of publication	Results of survey	Proposed/set DRLs or investigation levels	Ref
USA draft		Bitewing ESD in air: • 70 kVp, E-speed: 2.30 mGy • 70 kVp, D-speed: 3.50 mGy	(21)
UK draft	See UK 1999 below	Mandibular molar cone end dose: • 2.1 mGy	(12)
Luxembourg 2001		ESD for maxillary molar: • Investigation level >4 mGy • Suspension level >6 mGy	(22)
Spain 2001	ESD (average for all projections): • Mean 2.89 mGy • Third quartile 3.37 mGy	ESD: • 3.5 mGy	(34)
Finland 2000	Molar ESD: • Mean 3.5 mGy • Range 0.8-16.4 mGy		(32)
Finland 1999		ESD: • <7 mGy for any intraoral film • <3.5 mGy E-speed film and any digital system	(24)
UK 1999	Mandibular molar cone end dose: • Mean 3.3 mGy • Range 0.14 – 45.7 mGy • Third quartile 3.9 mGy For subgroup using 60-70 kV and E-speed film: • Third quartile 2.1 mGy	Mandibular molar cone end dose: • 4 mGy	(45)
Greece 1998	ESD (for mean exposure times): • 71%<5 mGy • 10%>10 mGy		(65)
Greece 1998	ESD for periapical: • Mean 6.9 mGy • Range 0.6-37 mGy D-speed: • Mean: 8.7 mGy E-speed: • Mean: 5.8 mGy		(57)
Luxembourg 1997	Cone end dose for maxillar molar: • Mean 3.2 mGy • Third quartile 3.8 mGy		(36)
IAEA 1996		Periapical ESD: • 7mGy	(14)
Denmark 1995	Cone end dose mandibular incisor: D-speed: • Mean 4.9 mGy • Third quartile 6.3 mGy E-speed: • Mean 3.2 mGy • Third quartile 3.5 mGy		(58)

Table 5.7 continued:

Country/ date of publication	Results of survey	Proposed/set DRLs or investigation levels	Ref
Portugal 1992	Cone end dose: • Posterior 1.63 mGy • Periapical 8.03 mGy		(53)
Portugal 1992	ESD for mandibular molar: • Mean 9.2 mGy • Median 6.3 mGy		(31)
New Zealand 1990	Cone end dose for bitewing Mean values for: • All kVs: 4.52 mGy, max >20 • 45-55 kV: 7.1 mGy • 60-70 kV: 4.0 mGy		(64)
France 1989	Range of projections: • Mean doses varied from 3.9-13.5 mGy Mandibular molar: • Mean 4.7 mGy		(27)
Holland 1989	• Mean 5.8 mGy • Range 0.7-43.2 mGy		(59)
Finland 1988	Cone end dose for bitewing projection: • Mean 6.2 mGy • Range 0.5-151 mGy		(40)

Table 5.8: Summary of surveys of panoramic dose quantities and DRLs.

Country/ date of publication	Results of survey	Proposed/set DRLs	Ref
Spain 2001	Occipital ESD: • Mean 0.53 mGy • Range 0.25-0.87 mGy • Third quartile 0.66 mGy	Occipital ESD: • 0.7 mGy	(34)
Finland 2000	DAP: • Mean 94 mGy cm^2 • Range 34-254 mGy cm^2		(32)
UK 1999	Dose-width product: • Mean 57.4 mGy mm • Range 1.7 – 328 mGy mm, Third quartile 66.7 mGy mm	Dose-width product: • 65 mGy mm	(45)
UK 2000	DAP: • Mean 11.3 cGy cm^2 Dose width product: • Mean 65.2 mGy mm • Third quartile 75.8 mGy mm		(63)

Table 5.9: Summary of surveys of cephalometric dose quantities and DRLs.

Country Date of publication	Results of survey	Proposed/set DRLs	Ref
USA draft		ESD in air: • 0.25mGy	(21)
UK 2002	Skull AP/PA: • Mean 2.3mGy • Third quartile 2.8 mGy Skull lat: • Mean 1.2 mGy • Thirdquartile 1.6 mGy	Skull AP/PA: • 3 mGy Skull lat: • 1.5mGy	(38)
EU 1999		Skull AP/PA: • 5 mGy Skull lat: • 3 mGy	(7)
Portugal 1992	Skull lat: • 7.2 mGy		(53)

importance that users of digital detectors monitor dose levels to provide continued assurance that they are being used optimally.

5.4.3 Panoramic radiography

5.4.3.1 Dose quantities

The establishment of DRLs for panoramic radiography is not as well developed as for intraoral film radiography. The UK have adopted the concept of dose width product i.e. the maximum dose at the film cassette slit multiplied by the width of the beam at the slit (45) measured without a patient. However, the methodology has not been well defined and significant differences in results occur due to the different measurement methods adopted (63). This will be particularly true for the newer panoramic units with narrow slits and a non-uniform dose profile across the slit. Other approaches suggested have been to use the product of dose and beam area as measured by a dose area product (DAP) meter or TLD stack (63) or to perform surface dose measurements on patients (34). This latter approach is thought to be of limited value as the surface dose distribution varies widely dependent of the type of panoramic unit in use (44) and will not give a good representation of the distribution of depth dose within the head.

5.4.3.2 European data

A summary of the dose surveys for panoramic radiography is given in Table 5.8. This indicates a scarcity of data and no clear agreement on approach. The working party feels unable to recommend a DRL at this stage.

Recommendation 5 G

The working party recommends that further work be carried out on establishing a measurement method (probably adopting the DAP approach) for panoramic dosemetry and to undertake further field measurements so that a European DRL can be adopted.

5.4.4 Cephalometry (teleradiography)

5.4.4.1 Dose quantities

Although a European DRL does exist for both PA and lateral skull radiography using ESD measurements (5), specific DRLs for cephalometry have yet to be established. Limited survey data exists for cephalometry as indicated in Table 5.9. Given the absence of the anti-scatter grid and the longer FFD employed in cephalometry, it is likely that any entrance surface dose would be lower than for skull radiography (usual FFD of 1 m). Differences might also be expected due to different contrast requirement requiring different kV selection. Finally, it is normally considered good practice to limit the field for cephalometry (see Section 4.3.3.). Although this will make little difference to

the ESD, a measurement of DAP would be a better indicator of dose optimisation and would be preferred for use as a DRL.

Recommendation 5 H

The working party recommends that dose surveys be undertaken within Europe using both ESD and DAP to facilitate the setting of a European DRL for standard cephalometry projections.

5.4.5 Using DRLs

Dentists should be aware how their average doses compare with the European and any national DRLs. It is not expected that dental practices will have the facilities to be able to assess this themselves and so will require the services of a medical physics expert. These assessments should be carried out on a regular basis, at least every 3 years or as required by national legislation.

These measurements can be seen to be a part of any QA programme adopted by the dental practice. Results above established DRLs should be investigated, again with the help of a medical physics expert, and any resultant recommendations should be implemented.

Recommendation 5 I

It is recommended that dentists arrange to audit their doses for comparison with European/National DRLs.

5.5 Dental X-ray equipment

This section relates to the maintenance and testing of dental radiology equipment.

Dental X-ray equipment should be designed, constructed and installed to be in compliance with recognised European standards pertaining to all aspects of equipment safety (e.g. electrical, mechanical and radiation protection (18)). It must meet the relevant essential requirements for safety and performance of the Medical Devices Directive (17). All products that fall within the scope of the Directive must meet certain essential safety and administrative requirements and are to be CE marked to show that they comply. Such products may then be freely sold throughout the EU without being subject to additional national regulations. It is required that suppliers, erectors or installers of dental X-ray equipment provide adequate information pertinent to

the proper use, testing and maintenance of the equipment. In some member states there maybe further requirements relating to the supply of X-ray equipment.

In addition, the European Council Directives (2, 3) covering the use of ionising radiation (see Chapter 1), place requirements on equipment owners to ensure equipment is tested so that the safety of both staff using the equipment and patients undergoing diagnosis is optimised. The overall aim being to ensure that dose to both staff and patients is kept as low as reasonably achievable.

5.5.1. Maintenance and testing

It is essential that the features of dental X-ray equipment pertaining to the radiation safety of both users and patients be correctly maintained. To ensure this, the equipment needs to be in good mechanical and electrical order. Regular maintenance and associated checks should be performed in accordance with the recommendations of the manufacturer, the supplier, and the qualified expert/medical physics expert. As well as the actual X-ray equipment, it should be remembered that automatic processors should be subject to a regular maintenance programme to ensure that they are operating optimally as this has a direct effect on patient dose.

Dental X-ray equipment should be subject to the following inspections/tests (2, 3):

- Critical examination of plans for installation from the point of view of radiation safety of staff and members of the public (2)
- Acceptance test – performed prior to the equipment's use in clinical practice (2, 3)
- Routine tests – these should be performed at regular intervals and following any significant maintenance procedure (2, 3)

The exact arrangements for carrying out these tests on dental X-ray equipment and the criteria for remedial action vary from country to country within the EU dependent on local legislative requirements and guidance. Qualified experts or medical physics experts should normally be involved. European criteria of acceptability have been established for intraoral radiography units and it is also recommended that the European criteria for general radiographic units can be applied to cephalometric units (4). In general, there is a significant level of agreement with regard to the main features to be tested and criteria of acceptability (1, 11, 19, 20, 23, 24).

5.5.2. Critical examination

The plans for the installation of a dental X-ray set should be critically reviewed by a qualified expert (or other approved body dependent on local arrangements) to ensure that all aspects of radiation safety for both practice staff and members of the public have been considered (see Chapter 6). In particular, the following aspects need evaluation(11):

- Location, with particular attention to the points outlined in Chapter 6
- Protection provided to adjacent areas
- The operator's position

- The room's warning signals, if appropriate
- The equipment's warning signals
    - There should be a functioning indicator light on the control panel to show that the mains is switched on indicating that the equipment is in a state of readiness to emit radiation.
    - A warning light must be fitted to the equipment that provides a clear and visible indication to the operator that an exposure is taking place. This should be triggered only when there is to be a commencement and termination of radiation emission.
- The exposure control
    - If more than one X-ray set is sited in the same room, it should not be possible for an operator either to inadvertently energise the incorrect X-ray set or to accidentally cause irradiation to persons in another part of the room. If the arrangement is such that from a single location it is possible to start the production of X-rays from more than one X-ray tube, then it is advised that each tube be fitted with a warning light that operates to alert that the tube is selected to emit X-rays.
- Corroboration of adequate equipment radiation protection and safety features (e.g. beam dimensions and alignment, beam filtration and timer operation)
- Any other safety systems fitted on the equipment (e.g. safety cut-out switches on panoramic equipment). This should also include all mechanical and electrical systems whose malfunction could affect radiation safety (e.g. rotational movement and braking on panoramic equipment, suitable counterbalance mechanisms on arms supporting intra-oral X-ray tubes)

5.5.3. Acceptance test

Prior to the equipment being introduced into clinical use, an acceptance test should be carried out (2, 3) . The essential content of the acceptance test is the same as for the critical examination. In addition, it should determine that the equipment operates properly within agreed performance parameters (e.g. operating potential, X-ray output, timer, accuracy) and provide baseline data for comparison against during routine testing throughout the life of the equipment.

The acceptance test should also consist of measurements to assess typical patient doses. It is advised that a representative patient dose be calculated and compared with an appropriate European, national or local DRL (see Section 5.4).

Tests of equipment function should be carried out in a consistent manner, methods being based on international (8-10) and national guidance (54).

Recommendation 5 J

All new installations should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal.

5.5.4. Routine tests

Routine tests should be performed at designated intervals and following any significant maintenance procedure. Ideally, this should be performed at least every three years (11, 20) and is often a more frequent regulatory requirement (1, 19, 23).

Annual testing should always be considered if:

- The assessed typical patient dose exceeds the DRL (see Section 5.4)
- Image quality is routinely poor (see Section 5.2)
- The QA programme indicates a significant performance weakness

Annual intervals should be maintained until full confidence is restored that acceptable performance is being maintained. The data collected should be retained as a permanent record for comparison with subsequent tests. This will form part of the QA Programme.

A routine test is essentially the same in content as the acceptance test above, but with a different emphasis. The intention is to establish that the equipment continues to operate optimally with respect to staff and patient safety as determined at the acceptance test. Hence, it will only be necessary to confirm that there have been no significant changes to the equipment's location and its function. Comparison should be made to the baseline data established during the acceptance test. It will be necessary to recognize and further examine any trends that indicate possible deterioration. Recommendations should be made to rectify any identified deficiencies. These should be followed up and the outcomes recorded within the QA Programme.

Routine tests should cover all mechanical and electrical systems whose malfunction could result in inadvertent radiation exposure. A record of maintenance, including any defects found and their repair should be kept for each item of X-ray equipment. Following maintenance the engineer should provide a satisfactory written report prior to the equipment being used once more for clinical practice. Any maintenance logs should be up-to-date and form part of the QA programme.

Recommendation 5 K

All dental X-ray equipment should undergo regular routine tests to ensure that radiation protection, for both practice users and patients, has not significantly deteriorated.

5.5.5. Assessment of representative patient doses

At specified intervals, measurements should be performed to assess representative patient doses (see Section 5.4). It is very important to take effective action to reduce patient doses that consistently exceed any established DRLs.

5.6. Darkroom, film, cassettes and processing

5.6.1 Darkroom and desktop processing units

Routine checks should be made to ensure that darkrooms remain light tight and that safelights do not produce fogging of films. Desktop units should be similarly checked for light-tightness. This can be done using a simple 'coin' test. Routine checks should be carried out every 12 months or if any alterations to darkroom or equipment have been performed. A written log of such checks helps in maintaining the QA programme.

5.6.2. Film

The quality of radiographs can be reduced by inadequate storage of film. The manufacturers will lay down the QA standards. Poor storage e.g. at excessive temperature, in close proximity to X-ray equipment or poor handling can all lead to artefacts. Film should not be used after its expiry date and the QA programme should include stock control measures.

5.6.3 Cassettes

For extraoral radiography cassettes incorporating intensifying screens are used. The cassettes may become damaged leading to light leaks and poor film/screen contact. It is important to recognise the faults that these produce and to check on cassettes as part of the QA programme.

The intensifying screens must be clean and undamaged to maintain good image quality. 'Screen artefacts' are very common. To combat these, screens should be protected by keeping the cassette closed, except when loading or unloading films. The screens should be cleaned using the appropriate screen cleaner on a regular regime detailed in the QA programme.

5.6.4. Processing

Inadequate processing always compromises diagnostic information. QA standards will be laid down by manufacturers of processing solutions and equipment and will include:

- Processing conditions (time and temperatures)
- Changing frequency for processing solutions
- Cleaning instructions for automatic processors

The QA programme should ensure that these standards are adhered to by means of:

- Records to control and validate the chemical changes
- Cleaning procedures for automatic processors

The overall performance of the processing also needs to be monitored. One of the simplest means of achieving this is with the use of a test object such as a step wedge (49, 51). This object is routinely radiographed, always using the same exposure parameters. A simple visual comparison between the resultant image and a reference film can detect variations in processing quality before they affect patient films. Such checks should be made at least after every change of processing solutions to ensure that conditions are satisfactory before patients' films are processed. More frequent checks are preferable (every 2-3 days), to ensure consistent processing. Fluctuations in X-ray equipment output will also manifest as an alteration in step wedge densities. If changes occur in the absence of any identifiable processing problems then an equipment fault should be considered.

Recommendation 5 L

A QA system for monitoring darkroom and processing conditions should be instituted in each dental facility. As a minimum:

- The temperature of the developer should be checked prior to film processing and the development time adjusted in accordance.
- For automatic processing, the processor should be properly cleaned and maintained.
- Processing solutions should be changed at regular intervals as indicated by routine monitoring tests.

5.6.5. Digital systems and quality control

Errors in film positioning and beam alignment are similar to those discussed for conventional film based radiography (see elsewhere in this chapter). The size of the digital sensor and the lack of flexibility, specially in case of a solid state sensor, can make the positioning more difficult, and therefore more prone to misalignment and the need for retakes (28, 43, 60)

Solid-state sensors (CCD, CMOS) are protected inside a plastic casing. This protects the sensor surface against damage. PSP sensors on the other hand, are much more vulnerable to scratches of the phosphor layer. These are visible as white lines and spots in the image when the plate has been read. Small scratches may mimic radiopaque objects such as endodontic fillings. Plates that are damaged should be replaced.

Plates should not be kept in the protective envelope for a long period before being used. Cosmic radiation will reach the phosphor surface and transfer energy to electrons. This will result in 'noise' visible in the final image as black spots. After the plates are exposed, they should be read as soon as possible. When the plates are kept for a longer, especially when they are exposed to ambient light, the latent image will fade and the resulting image will lack contrast and be noisier.

An important fact in the use of digital images is the quality of the monitor. The monitor should have enough resolution to accommodate the current size of digital images. A resolution of 1024 x 768 pixels is the minimum, but larger is preferable. In order to show the details at a magnification that is not too difficult to interpret, the screen size of the monitor should be at least 17 inch for a conventional monitor and 15 inch for a flat panel monitor. The gray level resolution of the monitor should be set to at least 'High Colour' (16 bit), in order to display small contrasts. Finally, brightness and contrast should be checked and adjusted so that all gray values between black and white are displayed correctly. A method of back up for image data should be available and used. If a dentist refers patients to colleagues, a means should be available to transfer the digital image (electronic transfer or hard-copy facility).

5.6.6. Viewing and reporting the radiograph

Ideal viewing conditions are essential in order to obtain maximum diagnostic information yield from the radiograph. This requires the use a dental light box positioned well away from strong ambient light, the peripheral masking of films to eliminate extraneous light and a method of magnifying the image by a factor of two. Commercially available film viewers are available which combine peripheral masking and magnification. Research has shown that use of dedicated viewing conditions considerably improve diagnostic interpretation and yield (48). Performance levels and operating parameters for illuminators have been set and should be observed (16, 39). While checks on the light output of viewing boxes is probably beyond the means of dental practices, routine cleaning of the viewing surface should be part of routine quality procedures.

All radiographs must be evaluated by the dentist and an appropriate report on the radiological findings made. This reporting of films is also amenable to audit.

5.7 Training

All those involved in radiology in dentistry should have received training that is adequate for their particular role. The roles can be divided into:

- *The Holder*: the person with legal responsibility under national law for a given installation.
- *The Practitioner*: The dentist (or other health professional) who is entitled to take responsibility for an individual medical exposure in accordance with national requirements.

- *The Prescriber*: A dentist (or other health professional) who is entitled to refer an individual to a Practitioner for medical exposure in accordance with national requirements.
- *Medical Physics Expert*: An expert in radiation physics or radiation technology applied to exposure whose training and competence to act is recognised by the competent authorities and who acts or gives advice on matters related to radiation protection.
- *Operators*: Health professionals who are entitled in accordance with national requirements to play a part in medical exposures (for example by performing radiography under the supervision of a Practitioner). Ancillary staff may carry out supporting duties such as processing of radiographs or aspects of QA.

Clearly, not all these roles require the same level of training, but each should have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection appropriate to dental radiography.

Continuing education and training after qualification is required. In the special case of new techniques, for example when a dentist buys a new type of equipment or changes to using digital radiography, specific training should be sought.

5.7.1 Procedures

All individuals involved in radiology should work according to specific procedures as detailed in Directive 97/43 Euratom of June 1997 (3, 6).

Recommendation 5 M

All those involved in radiography should have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection. Continuing education and training after qualification is required, particularly when new equipment or techniques are adopted.

ED

5.8. Quality assurance audit

Each procedure within the QA programme includes a requirement for records to be made by the responsible person (dentist, assistant) at varying intervals. The person with overall responsibility for the QA programme should check the full programme at intervals not exceeding 12 months. This is essential to demonstrate effective implementation of the programme.

Recommendation 5 N

The person responsible for the QA programme should make an audit of the programme at intervals not exceeding 12 months.

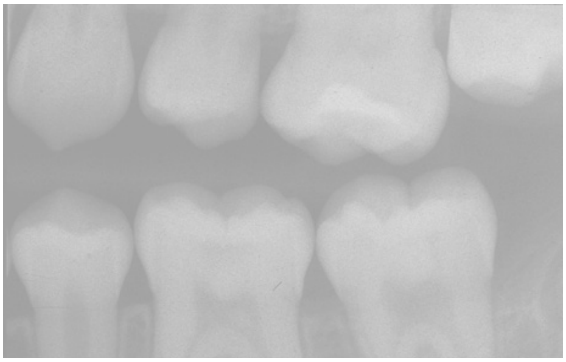
C

5.9. Common problems in radiography

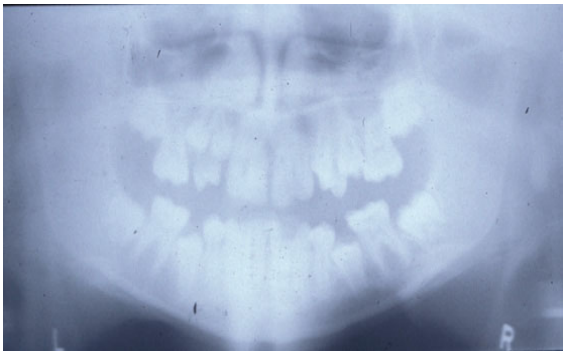
5.9.1. *All radiographs*

5.9.1.1 Low density and contrast

A

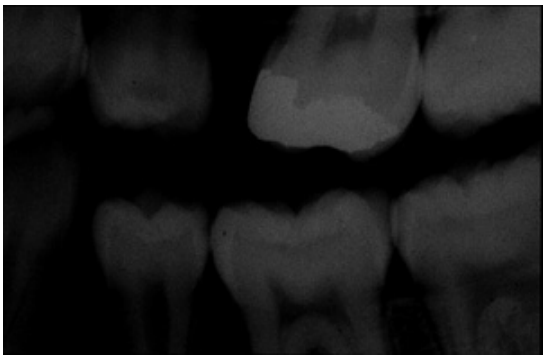


B



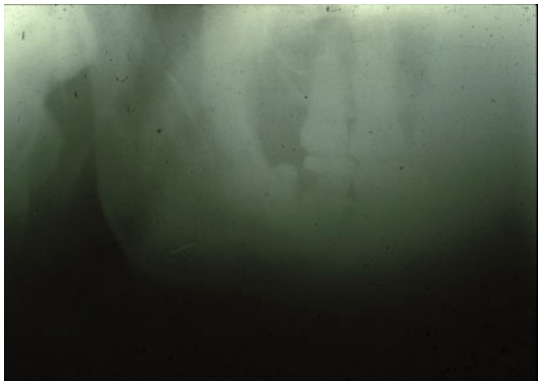
Cause: Under-development: developer temperature too low, film development too short; solutions dilute or exhausted (A). or, underexposure to X-rays (B).
Effect: Difficulty in visualising fine detail; caries less easily detected.

5.9.1.2. High density



Cause: Over-development: developer temperature too high, film development too long, solutions too concentrated or overexposure to X-rays
Effect: Difficulty in visualising fine detail; caries less easily detected.

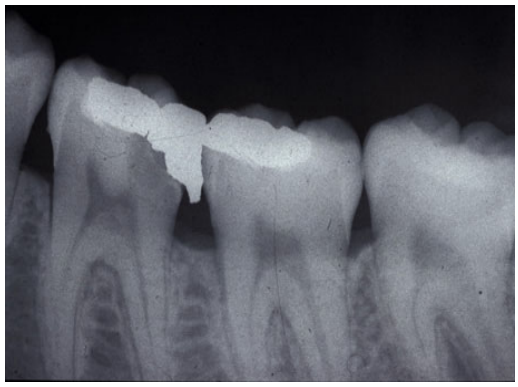
5.9.1.3. Fogging



Cause: Old film stock, poor film storage conditions, darkroom leaking white light or inadequate safelights, high developer temperature, under fixation (milky-pale surface).
Effect: Difficulty in visualising fine detail; caries less easily detected.

5.9.2 Intraoral radiographs

5.9.2.1 Film position



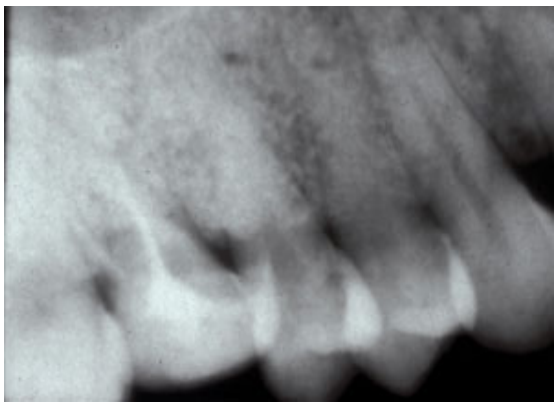
Cause: Incorrect initial placement, or shifting of the film from position before exposure.
Effect: Loss from the image of the area of interest; in this case, loss of the root apices and periapical region.

5.9.2.2. X-ray beam position

Cause: Incorrect alignment of the X-ray beam with the film.

Effect: Parts of the film receive no exposure (blank) with the edge of the X-ray beam visible ('coning off').

5.9.2.3. Overlapping

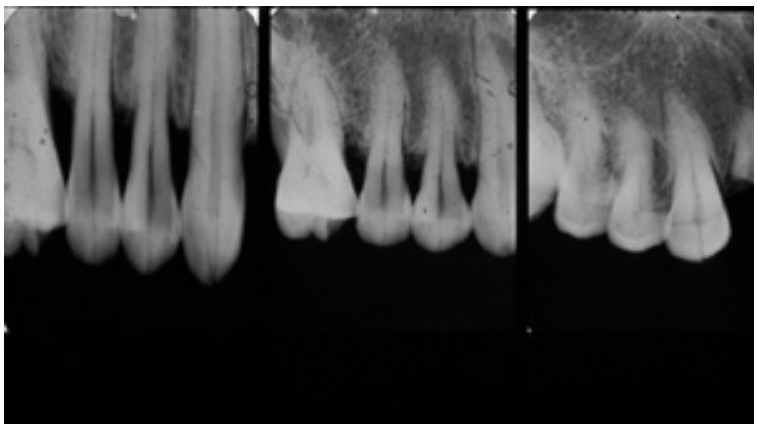


Cause: Incorrect X-ray beam angulation.
Effect: Superimposition of crowns and roots of adjacent teeth.

5.9.2.4. Distortion

A

B

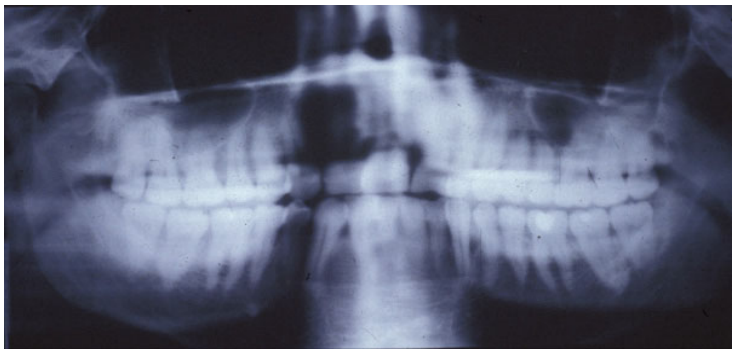


Cause: Bending of the film, or incorrect vertical X-ray beam angulation.
Effect: If the film is bent (not completely flat) the image periphery will be distorted and 'stretched out' (A). If there is a vertical X-ray beam angulation fault the result is either elongation or foreshortening of the image (B).

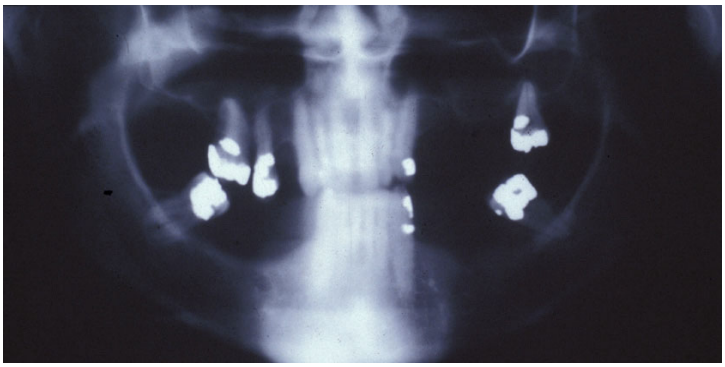
5.9.3 Panoramic radiographs

5.9.3.1. Positioning errors

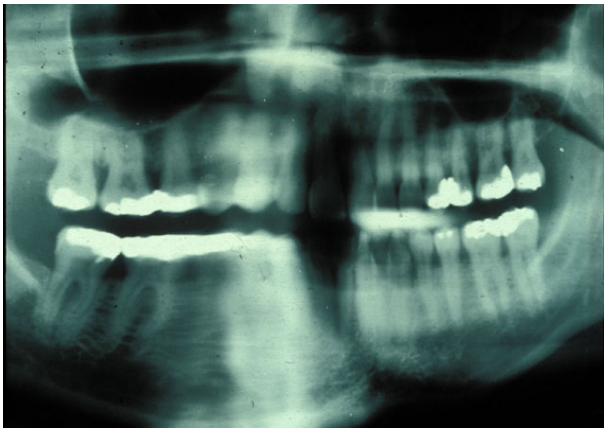
A



B



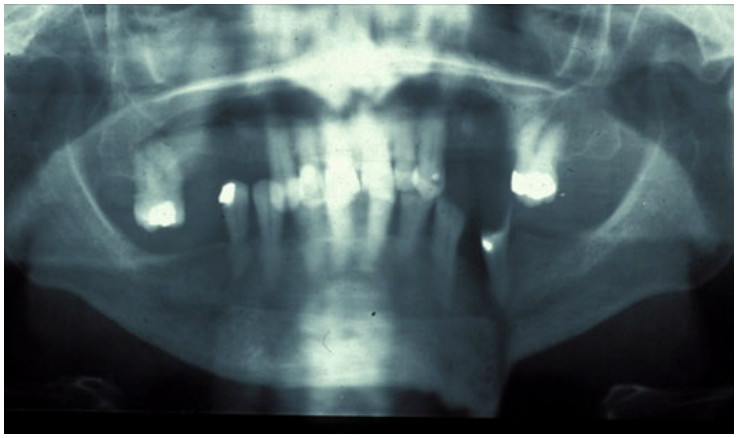
C



Cause: Incorrect patient position relative to the image layer (focal plane) of the X-ray machine. This is usually due to failure to correctly use the positioning aids on the X-ray machine.
Effect: Depends upon the position. If the patient is positioned behind the image layer (too far back in the machine) the anterior teeth are magnified horizontally (A). If the patient is positioned anterior to the image layer (too far

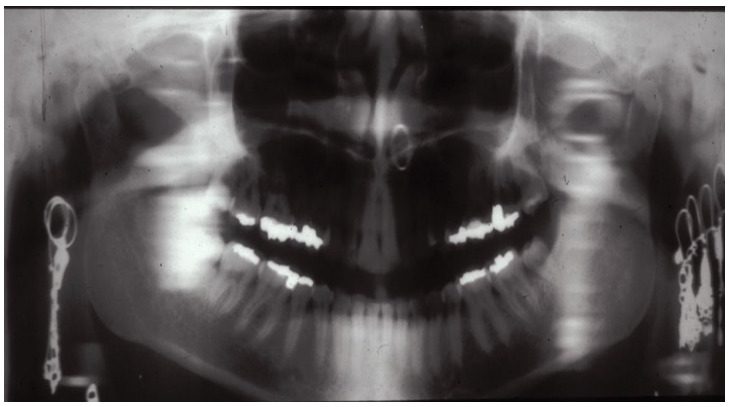
forward in the machine) the anterior teeth are become narrow (B). A ‘twisted’ position results in asymmetry in size between right and left sides (C).

5.9.3.2. Movement



Cause: Patient moves during the exposure.
Effect: Irregular outline to the mandible. Localised narrowing or magnification of teeth. Vertical bands of increased or decreased density.

5.9.3.3. *Secondary images*



Cause: Retained metallic objects, most importantly earrings or objects around the ear region (hairclips, hearing aids).
Effect: Radiopaque images overlying the posterior teeth.

5.10 References

1. 1996. Code of practice for radiological protection in dentistry. Radiological Protection Institute of Ireland.
2. 1996. Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health workers and the general public against the dangers arising from ionizing radiation.
3. Council Directive 97/43/Euratom on health protection of individuals against the dangers of ionising radiation in relation to medical exposure 1997. Official Journal of the European Communities **No L 180/22**.
4. Criteria for acceptability of radiological (including radiotherapy) and nuclear medicine installations. EU Radiation Protection 91.
5. 1999. EU Guidance on Diagnostic Reference Levels (DRLs) for Medical Exposures. Radiation Protection **109**.
6. 2000. EU Guidelines on Education and Training in Radiation Protection for Medical Exposures. Radiation Protection **116**.
7. 1996. European Guidelines on Quality criteria for diagnostic radiographic images EN,. European commission EUR 16261.
8. 1999. Evaluation and routine testing in medical imaging departments Part 2-7 Constancy tests - equipment for intraoral dental radiography excluding dental panoramic euipment IEC 61223-2-7.

9. 1999. Evaluation and routine testing in medical imaging departments Part 2-11Constancy tests - equipment for general direct radiography. IEC 61223-2-11.
10. 2000. Evaluation and routine testing in medical imaging departments Part 3-4:accepatnce tests - imaging performance of dental x-ray equipment. IEC 61223-3-4.
11. 2001. Guidance Notes for Dental Practitioners on the Safe Use of X-Ray Equipment. National Radiological Protection Board.
12. 2002. Guidance on the Establishment and Use of Diagnostic Reference Levels for Medical X-ray Examinations. IPEM/BIR/CoR/NRPB/RCR joint working party 2002 draft.
13. 1996. ICRP 73 Radiological Protection and Safety in Medicine, vol. Volume 26.
14. 1996. International basic safety standards for protection against ionising radiation and for the safety of sources. Safety Series 115 IAEA.
15. 2001. International Commission on Radiological Protection. ICRP Supporting Guidance 2, Radiation and your Patient: A Guide for Medical PractitionersDiagnostic Reference Levels in Medical Imaging. Annal of the ICRP **31/4:**12.
16. 1988. Measurement of the variation in intensity in one illuminator or a bank of illuminators. In : Assurance of quality in the diagnostic X-ray department. Part M1.3(m). British Institute of Radiology.
17. 1992. Medical Devices Directive 93/42/EEC. Opinionon the proposal for a Council directive concerning medical devices. Official Journal of the European Communities **5**.
18. 1994. Medical electrical equipment Part 1. general requirements for safety, 3Collateral standard:general requirements for radiation protection in diagnostic x-ray equipment EN 60601-1-3.
19. 2000. Radiation protection in dentistry recommended safety procedures for the use of dental x-rayequipment safety code 30. Enviromental Health Directorate, Canada.
20. 1997. Recommended standards for the routine performance testing of diagnostic x-ray imaging systems. IPEM Report 77.
21. 2002. Reference values for diagnostic radiology: application and impact draft. AAPM.
22. 2001. Reglement gran-ducal du 16 mars 2001 relatif a la protection sanitaire des personnes contre les dangers des rayonnements ionisants lors d'expositions a des fins medicales,. Journal Officiel du Grand-duche de Luxembourg, Receuil de Legislation 6 juin 2001, Luxembourg.
23. 2000. Regulations on x-ray diagnostics, Statens stralskyddsinstitut SSI FS 2000:2. The Swedish Radiation Protection Institute.
24. 1999. Use and regulatory control of dental x-ray installations ST3.1. Radiation and Nuclaer Safety Authority, Finland.
25. **Akesson, L., J. Hakansson, M. Rohlin, and B. Zoger.** 1991. An evaluation of image quality for the assessment of the marginal bone level in panoramic radiography. Swed Dent J, **Suppl. 78:** 101-129.
26. **Beideman, R. W., O. N. Johnson, and R. W. Alcox.** 1976. A study to develop a rating system and evaluate dental radiographs submitted to a third party carrier. 1976. J Am Dent Assoc **93:**1010-13.
27. **Benedittini, M., Maccia, C., Lefaure, & Fagnani, C.** 1989. Doses to patients from dental radiology in France 1989. Health Physics **56:**903-910.
28. **Berkhout, W. E., G. C. Sanderink, and P. F. Van der Stelt.** 2002. A comparison of digital and film radiography in Dutch dental practices assessed by questionnaire. Dentomaxillofac Radiol **31:**93-99.
29. **Berkhout, W. E. R., D. A. Beuger, G. C. H. Sanderink, and P. F. van der Stelt.** 2002. The dynamic range of digital radiographic systems -dose reduction or risk of over exposure? Dento maxillofacial Radiology Submitted.
30. **Brezden, N. A., and S. L. Brooks.** 1987. Evaluation of panoramic dental radiographs taken in private practice. Oral Surg Oral Med Oral Pathol **63:**617-21.
31. **Carvalho, A. e. a.** 1992. Dental Radiographic Exposures in Portugal. Radiat Protect Dosim **43:**61-64.
32. **Ed: Rantanen, E.** 1999. Radiation Practices Annual report STUK-B-STO42 2000. Radiation and Nuclear Safety Authority, Finland.
33. **Eliasson, S., S. Lavstedt, F. Wouters, and L. Ostlin.** 1990. Quality of intraoral radiographs sent by private dental practitioners for therapy evaluation by the Social Insurance Office. Swed Dent J **14:**81-89.
34. **Gonzalez, L., E. Vano, and R. Fernandez.** 2001. Reference doses in dental radiodiagnostic facilities. British Journal of Radiology **74:**153-6.
35. **Gröndahl, H.-G., L. Hollender, and O. Osvald.** 1974. Röntgendiagnostik i tandläkarpraxis. En studie av bildkvalitet och -kvantitet vid yrkesskadefall. Sverig Tandl-Förd Tidn **66:**103-106.
36. **Harpes, N.** 2002. Personal Communication to A. Walker.
37. **Harpes, N. B., C Gilson, N.** 1997. Resultes des controles des appareilsradiologiques de medicine dentaire. Direction de la Sante, Luxembourg.
38. **Hart. D, M. C. Hillier, B. F. Wall, P. C. Shrimpton, and D. Bungay.** 1996. Doses to patients from medical x-ray examinations in the UK (Review 1995), vol. R289. NRPB.
39. **Hartmann, E., and F. E. Stieve.** 1989. Quality control of radiographic illuminators and associated viewing equipment. In: Technical and physical parameters for quality assurance in medical diagnostic radiology pp1 BIR 18. British Institute of Radiology.
40. **Havukainen, R.** 1988. Survey of dental radiographic equipment and radiationdoses in Finland. Acta Radiologica **29:**481-485.
41. **Helminen, S. E., M. Vehkalahti, J. Wolf, and H. Murtomaa.** 2000. Quality evaluation of young adults' radiographs in Finnish public oral health service. Journal of Dentistry **28:**549-55.
42. **Hewitt, J., P. G. Shuttleworth, P. A. Nelthorpe, and A. P. Hudson (ed.).** 1989. Improving protection standards in dental radiography. 4th International Syposium of the Society for Radiological Protection. Radiological Protection -theory and practice. Institute of Physics, Bristol UK.
43. **Koch, S., I. V. Wagner, and W. Schneider.** 2000. Effective and quality-controlled use of digital radiography in dental practice. International Journal of Computerized Dentistry **3:**107-18.
44. **Lecomber, A. R., and K. Faulkner.** 1998. Dose and risk in Dental Radiography:. Radiation Protection Dosimetry **80:Reference Doses and Quality in Medical Imaging: What the referring practitioner and directing medical staff should know**.
45. **Napier, I. D. D. i. A.** 1999. Reference doses for dental radiography. British Dental Journal **186:**392-6.

46. **National Radiological Protection Board.** 2001. Guidance notes for dental practitioners on the safe use of x-ray equipment. NRPB dental x-ray protection services.
47. **Nixon, P. P., J. Thorogood, J. Holloway, and N. J. Smith.** 1995. An audit of film reject and repeat rates in a department of dental radiology. British Journal of Radiology **68:**1304-7.
48. **Patel, N., V. E. Rushton, T. MacFarlane, and K. Horner.** 2000. The influence of viewing conditions on radiological diagnosis of periapical inflammation. Br Dent J **189:**40-42.
49. **Ponce, A. Z., and M. L. Ponce.** 1984. The X-ray checker. Basic radiographic quality assurance. Clin Prevent Dent **6:**27-29.
50. **Rushton, V. E., and K. Horner.** 1994. A comparative study of radiographic quality with five periapical techniques in general dental practice. Dentomaxillofac Radiol **23:**37-45, 96.
51. **Rushton, V. E., and K. Horner.** 1994. A laboratory study of 4 quality test devices for monitoring radiographic processing. J Dent **22:**213-22.
52. **Rushton, V. E., K. Horner, and H. M. Worthington.** 1999. The Quality of Panoramic Radiographs in General Dental Practice. Br Dent J **186:**630-633.
53. **Serro, R., Carreiro, J.P. Galvao, J.P. and Reis, R.** 1992. Population dose assessment from radiodignosis in Portugal R Serro et al Rad Prot Dos 43(1-4) 65-68. Rad Prot Dos **43:**65-68.
54. **Starritt, H., P. Faulner, K. Wankling, K. Cranley, J. Robertson, and K. Young.** 1991. Quality Assurance in dental radiology 67. IPSM.
55. **Svenson, B., T. Eriksson, M. Kronstrom, and S. Palmquist.** 1995. Quality of intraoral radiographs used for Prosthodontic treatment by general dentists in the Public Dental Health Service. Swed Dent J **19:**47-54.
56. **Svenson, B., T. Eriksson, M. Kronstrom, and S. Palmqvist.** 1994. Image quality of intraoral radiographs used by general practitioners in prosthodontic treatment planning. Dento-Maxillo-Facial Radiology **23:**46-8.
57. **Syriopoulos, K., X. L. Velders, P. F. van der Stelt, F. C. van Ginkel, and K. Tsiklakis.** 1998. Mail survey of dental radiographic techniques and radiation doses in Greece. Dento-Maxillo-Facial Radiology **27:**321-8.
58. **Teunen, D., A. Wambersie, O. Hjardemaal, A. Costa, B. Bauer, P. Dimitriou, G. O'Reilly, F. Mazzei, M. Paganini Fioratti, C. Back, J. Zoetelief, A. Ferro de Carvalho, E. Vano, and S. Ebdon Jackson.** 1995. Round table on initiatives, achievements and perspectives with regard to the Council Directive of September 1984 laying down basic measures for the radiation protection of persons undergoing medical examination or treatment. Radiation Protection Dosimetry **57:**33-71.
59. **Velders, X. L.** 1989. Patient exposure due to bitewing radiography. 1989. Universiteit Amsterdam,, Amsterdam.
60. **Versteeg, C. H., G. C. Sanderink, F. C. van Ginkel, and P. F. van der Stelt.** 1998. An evaluation of periapical radiography with a charge-coupled device. Dento-Maxillo-Facial Radiology **27:**97-101.
61. **Wall, B. a. S., P C.** 1998. The Historical Development of reference doses in Diagnostic radiology. Rad Prot Dosim **80:Reference Doses and Quality in Medical Imaging: What the referring practitioner and directing medical staff should know" Proceedings of a workshop Luxembourg 23-25 1997**.
62. **Wall, B. F.** 1998. Diagnostic reference levels,including patient dosimetry, Implementation of the Medical Exposure Directive European Commission:Radiation Protection 102.
63. **Williams, J. R., and A. Montgomery.** 2000. Measurement of dose in panoramic dental radiology. British Journal of Radiology **73:**1002-6.
64. **Williamson, B. D. P.** 1990. Radiation Doses to patients from dental radiographyin New Zealand. NRL report 1990/6 National Radiation Laboratory Christchurch New Zealand http://www.nrl.moh.govt.nz/ieindex.html.
65. **Yakoumakis, E., C. Tierris, I. Tsalafoutas et al.** 1998. Quality control in dental radiology in Greece. Radiat. Prot. Dosim. **80:**89-93.
66. **Yakoumakis, E. N., C. E. Tierris, E. P. Stefanou, I. G. Phanourakis, and C. C. Proukakis.** 2001. Image quality assessment and radiation doses in intraoral radiography. Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics **91:**362-8.

6. Staff protection

The aim of this Section is to describe how to achieve radiation protection of staff working in the dental practice by:

- **Following relevant national legislation**
- **Seeking expert advice and support**
- **Having clear procedures for working with X-rays**
- **Appropriate design of the facility**
- **Staff training**

6.1. Overall responsibility of Dental Practice

6.1.1. Own country legislation

There is a European Directive (3), commonly referred to as the Basic Safety Standards (BSS) Directive, which covers all matters concerning the radiation safety of employees and members of the public as a result of work practices using ionising radiation. It requires member states of the European Union to implement legislation in line with the requirements of the Directive. This Directive was revised in May 1996 and required revised legislation to be in place by May 2000.

Although the same basic concepts appear in each country's regulations implementing the BSS, interpretation can vary. These guidance notes will outline the requirements of the BSS and how they may be implanted, however it is essential that dental practices implement the specific requirements of their own country legislation.

In general, responsibility is placed on the 'undertaking', i.e. the employer legally responsible for a given work activity, to ensure that staff safety provisions are implemented and that members of the public are not significantly exposed as a result of the work.

6.1.2 Reporting use of X-ray equipment to competent authorities

Article 3 of the BSS Directive (3) requires the use of ionising radiation for work purposes to be reported to the relevant competent authority. Each member state will have set up a system for notification of the use of ionising radiation, some will require prior authorisation. The use of any X-ray set for medical diagnosis is likely to require notification.

6.1.3. Assessing risk

The BSS (3) requires staff protection measures to be based on a prior evaluation of the risk associated with the work, an assessment of the required arrangements to limit staff dose and their implementation. In general, the employer will be responsible for ensuring that the requirements for radiation protection, in terms of equipment, facilities and work procedures are assessed. This is often best carried out as a formal risk assessment with the main findings being documented (17).

6.1.4. Seeking advice of qualified expert

To be able to adequately assess the protection measures required, to ensure their implementation and then continued monitoring, the lead practitioner will often require advice from a radiation protection expert. The BSS requires the consultation of 'qualified experts'. Qualified experts are referred to by different titles dependent on the country's legislation. For example, in the UK such experts are called 'Radiation Protection Advisers' and there is a system of accreditation for such advisers who will often be medical or radiation physicists (17). It is important the practice consults 'qualified experts' who are appropriately accredited in line with local legislation and who also have an understanding of the use of X-ray equipment for dental diagnosis.

Recommendation 6 A

The lead dental practitioner should ensure that the arrangements for staff protection are assessed and implemented in line with the requirements of the country legislation and in consultation with appropriate medical physics experts.

ED NR

6.2. Staff dose levels

6.2.1. Typical dose level

In dental practice, relatively simple measures can be instituted to limit staff dose. Consequently, employees working in a dental practice should not normally receive significant radiation doses. The National Commission for Radiation Protection (NCRP) in the United States report that mean dose received by dental workers is 0.2 mSv per year(6). Similarly, the National Radiological Protection Board (NRPB) (7) in the UK estimates a mean level of less than of 0.1 mSv per year.

6.2.2. Dose limits

The BSS (3) lays down upper levels of annual dose for workers and the public. For workers, the current effective dose limit is 100 mSv in any consecutive 5 years with a maximum of 50 mSv in any year. Member states are given the freedom to set lower annual limits. The dose limit for skin is 500 mSv p.a. averaged over 10 mm^2. These limits are based on guidance from the International Commission of Radiological Protection (5), the effective dose limit being set at a level at which the stochastic risk is considered to be at the limit of acceptability. The skin dose limit is set to ensure that deterministic damage is prevented.

In normal dental practice, effective dose should never exceed 1 mSv per year, which is the annual dose limit for the public (and would normally be expected to be lower). Likewise, dose to the skin of the hands should be well below the dose limit. However, in the past, incidences of deterministic damage to fingers have been reported (16, 20, 21) in dentists due to the custom of holding the film in the patient's mouth, a practice that should never happen now.

6.2.3. Applying ALARA

The overriding principle of staff radiation protection is to ensure that dose is kept 'as low as reasonably achievable' (3, 5). This principle is know as the ALARA principle

and is the backbone of all radiation protection practice. Essentially, ALARA requires that any measure that can reasonably be implemented should be to ensure that radiation protection is optimised. In deciding reasonableness, economic and social factors can be taken into account.

In dental practice relatively straightforward measures can be taken to ensure that staff dose is kept ALARA, as detailed below.

6.2.4. Need for personal monitoring

Given the low dose received by most dental practice staff, the provision of routine personal monitoring is generally considered desirable but not universally necessary. UK guidance(17) recommends that monitoring is not normally required unless the risk assessment indicates that individual doses are likely to exceed 1 mSv per year (e.g. because of a high workload above 100 intraoral or 50 panoramic films per week), however other national guidance recommends personal monitoring for all dental practices using X-ray equipment (2, 8, 9, 11).

6.2.5. Pregnant staff

It is well documented that the fetus is sensitive to ionising radiation(1). Consequently, special attention is paid to workers using ionising radiation who are pregnant and BSS (3) includes a separate dose limit of 1 mSv to the fetus during the declared term of pregnancy. In dental practice, it would be considered unusual for any members of staff to be exposed to radiation to an extent that would lead to this level of fetal dose (6, 7, 22). However, female staff should be encouraged to inform their employer of pregnancy. The lead practitioner should ensure that the pregnant employee work load is assessed and if there is a likelihood of the fetal dose exceeding this level then a qualified expert should be consulted for specific advice to ensure that the fetal dose will be limited.

Recommendation 6 B

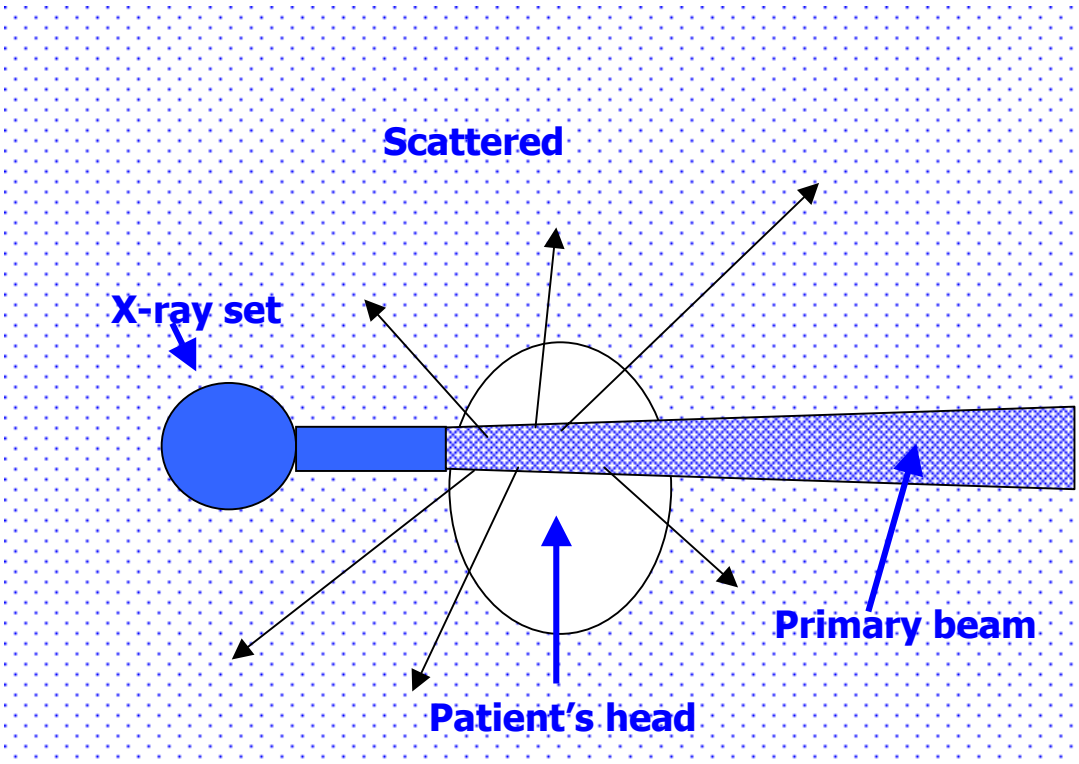
Normal dental practice should not lead to members of staff receiving doses above 1 mSv per year provided the ALARA principle is applied. Special precautions for pregnant staff are not normally required when it can be assured that the dose during pregnancy is 1 mSv (which is normally the case in dental practice).

6.3. Principles of protection

6.3.1. Primary and scattered radiation

X-rays travel in a straight line unless they interact with matter when their direction of travel can change. The main beam of X-rays emitted by the X-ray tube is known as

Figure 6.1 Radiation scattered from the primary beam



the primary beam. When this primary beam interacts with the patient's head, radiation will be scattered in all directions (Figure 6.1). For intraoral film radiography, the radiation dose in the primary beam is typically a few mGy (see Tables 5.7-5.9) at the end of the cone with the dose at 1 m, due to scattered radiation, being at least 1,000 times less than this (12, 14, 18, 19, 23).

6.3.2. Use of distance

For a point source of radiation, the dose rate falls off as the inverse of the square of the distance from the source (as light intensity falls off at distance from a light bulb). Standing at a distance of 2 m from the patient's head will lead to a dose of roughly a quarter of that received standing only 1 m away. For scattered radiation, the use of distance alone is often adequate protection in the dental situation. For both intraoral and panoramic/cephalometry work standing at a distance of greater than 1.5 m should ensure that annual dose is kept below 1 mSv provided the weekly workload is less than 100 intraoral or 50 panoramic/cephalometry films (17). National guidance generally recommends standing at a distance of between 2 -3 m from the patient (2, 8, 9, 11, 15).

When relying on distance to provide protection, it is important to ensure that all staff stand out of the direction of the primary beam and special care is taken during intraoral radiography not to direct the primary beam in the direction of entrance doors or other non-protected areas. It is generally considered good practice for non-essential staff to leave the room during radiography.

The operator of the equipment should position themselves so that they have a clear view of the patient, any other staff in the room, and the X-rays on light. This is so that

they can assess that all are correctly positioned at exposure initiation and that the exposure terminates correctly.

6.3.3. Use of protective screens etc

For low workload situations (i.e. less than the workload in Section 6.3.2 above) extra protection for staff is not usually required provided that the room is large enough to allow staff to stand some 2 m away from the patient (17). However, for high radiographic workload or very cramped location, extra protection can be provided, either in the form of protective panels for staff to stand behind or as protective aprons for staff to wear. If such protection is required it is recommended that the advice of a 'qualified expert' be sought.

6.3.4. Classification of areas

Article 18 of the BSS requires the designation of controlled areas, defined as an area subject to special rules to ensure staff safety. For hospital radiography it is normal for the whole X-ray room to be designated as controlled. However, for the low workload dental situation, UK guidance (17) has taken a pragmatic view of this requirement and advises that the controlled area be defined as the area around the X-ray equipment that staff should vacate during exposure. Consequently, in the UK it is recommended that for panoramic (no more than 50 exposures taken per week) and intraoral units (no more than 100 exposures taken per week) the controlled area is defined during X-ray exposure as: within 1.5 m of the X-ray tube and patient and within the primary X-ray beam until sufficiently attenuated by distance or shielding, (illustrated in Figure 6.2 - for the intraoral unit). Staff should ensure that they are well out of this area, i.e. some 2-3 m away or out of the room, during radiography. However, it is emphasised that the advice of a 'qualified expert' should be sought in defining controlled areas. Such advice is essential for higher workload situations or for cephalometry units.

Recommendation 6 C

Maintaining adequate distance is normally the only measure required to ensure staff dose is ALARA. This can be achieved by defining an area that staff do not normally enter during X-ray exposure.

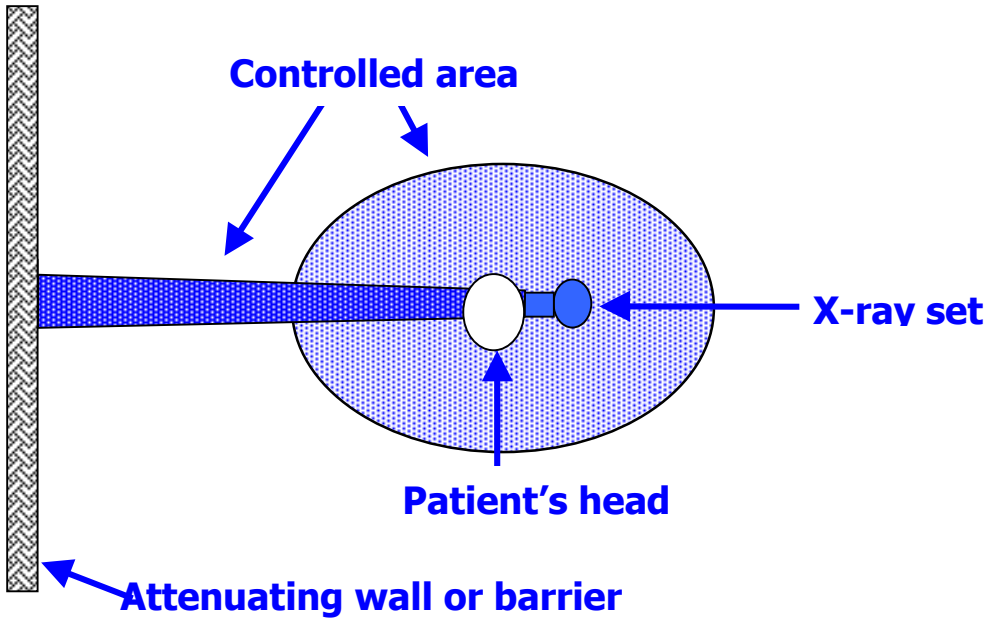
ED NR

6.3.5. Holding patients

Exceptionally, it might be necessary to provide assistance by supporting a handicapped patient or child. If patient assistance is required, the assisting adult should be provided with a lead apron and positioned so that all parts of their body are out of the main beam. If this is a regular requirement within a practice, then the advice of a qualified expert should be sought as to the best methods of protection for the assistant and the need for personal monitoring.

The dental film or detector should only be held by the patient when it cannot otherwise be kept in position. It should never be hand held by a member of the dental practice staff. If it is necessary for someone other than the patient to hold the film,

Figure 6.2 Diagram of a controlled area designation around an intraoral radiography unit.



this should be done using long handled forceps or other device so that the fingers are not in the primary beam. The anaesthetised patient presents a particular challenge but it is usually possible to ensure that the film remains in the correct position by immobilisation methods (13).

Recommendation 6 D

The advice of a qualified expert should normally be sought regarding staff safety measures and is essential for high workload practices, practices using cephalometry and practices where patient assistance is often required.

ED NR

6.3.6. Written procedures and supervision

To ensure staff are fully aware of the precautions to be taken it is desirable that written instructions are in place and displayed near the X-ray equipment. These instructions should detail the responsibility for exposure, positioning of staff, use of protective devices, any restriction on primary beam direction and personal monitoring arrangements if appropriate. In addition a system of supervision of staff should be instituted to ensure the radiation safety work instructions are followed and revised as necessary.

Recommendation 6 E

All practices should have written instructions for staff radiation safety.

6.4. Design of the facility

6.4.1. Protection for adjacent areas

In deciding where to install dental X-ray equipment, it is essential to consider the likely consequences in terms of radiation dose to staff and members of the public in adjacent areas. This is particularly important if equipment is located close to a partition wall (i.e. within 1.5m for low workload situations), for any walls or floor in the direction of the primary beam (intraoral and cephalometry) and for high workload use. Ideally, the advice of a qualified expert should be sought to establish the required wall and floor structural attenuation.

Protection is often quoted in terms of the thickness of lead (usually some 0.1-1mm) required and this will be dependent on such factors as distance of the barrier from the X-ray tube, the use of adjacent area, workload etc (10, 11, 19). To achieve such levels of protection, it is usually sufficient to ensure that walls and floors are of solid construction, e.g. concrete blockwork or brick construction. Alternatively lead lined plywood or plasterboard can be used to obtain the desired protection. For the average dental facility, structural protection can readily be achieved using traditional building materials.

It is possible that the dental supplier installing the equipment will be able to provide the advice of a qualified expert to assist with installation design and commissioning checks.

6.4.2. Room layout

Consideration needs to be given to the layout of the room so that radiation safety is optimised. The room should be of adequate size to allow all staff who need to remain within the room to position themselves outside the controlled area during exposure. As described in 6.3.2 above, it is essential that the operator of the equipment can position themselves so that they have a view of: patient, controlled area and ‘X-rays on’ indicator light. If the room size is limited, it might be necessary for staff to position themselves outside the room, in which case a mirror might be required to ensure that a clear view of the room is maintained.

The equipment should be positioned so that the controlled area does not extend to any entrances and so that the primary beam will not be directed towards any doorways or ground floor windows.

The exposure switch should be located so that that the operator can either remain outside of the controlled area or be behind a protective screen. In addition, attention should be given to the location of the mains on switch. This should be placed so that, in the unlikely event of failure to terminate exposure, the unit can be readily

disconnected from the mains supply without members of staff being exposed to primary radiation.

6.4.3. Signs and warning lights

It is important to ensure that unauthorised access into the controlled area is limited during X-ray exposure. This may be achieved by supervision by the operator backed up by the use of warning signs and lights. The requirement for warning signs and lights varies from country to country within the EU. It is a common requirement that all doors leading into a room where dental X-ray equipment is used should have a sign that indicates the presence of the X-ray equipment. However, such permanent signs have little value if the room is used for other activities apart from X-ray work as practice staff quickly learn to ignore them.

A pragmatic approach to this is given in the UK guidance (16). Provided the controlled area does not extend to an entrance, then access to the area can be controlled by the operator of the equipment and no warning lights or signs are necessary. However, if the controlled area does extend to an entrance, then an automatic warning light should be provided to indicate that radiography is in progress. This light should be illuminated when the mains supply is on, and the mains supply should be kept switched off unless radiography is imminent. A warning notice should also be provided explaining the significance of the light. Such a warning may be unnecessary if the operator is always able to stand in the doorway to prevent access whilst radiography is underway.

Recommendation 6F

It is essential that consideration be given to the layout and structural protection of any dental X-ray facility. A qualified expert should be consulted when planning new facilities or making significant changes.

ED NR

6.5 Training staff

All staff in a dental practice (not just the equipment operator) must be aware of the risks associated with the use of X-ray equipment, the precautions required to keep their dose ALARA and the importance of complying with these arrangements (4). Many dental employees will receive some radiation awareness training as part of their professional training. It is, however, essential that local arrangements be explained to all staff. For members of staff who have not received any radiation safety training (e.g. some dental nurses) then it is important that arrangements be made (by either attending suitable training courses or the provision of adequate in-house training) to ensure that they have adequate training.

Recommendation 6 G

Dental practice employees should receive training in radiation protection so that they understand the risks involved and the precautions to be taken.

ED NR

6.6 Dealing with incidents

It is very rare in dental practice for incidents to occur that lead to staff receiving significant dose levels. However, exposure to the primary beam, especially if the unit fails to terminate correctly, can be such a cause and would require investigation. It is important that the investigation be carried out promptly, whilst the details of the incident are still fresh in people's memories. A qualified expert should normally be consulted to aid in estimation of dose levels received. Any incidents should be reported to the competent authorities in line with local legal requirements.

6.7 References

1. 1998. Advice on exposure to ionising radiation during pregnancy. Joint guidance from NRPB/CoR/RCR.
2. 1996. Code of practice for radiological protection in dentistry. Radiological Protection Institute of Ireland.
3. 1996. Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health workers and the general public against the dangers arising from ionizing radiation.
4. 2000. EU Guidelines on Education and Training in Radiation Protection for Medical Exposures. Radiation Protection **116**.
5. 1990. ICRP Publication 60. Recommendations of the International Commission on Radiatiological Protection. Annal of the ICRP **21**.
6. 1990. Implementation of the principle of as low as reasonably achievable (ALARA) for medical and dental personnel Report Number 107. NRCP.
7. 1993. Radiation Exposure of the UK population - Review NRPB R263.
8. 2000. Radiation protection in dentistry recommended safety procedures for the use of dental x-rayequipment safety code 30. Enviromental Health Directorate, Canada.
9. 1989. Recommendations on radiographic procedures. Revision of Federation Dentaire Internationale technical report No. 8. International Dental Journal **39:**147-8.
10. 1999. Use and regulatory control of dental x-ray installations ST3.1. Radiation and Nuclaer Safety Authority, Finland.
11. **A. D. A. Council on Scientific Affairs.** 2001. An update on radiographic practices: information and recommendations.ADA Council on Scientific Affairs. Journal of the American Dental Association **132:**234-8.
12. **de Haan, R. A., and J. van Aken.** 1990. Effective dose equivalent to the operator in intra-oral dental radiography. Dento-Maxillo-Facial Radiology **19:**113-8.
13. **Diner, M. H., P. Marcoux, and V. Legault.** 1990. Intraoral radiographic techniques for the anaesthetized patient. Journal of the International Association of Dentistry for Children **20:**17-21.
14. **Hirschmann, P. N.** 1987. The current status of panoramic radiography. International Dental Journal **37:**31-7.
15. **Matarasso, S., F. Coraggio, R. Martuscelli, and F. D'Antonio.** 1990. [Radiologic risk and INAIL insurance]. Stomatologia Mediterranea **10:**207-12.
16. **Monsour, P. A., B. J. Kruger, A. Barnes, and A. Sainsbury.** 1988. Measures taken to reduce X-ray exposure of the patient, operator, and staff. Australian Dental Journal **33:**181-92.
17. **National Radiological Protection Board.** 2001. Guidance notes for dental practitioners on the safe use of x-ray equipment. NRPB dental x-ray protection services.
18. **Reid, J. A., J. C. MacDonald, T. A. Dekker, and B. U. Kuppers.** 1993. Radiation exposures around a panoramic dental x-ray unit. Oral Surgery, Oral Medicine, Oral Pathology **75:**780-2.
19. **Sutton, and Williams.** 2000. Radiation Shielding for diagnostic X-rays BIR.
20. **Wagner , and Archer.** 1998. Minimizing risks from fluoroscopic x-rays, Partners in Radiation Management.
21. **Warin, A. P.** 1979. Radiodermatitis of the hands in a dental practitioner. Clinical & Experimental Dermatology **4:**129-32.
22. **Wasylko, L., D. Matsui, S. M. Dykxhoorn, M. J. Rieder, and S. Weinberg.** 1998. A review of common dental treatments during pregnancy: implications for patients and dental personnel. Journal/Canadian Dental Association. Journal de l Association Dentaire Canadienne **64:**434-9.
23. **Watkins, A. J.** 2002. Presented at the IPEM Annual Scientific Meeting.

Appendix 1 Methodology

1.1. Aim

To develop evidence based guidelines on radiation protection in dental radiology

1.2. Establishment of guideline development team and the scope of the guidelines

One of the first steps in production of evidence based guidelines is to establish a guidelines development panel. A multidisciplinary team was established for the production of the guidelines on radiation protection in dentistry (refer to Panel, page 8). A meeting of the team was convened (February 2002) and the scope and content of the guidelines was discussed and refined.

The consensus was that our target population for the guidelines was dentists working in general practice. We identified ten key topic areas that needed to be covered to produce a comprehensive guideline:

- Dose and risk
- Referral criteria
- Consent
- Diagnostic Reference Levels (DRLs)
- Previous radiographs and reports
- Techniques, equipment and dose limitation
- Quality standards
- Quality assurance
- Equipment acceptance tests
- Staff protection

Members of the guideline development team were divided into sub-groups and assigned to topic areas on the basis of personal expertise and skills. It was recognised that there would be some overlap between certain topics. We attempted to ensure that any of the overlapping topics had at least one member of the team working on both sub-groups.

Each sub-group was responsible for outlining relevant issues to be covered within their topic area, the screening and data extraction of relevant identified papers, the grading of the scientific content of these papers and the report of the findings.

The overall administration of the guidelines was undertaken by a Project Coordinator based in Manchester, UK.

1.3. Identification of the literature

We undertook an initial search for existing guidelines within the area of radiation protection. We searched the FDI guideline database (www.fdiworldental.org), the National Guidelines Clearing House (www.guidelines.gov/index.asp) and Medline. A list of identified guideline literature was circulated to all members of the development team for screening. Any guideline identified by one or more members of the team as being potentially relevant was obtained and distributed to the whole team.

We also performed searches for papers on the ten identified topic areas. The development of the search strategies for each topic was an iterative process. An initial 'scoping' search was undertaken. The aim of these scoping searches was to gain an overview of the volume of literature; identify further questions that may need to be addressed; establish the research methodologies used within each area and identify further search terms for refining the search strategy.

A set of key terms (controlled vocabulary (e.g MeSH) and free text words) was used as the basis for all the sub-group scoping searches (Box 1), with additional subject specific search terms added as appropriate.

Box 1.

MeSH and free text terms used (MEDLINE via OVID BIOMED)

1 exp Radiography/
2 radiograph$.mp.
3 radiation.mp.
4 exp Radiology/
5 radiol$.mp.
6 exp X-Rays/ or x-ray.mp. (80927)
7 xra$.mp.
8 (dental or dentistry).mp.
9 exp Dentistry/
10 (intra-oral or intraoral).mp.
11 cephalometr$.mp.
12 orthopantom$.mp.
13 panoramic.mp.
14 (bite-wing or bitewing).mp.
15 MANDIBLE/ or mandible.mp.
16 MAXILLA/ or maxilla.mp.
17 or/1-7
18 or/8-16

The results of the searches were imported into Endnote 5.0 and coded accordingly. We distributed the results for each individual scoping search to the appropriate topic-group where the titles and abstracts were reviewed. Members of the topic-groups were asked to comment on the sensitivity and

specificity of the search results. Where the scoping searches did not appear to identify relevant articles, or the search results identified to many non-relevant articles, the search strategies were refined following discussion (via email) with the team members. This process often took several rounds of discussion and refinement before we established sensitive search strategies.

We searched MEDLINE (OVID BIOMED) for each topic back to 1966 except for the Dose & Risk topic group. With regard to Dose & Risk, it was felt that the International Commission on Radiation Protection report 60 (2), which changed the methodology of risk calculation in relation to radiation exposure, acted as an appropriate starting point. Previous calculations of risk would not be comparable. In addition the benchmark review paper by White (3) recalculated pre1990 dose/risk papers using ICRP 60 methods (2), therefore for this topic group, searching commenced at 1990.

We undertook additional citation searches of key authors/papers and searches of websites of National/International professional bodies. The expertise of the project team was exploited to identify both unpublished and ongoing studies. Non-English language articles were included where translations were available.

1.4. Assessment of relevance

Each sub-group was responsible for the screening of titles and abstracts identified through the electronic searching. The process was carried out independently by sub-group team members. The details of those records deemed potentially relevant to the subject area by at one or more members of the sub-group were passed back to the Project Coordinator for collection of the full article.

During this process, members of the sub-groups were asked to 'flag-up' any records identified in their search results that might be of relevance to the other topic areas of interest.

1.4.1. Data extraction

All studies obtained through the searching were distributed to all members of the relevant sub-group. The papers were reviewed and data extracted independently. The data extracted was used to form evidence tables, providing details of the study design, aims, methods, results and conclusions. Due to the wide variation in study designs utilised in this area, a single validity assessment form was not used, however the strengths and weaknesses of each study were noted and an attempt to grade the paper on its scientific merit was performed.

1.4.2. Data synthesis and grading of recommendations

Draft guidelines, based on the information produced in the evidence tables, was then drawn up by each sub-group. These were circulated to all members of the guideline development team, along with tables, prior to a final meeting

(October 2002). The group discussed the evidence giving consideration to the volume, consistency and generalisablity of the findings.
Recommendations were produced, based on the available evidence and graded using an adaptation of the SIGN grading system to reflect the study types utilised in this area of research (1). Where European Directives exist, these were noted. (Refer to Table 1.1, Chapter 1.)

1.5 References

1. May 2002. Scottish Intercollegiate Guidelines Network (SIGN). A guideline developers' handbook. Report No.: SIGN 50.
2. **International Commission on Radiological Protection.** 1991. ICRP Publication 60. Recommendations of the International Commission on Radiological Protection. Annals of the International Commission on Radiological protection Vol. 21, No 1-3. Pergamon, Oxford, UK.
3. **White, S. C.** 1992. Assessment of radiation risk from dental radiography. Dentomaxillofac Radiol **21:**118-26.

Appendix 2: Summary of Recommendations/Statements:

Criteria used to grade recommendations

Symbol used	Criteria used to assign grading to reviewed literature
ED	**Article or other requirement of the EURATOM Directive(s) that must be applied.**
A	**Meta-analyses/systematic reviews of randomised control trials (RCTs) or laboratory studies with low risk of bias.** *or* **RCTs.**
B	**Meta analyses/ systematic reviews of case-control or cohort studies with high risk of bias.** *or* **Case-control, cohort studies with a low risk of confounding, bias or chance and a moderate probability that the relationship is causal.** *or* **Good quality laboratory studies with little or no evidence of bias/experimental error.**
C	**Non-analytic studies (e.g. case reports, case series, cross-sectional surveys).** *or* **Laboratory studies with risk of bias/experimental error.** *or* **Expert opinion/non-systematic review article.**
NR	**National Recommendations in some Member States. In some cases, however, National requirements will differ from the recommendations made in this document and will overrule these.**

Recommendation/Statement	Evidence-Based Grading
2. Dose and Risk	
Statement 2.A Individual doses in basic dental radiography (intraoral, panoramic and cephalometric) are low, being equivalent to those associated with a few days of background radiation. Individual doses from more complex imaging (CT scans and multiple slice cross-sectional tomography) can be substantially higher.	A
Statement 2.B Individual risks in dental radiography are small but are greater in the younger age groups in which dental radiography is most frequently performed.	B
3. Justification: referral criteria	
Recommendation 3 A All X-ray examinations must be justified on an individual patient basis by demonstrating that the benefits to the patient outweigh the potential detriment. The anticipated benefits are that the X-ray examination would add new information to aid the patient's management.	ED
Recommendation 3 B No radiographs should be selected unless a history and clinical examination have been performed. 'Routine' radiography is unacceptable practice. * The statement/recommendation although not specifically stated in the European Directive is intrinsic to the process of justification as defined by the Directive. There are no randomised controlled trials to support the recommendation; such a study design would neither be possible nor ethical to perform.	ED* NR

Recommendation/Statement	Evidence-Based Grading
Recommendation 3 C When referring a patient for a radiographic examination, the dentist should supply sufficient clinical information (based upon a history and clinical examination) to allow the practitioner taking clinical responsibility for the X-ray exposure to perform the justification process.	ED
Recommendation 3 D Prescription of bitewing radiographs for caries diagnosis should be based upon caries risk assessment. Intervals between subsequent bitewing radiographic examinations must be reassessed for each new period, as individuals can move in and out of caries risk categories with time.	B
Recommendation 3 E It is recommended that when children are designated as high caries risk they should have six-monthly posterior bitewing radiographs taken. This should continue until no new or active lesions are apparent and the individual has entered a lower risk category. .	B
Recommendation 3 F It is recommended that when children are designated as moderate caries risk they should have annual posterior bitewing radiographs. This should continue until no new or active lesions are apparent and the individual has entered a lower risk category.	B
Recommendation 3 G Radiography for caries diagnosis in low caries risk children should take into account population prevalence of caries. Intervals of 12-18 months (deciduous dentition) or 24 months (permanent dentition) may be used, although longer intervals may be appropriate where there is continuing low caries risk.	C

Recommendation/Statement	Evidence-Based Grading
Recommendation 3 H It is recommended that adults designated as high caries risk have six-monthly posterior bitewing radiographs taken until no new or active lesions are apparent and the individual has entered another risk category.	C
Recommendation 3 I It is recommended that adults designated as moderate caries risk have annual posterior bitewing radiographs taken until no new or active lesions are apparent and the individual has entered another risk category.	C
Recommendation 3 J It is recommended that adults designated as low caries risk have posterior bitewing radiographs taken at approximately 24 month intervals. More extended intervals may be used where there is continuing low caries risk	C
Recommendation 3 K Alternative methods to using ionising radiation in caries diagnosis should be considered once their diagnostic validity has been clearly established.	C
Recommendation 3 L Guidelines on orthodontic radiography should be consulted as an aid to justification in the management of the developing dentition in children.	C
Recommendation 3 M Radiographs should be used in the management of periodontal disease if they are likely to provide additional information that could potentially change patient management and prognosis.	C
Recommendation 3 N There is insufficient evidence to propose robust guidelines on choice of radiography, but existing radiographs e.g. bitewing radiographs taken for caries diagnosis should be used in the first instance.	C

Recommendation/Statement	Evidence-Based Grading
Recommendation 3 O It is recommended that radiographic examinations are carried out at the following stages of endodontic treatment: 1. Pre-operative assessment 2. Working length estimation 3. Post-operative 4. At review or if symptomatic	1. Pre-operative assessment **B** 2. Working length estimation* **B** 3. Post-operative **B** 4. At review or if symptomatic **C** * For those practitioners without access to electronic apex locators, a working length estimation will be required.
Recommendation 3 P For a new adult dentate patient, the choice of radiography should be based upon history, clinical examination and an individualised prescription (as illustrated in Table 3.4).	**C**
Recommendation 3 Q For a new adult dentate patient, panoramic radiography may be indicated in a limited number of dental treatments, notably orthodontic assessment and certain oral surgical procedures (i.e. lower third molars).	**C**
Recommendation 3 R There is no justification for radiography of edentulous patients without a specific indication such as implant treatment or clinical signs or symptoms.	**B**
Recommendation 3 S Imaging is essential in implantology in pre-operative planning and to review the fixture.	**C**

Recommendation/Statement	Evidence-Based Grading
Recommendation 3 T Pre-extraction radiography may be indicated in the following situations: • a history of previous difficult extractions • a clinical suspicion of unusual anatomy • a medical history placing the patient at special risk if complications were encountered • prior to orthodontic extractions • extraction of teeth or roots that are impacted, buried or likely to have a close relationship to anatomical structures (i.e. mental/inferior dental nerve, the maxillary antrum and /or tuberosity and the lower border of the mandible).	C
Recommendation 3 U There is no evidence that normal selection criteria for dental radiography need be altered if a patient is or may be pregnant.	C NR
Recommendation 3 V Informed consent should be obtained from patients prior to radiography in accordance with national requirements.	ED
Recommendation 3 W Access to previous radiographs will avoid unnecessary exposures and aid patient management.	ED
Recommendation 3X Information given to patients prior to dental radiography should stress the very low risk set against the potential benefits for their treatment.	C
4. Equipment factors in reduction of radiation doses to patients	
Recommendation 4 A 65 to 70 kV is recommended as the kilovoltage of choice for dental (intraoral) X-ray sets using AC equipment, with 60kV for those using DC X-ray sets.	B

Recommendation/Statement	Evidence-Based Grading
Recommendation 4B Constant potential ('DC') X-ray equipment is recommended when purchasing new X-ray equipment, especially when digital image receptors systems are chosen.	C
Recommendation 4 C Filtration by aluminium is a key method of reducing skin dose to patients.	B
Recommendation 4 D Rectangular collimation is a highly effective means of dose reduction in intraoral dental radiography. It should be used in combination with film holders incorporating beam-aiming devices. In those cases where film holders are not possible, rectangular collimation should still be considered.	B
Recommendation 4 E If available, limitation of field size to the area required for diagnosis should be used for panoramic radiography.	B
Recommendation 4 F Where possible, lateral cephalograms should be collimated to limit the field to the area required for diagnosis. Manufacturers should incorporate this feature into the design of cephalographic equipment.	B
Recommendation 4 G For intraoral radiography, only the fastest available (Group E or faster) films should be used, as they significantly reduce patient dose.	A NR
Recommendation 4 H For extraoral radiography the fastest available rare-earth intensifying screen/film combination consistent with satisfactory diagnostic results should be used. The speed of the system should be at least 400.	A

Recommendation/Statement	Evidence-Based Grading
Recommendation 4 I Intraoral digital radiography offers a potential dose reduction. A medical physics expert should be consulted to achieve dose reduction optimisation.	B
Recommendation 4 J It is unlikely that digital panoramic and cephalometric radiography can routinely offer dose reduction compared with conventional screen/film combinations. A medical physics expert should be consulted to achieve dose reduction optimisation.	C
Recommendation 4 K There is no evidence to justify routine use of abdominal (gonadal) lead protection for dental radiography.	C NR
Recommendation 4 L Lead shielding of the thyroid gland should be used in those cases where the thyroid is in line of the primary beam.	C
5. Quality Standards and Quality Assurance	
Recommendation 5 A A radiological QA programme should be implemented by the Holder of the dental facility.	ED
Recommendation 5 B As a minimum target, no greater than 10% of radiographs should be of unacceptable quality. The aim should be to reduce the proportion of unacceptable radiographs by 50% at each successive audit cycle.	C
Recommendation 5 C Film holders incorporating beam-aiming devices using the paralleling technique and facilitating rectangular collimation should be used for intraoral radiography wherever possible.	B

Recommendation/Statement	Evidence-Based Grading
Recommendation 5 D Accurate positioning in panoramic radiography can be facilitated by using all available positioning aids correctly and by adequate training of users. When buying new equipment it is important to ensure that light beam positioning aids are included.	B
Recommendation 5 E A cephalostat and a fixed X-ray source/patient/image receptor relationship should be used for cephalometric radiography.	B
Recommendation 5 F The Medical Directive requires the establishment of DRLs. The working party recommends a DRL of 4 mGy absorbed dose in air measured at the end of the spacer cone for a standard maxillary molar projection.	ED
Recommendation 5 G The working party recommends that further work be carried out on establishing a measurement method (probably adopting the DAP approach) for panoramic dosimetry and to undertake further field measurements so that a European DRL can be adopted.	ED
Recommendation 5 H The working party recommends that dose surveys be undertaken within Europe using both ESD and DAP to facilitate the setting of a European DRL for standard cephalometry projections.	ED
Recommendation 5 I It is recommended that dentists arrange to audit their doses for comparison with European/National DRLs.	ED
Recommendation 5 J All new installations should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal.	ED

Recommendation/Statement	Evidence-Based Grading
Recommendation 5 K All dental X-ray equipment should undergo regular routine tests to ensure that radiation protection, for both practice users and patients, has not significantly deteriorated.	ED NR
Recommendation 5 L A QA system for monitoring darkroom and processing conditions should be instituted in each dental facility. As a minimum: • The temperature of the developer should be checked prior to film processing and the development time adjusted in accordance. • For automatic processing, the processor should be properly cleaned and maintained. Processing solutions should be changed at regular intervals as indicated by routine monitoring tests.	B
Recommendation 5 M All those involved in radiography should have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection. Continuing education and training after qualification is required, particularly when new equipment or techniques are adopted.	ED
Recommendation 5 N The person responsible for the QA programme should make an audit of the programme at intervals not exceeding 12 months.	C

Recommendation/Statement	Evidence-Based Grading
6. Staff protection	
Recommendation 6 A The lead dental practitioner should ensure that the arrangements for staff protection are assessed and implemented in line with the requirements of the country legislation and in consultation with appropriate medical physics expert.	ED NR
Recommendation 6 B Normal dental practice should not lead to members of staff receiving doses above 1 mSv per year provided the ALARA principle is applied. Special precautions for pregnant staff are not normally required when it can be assured that the dose during pregnancy is 1 mSv (which is normally the case in dental practice).	C
Recommendation 6 C Maintaining adequate distance is normally the only measure required to ensure staff dose is ALARA. This can be achieved by defining an area that staff do not normally enter during X-ray exposure.	ED NR
Recommendation 6 D The advice of a qualified expert should normally be sought regarding staff safety measures and is essential for high workload practices, practices using cephalometry and practices where patient assistance is often required.	ED NR
Recommendation 6 E All practices should have written instructions for staff radiation safety.	ED
Recommendation 6F It is essential that consideration be given to the layout and structural protection of any dental X-ray facility. A qualified expert should be consulted when planning new facilities or making significant changes.	ED NR
Recommendation 6 G Dental practice employees should receive training in radiation protection so that they understand the risks involved and the precautions to be taken.	ED NR

Appendix 3: Glossary

Absorbed dose: The quantity of energy deposited by the radiation per unit mass of tissue. The unit of absorbed dose is the Gray (Gy) and one gray is equal to 1 joule of energy deposited in 1 kg of tissue.

Additional filtration: This is a filter added to the inherent filter and placed in the path of the main X-ray beam.

ALARA (As Low As Reasonably Achievable): This statement endorses the principle that (individual) doses should be as low as reasonably achievable, economic and social factors being taken into account.

Aluminium equivalent: The thickness of aluminium alloy affording the same attenuation as the material in question.

Anode: The positive terminal of the X-ray tube.

Attenuation: Loss of energy from ionising radiation by absorption and scatter as it passes through matter.

Bisecting angle technique: A technique for intraoral periapical radiography in which the X-ray beam is directed perpendicular to the bisected angle formed by the long axis of the tooth (teeth) to be imaged and by the film.

Bitewing radiograph: This is an intraoral radiographic view that demonstrates the crowns of the teeth and the alveolar crestal bone of the premolar and molar regions of both the maxilla and mandible.

Case-control study: This is a study that identifies patients with an outcome of interest (i.e. cases) and control patients without the same outcome and retrospectively assessing if they had the exposure of interest.

Case series: A report on a series of patients with an outcome of interest in which no control group was involved.

Cephalometric radiography: A method whereby reproducible lateral and postero-anterior views of the skull are obtained by standardising head position using a cephalostat. Synonyms: Cephalometry; teleradiography.

Cephalostat: A rigid device to localise the patient's head in a standardised way.

Cohort study: Two groups of patients (cohorts) are chosen, one that has received an exposure of interest and one that has not. Both are followed to derive the outcome of interest.

'Coin' test: A method to test the safelight(s) in the dark room. An object e.g. a coin or key is placed on a piece of unexposed screen film or an unwrapped dental film with the safelight on and is left for the normal handling time of the

film. Following normal processing, safelight fogging will be obvious if there is a clear area on the film where the coin protected the film from light. The same test can be carried out with desktop automatic processors. N.B. Screen film, due to its greater light sensitivity, is predominately used for this test unless only dental films are used in the practice.

Collimation: A method of restricting the dimensions of the X-ray beam. The term 'field size trimming' is synonymous.

Collective dose: The multiple of average effective dose by the number of people within the population. The measurement is in man-sieverts.

Computed tomography (CT): An imaging procedure in which multiple projections are reconstructed to produce tomographic images of the patient.

Contrast: Differences of density in a radiographic image

Constant potential ('direct current') X-ray generation: This equipment produces an X-ray beam with a higher proportion of high-energy photons and may be accomplished by capacitor smoothing, triodes for ripple suppression or 3-phase supplies.

Controlled area: An area subject to special rules to ensure staff safety and is that area around the X-ray equipment that staff should vacate during an exposure.

Dose area product (DAP): The product of dose and beam area that can be measured using a large area ionisation chamber.

Cross-sectional survey: The observation of a defined population at a single point in time or interval of time in which exposure and outcome are determined simultaneously.

Dental panoramic tomography: This is a technique that produces an image of both jaws and their respective dentitions on a single extra-oral film. The film is known as a **panoramic radiograph**.

Deterministic effects: Effects from ionising radiation in which there is a threshold below which no effect occurs and severity of the effect varies with the dose received.

Diagnostic Reference Levels (DRLs): This measurement represents a reference dose level as part of an optimisation process. They are based upon entrance dose surveys.

Digital radiography: A method of presentation of the image in a digital rather than an analog form.

Dose limits: Dose limits (i.e. effective or equivalent dose) for workers and members of the public are specified in order to minimise detriment from ionising radiation.
Specifically, dose limits are defined in the European Basic Safety Standards as the maximum references for the doses resulting from the exposure workers, apprentices and students and members of the public to ionising radiation that apply to the sum of the relevant doses from external exposures in the specified period and the 50-year committed doses (up to age 70 for children) from intakes in the same period.

Dosemeter: A dose-measuring device. See also *film badge* and *thermoluminescent dose meter (TLD).*

Effective dose: Effective dose is derived from the absorbed doses in specific tissues, the relative effect of the type and energy of radiation encountered, and the relative radiation sensitivity for the stochastic health detriments associated with the specific tissues. It is an indicator of the increase in probability for stochastic effects later in life for a population exposed to the given levels. (ICRP Publication 85. Avoidance of radiation injurie from medical interventional procedures. Ann ICRP 2000, 30(2) Pergamon. Elsevier Science Ltd, Oxford, UK)This is an indicator for the probability of occurrence of stochastic effect and is the sum of the weighted equivalent doses in all of the tissues and organs of the body affected by ionising radiation. Thus the multiplicity of the individual doses received are expressed as a single value representing that radiation dose that would have the same effect if it were applied uniformly to the whole body. The SI unit of measurement is the sievert (Sv).

Entrance surface dose (ESD): This is the dose measured at the surface of an irradiated structure and includes primary radiation. Backscatter from the irradiated mass may or may not be included.

Equivalent dose: This is the product of the absorbed dose multiplied by a radiation weighting factor for the nature of the incident radiation. The SI unit of measurement is the sievert (Sv).

eV: A unit to measure the energy of photons. An electron volt is the amount of energy that an electron gains as it is accelerated by a potential difference of 1 V. X-ray energies are usually measured in Kiloelecton volts.

Exposure: This is defined as the electric charge released per unit mass by ionising radiation. The SI unit of measurement is coulombs per kilogram (C/kg).

Field size: The projection of the X-ray beam on a plane perpendicular to the central ray of X-ray beam.

Film: X-ray film consists of an emulsion sensitive to radiation and to light coated onto a transparent sheet of plastic. 'Direct' film is highly sensitive to X-rays whereas 'screen film' depends upon light absorption, the spectral absorption of which is identically matched to screen emission.

Film badge: A small device consisting of holder containing a variety of filters of differing thicknesses and a double-emulsion film to monitor and determine the energy and type of radiation received.

Film holder: This is the generic term applied to film holding instruments and film holding beam alignment instruments. A film holding instrument localises the film intraorally whereas a film holding/beam alignment device locates the film intraorally and, additionally, aligns the X-ray tube relative to the film.

Film speed: The amount of exposure to X-rays or light required to produce a standard image density.

Filtration: Filtration is the method whereby a material positioned in the emerging beam preferentially absorbs less penetrating radiation. Filtration occurring within the X-ray tube and its housing is known as **inherent filtration** and is measured in aluminium equivalents. See also *Additional filtration* and *K-edge filters.*

Focus-to-film distance: The distance between the focal spot and the film.

Focus-to-skin (FSD) distance: The distance between the focal spot and the skin surface.

Fog: Film fog is the result of development of unexposed silver halide grains by sources other than the primary beam. The darkening of the X-ray film, as a whole or in part, may be due to chemicals, light or non-primary beam.

Gray (Gy): This is the SI unit of absorbed dose.

Guideline: A systematically developed statement designed to assist clinician and patient decisions about appropriate health care in a specific clinical situation.

Half value layer (HVL): The thickness of aluminium required to reduce the X-ray exposure by one-half.

Heredity effects: Effects that occur in the descendents of exposed individuals.

Holder: The person with legal responsibility under national law for a given radiological instillation. In a dental context the ‘installation’ would be a dental practice/clinic.

Image receptor: A method whereby all the information carried by the attenuated emergent X-ray beam can be transferred to a medium suitable for viewing. The method of transfer may be film, photostimulable phosphors or a solid-state detector.

Inverse square law: This law of physics states that the intensity is inversely proportional to the square of the distance from the point source. It was originally related to the physical laws of light but is equally applicable to ionising radiation.

Ionisation: This is the removal of electrons from atoms as an X-ray photon passes through tissue. The effect of ionisation will depend upon where in the cell ionisation has occurred.

K-edge filter: These filters make use of the K-absorption edge of elements with atomic numbers greater than 60. The resultant beam has a significantly narrowed spectrum of energies reducing patient dose, improving image contrast and closely matching spectral sensitivity of film.

Kilovoltage (kv): The potential difference between the anode and the cathode of an X-ray tube.

kVp: The peak(p) kilovoltage (kV) applied across the electrodes of an X-ray tube during an exposure. The kVp defines the maximum energy of the resulting X-rays.

Latitude: This is the range of (log relative) exposures that will produce density within an acceptable range. The latitude of the film varies inversely with the film contrast. Wide latitude films (with lower contrast) allow wider range of subject contrast to be recorded.

Lead apron: A protective apron to reduce radiation exposure.

mAs: This is the product of the electrical current (mA) across the X-ray tube and the exposure time(s).

Meta-analysis: A systematic review that uses quantitative methods to summarise results.

Multiplicative risk projection model: This is an empirically based model in which a constant multiplying factor is applied to the natural incidence of cancers resulting in a higher cancer level at the end of the life span.

Natural background radiation: This is radiation occurring from natural sources. These include cosmic radiation, terrestrial gamma radiation, internal radiation, radon and thoron and their decay products.

Noise: Presence of random fluctuations in image intensity.

Oblique lateral radiograph: This view shows large areas of either the left or right hand sides of the maxilla and mandible with the region imaged dependant on the technique chosen.

Occlusal radiography: These views are taken with the film positioned in the occlusal plane.

Qualified Expert / Medical Physics Expert: An expert in radiation protection physics or radiation technology applied to exposure whose knowledge and training is recognised by the competent authorities and who acts or gives advice on matters relating to radiation protection.

PA: Acronym for **P**osterior-**A**nterior. Used in radiography to define the direction of the primary beam relative to the patient and image receptor e.g. PA skull, PA chest.

Panoramic radiography: Both jaws and their respective dentitions on a single extraoral film, utilising continuous tomographic imaging.

Paralleling technique: In this intraoral technique, the plane of the film is parallel to the long axis of the tooth (teeth) to be imaged with the X-ray beam passing at right angles to both.

Penumbra: This is the secondary shadow that surrounds the periphery of the primary shadow and is a zone of unsharpness.

Periapical radiograph: This is a lateral projection displaying both the crown and root of the tooth and the surrounding bone.

Personal monitoring: The wearing of a small radiation detector (i.e. film badge, TLD, pocket dosemeter) by an individual. These devices are used to record the absorbed or effective dose received by that individual.

Pixel: Is the smallest two-dimensional picture element in a digital image.

Photon: A quantum of electromagnetic radiation.

Photostimulable storage phospor (PSP): Image receptor used in digital radiography.

Poor film/screen contact: This occurs when there is poor contact between the screens and the intervening film resulting in an unshaped image as light diffuses before it reaches the film. This is often due deterioration of the screen backing or damage to the locking mechanism of the cassette.

Position indicating device (PID): This can either be a pointed conical shaped device on older X-ray equipment or an open-ended cylinder on newer equipment. Both are attached to the tube head indicating the direction of the central ray. The PID, when placed adjacent to the patient's skin, delineates the focus to skin distance.

Primary beam: The radiation emanating from the X-ray tube.

Protective screen: This is a barrier used to attenuate the beam and reduce radiation exposure for radiation protection purposes.

Randomised controlled clinical trial (RCT): A group of patients is deliberately randomised into a control group and into an experimental group. These groups are subsequently followed up to determine the variables/outcomes of interest. The technique enhances the statistical validity of any results obtained.

Radiation weighting factor: This is used to relate the absorbed dose to the equivalent dose for the various types and energies of radiation. The radiation weighting factor for X-rays of all energies is one.

Rare earth filtration: Filters using rare earth elements.

Rare earth intensifying screens: Intensifying screens that contain one or more rare earth elements which have increased absorption and significantly greater light conversion efficiency than those of calcium tungstate.

Rectangular collimation: This involves restricting the dimension of the primary beam to a size just slightly larger that the intraoral X-ray film. This optimises dose reduction and can be employed for intraoral radiography.

Resolution: Is the ability of an imaging system to differentiate small, high-contrast objects within the image.

Scattered radiation: Radiation whose direction is changed after interacting with tissue within the patient. This interaction is usually accompanied by a decrease in photon energy.

Screen artefacts: These are caused by dust and/or foreign material covering and thereby reducing light-emission from the surface of the screen.

Sensor: A device for detecting a final image from the X-rays that have been transmitted through the patient.

Sievert: This is the SI unit for equivalent dose and effective dose.

Spatial resolution: See resolution.

Spectral sensitivity of direct film: The sensitivity of film to direct X-ray exposure varies significantly with the energy (kVp) of the X-ray beam. At about 50kVp, the average keV of the X-rays produced will be close to the K-shell binding energy of silver and bromine and the film will exhibit maximum photoelectric absorption. Above this kV, this efficiency dramatically reduces.

Spectral sensitivity of film/screen combination: To obtain optimum efficiency of these systems, the light output of the screen and the maximum sensitivity of the film used must be matched.

Step wedge: A device consisting of increments of thickness of an attenuator which when X-rayed will produce a range of film density.

Stochastic effects: Effects for which the probability of an effect occurring, rather than its severity, is regarded as a function of dose without a threshold.

Systematic review: This is a summary of the medical literature that uses explicit methods with which to perform a thorough literature search in combination with a critical appraisal of individual studies with appropriate statistical techniques to combine these valid studies.

Thermoluminescent (TLD) Dosemeter: This is an extremely sensitive dosemeter containing a crystalline solid and filters to measure and characterise dose received.

Threshold Dose: This is the dose below which a deterministic effect does not occur.

Tissue weighting factor: A factor representing the radiosensitivity of a particular tissue or organ.

X-rays: Electromagnetic radiation of photon energy capable of causing direct ionising radiation. X-rays are generated by the interaction of electrons with matter.

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