Australian Government

Australian Radiation Protection and Nuclear Safety Agency

Code of Practice and Safety Guide

Radiation Protection in Dentistry (2005)

Consultation Draft – July 2005

Radiation Protection Series

The ***Radiation Protection Series*** is published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to promote practices which protect human health and the environment from the possible harmful effects of radiation. ARPANSA is assisted in this task by its Radiation Health and Safety Advisory Council, which reviews the publication program for the ***Series*** and endorses documents for publication, and by its Radiation Health Committee, which oversees the preparation of draft documents and recommends publication.

There are four categories of publication in the ***Series***:

Radiation Protection Standards set fundamental requirements for safety. They are prescriptive in style and may be referenced by regulatory instruments in State, Territory or Commonwealth jurisdictions. They may contain key procedural requirements regarded as essential for best international practice in radiation protection, and fundamental quantitative requirements, such as exposure limits.

Codes of Practice are also prescriptive in style and may be referenced by regulations or conditions of licence. They contain practice-specific requirements that must be satisfied to ensure an acceptable level of safety in dealings involving exposure to radiation. Requirements are expressed in 'must' statements.

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Safety Guides provide practice-specific guidance on achieving the requirements set out in **Radiation Protection Standards** and **Codes of Practice**. They are non-prescriptive in style, but may recommend good practices. Guidance is expressed in 'should' statements, indicating that the measures recommended, or equivalent alternatives, are normally necessary in order to comply with the requirements of the **Radiation Protection Standards** and **Codes of Practice**.

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All publications in the ***Radiation Protection Series*** are informed by public comment during drafting, and **Radiation Protection Standards** and **Codes of Practice**, which may serve a regulatory function, are subject to a process of regulatory review. Further information on these consultation processes may be obtained by contacting ARPANSA.

Australian Government

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CODE OF PRACTICE & SAFETY GUIDE

Radiation Protection in Dentistry

Radiation Protection Series Publication No. #

Consultation Draft: July 2005

This publication was approved by the Radiation Health Committee on dd mmmm yyyy, and the Radiation Health & Safety Advisory Council, at its meeting on dd mmmm yyyy, advised the CEO to adopt the Code of Practice and Safety Guide.

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The mission of ARPANSA is to provide the scientific expertise and infrastructure necessary to support the objective of the ARPANS Act — to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation.

Published by the Chief Executive Officer of ARPANSA in [MONTH YEAR]

Foreword

John Loy
CEO of ARPANSA

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Australian Government

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CODE OF PRACTICE

Radiation Protection in Dentistry

Radiation Protection Series Publication No. #

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1. Introduction

1.1 CITATION

This Code may be cited as the *Code of Practice for Radiation Protection in Dentistry (2005).*

1.2 BACKGROUND

This Code of Practice replaces an earlier code entitled *Code of Practice for Radiation Protection in Dentistry (1987)* published by the National Health and Medical Research Council, following its one hundred and third session in June 1987.

Radiology plays an essential part in dental health practice and clinicians who advise patients to undergo X-ray examinations must be aware of the nature of any possible harmful effects and of the risks involved (see Safety Guide, Annex 1 for further information). If the principles and practices set out in this Code are adopted a satisfactory radiograph should be obtained with a minimum exposure to radiation of the patient, the clinician and other persons involved with the examination.

1.3 PURPOSE

This Code has been prepared to establish practices and procedures in the use of ionizing radiation in dentistry that will ensure that the risk of radiation exposure to the patient, clinician and other persons is minimised.

This Code lays down detailed requirements for the following protective measures:

- allocation of responsibility;
- need for clinical assessment of the indications for radiography;
- provision of appropriate equipment, film and processing facilities;
- adoption of procedures to minimise exposure to radiation.

The Code is intended to be used as a supplement to the relevant radiation control regulations applicable in the States and Territories and the Commonwealth (see Annex 2 for details of Radiation Protection Authorities). Where there is a conflict between this Code and the legislation of the States, Territories or the Commonwealth, the provisions of the legislation prevail.

1.4 SCOPE

This Code applies to the responsible person[1] and to any person performing a dental radiographic examination (e.g. dentists, radiographers, dental therapists, dental hygienists and dental assistants with extended duties) in dental practice, and to persons supplying, installing and servicing dental X-ray equipment.

This code deals with radiographic procedures used in general and specialist dental practice, including:

- intra-oral radiography: periapical, bitewing and occlusal views;
- panoramic radiography;

[1] See glossary

- cephalometry;
- other forms of radiography of the complete skull or certain parts of the dento-maxillofacial region;
- hand and wrist radiography for the purpose of the determination of the bone age.

Certain of the above procedures may be restricted or have special licensing requirements in some jurisdictions. Licensees may be restricted to possessing specified types of dental X-ray equipment and/or performing specified types of radiographic examinations. Licences for different categories of staff may specify different responsibilities for each category.

1.5 STRUCTURE

The Code of Practice sets out requirements to be met to achieve a satisfactory level of radiation protection. It sets out material that may be adopted by State, Territory and Commonwealth regulatory authorities as part of their regulatory controls, and in conditions of licence or registration associated with the use of ionizing radiation within their jurisdiction.

Schedules set out additional information that form part of the Code of Practice, and are therefore part of the material referenceable by regulatory authorities.

Material in the Annexes is for clarification and guidance only. It does not form part of the Code that may be adopted by regulatory authorities.

2. Responsibilities

2.1 Overall Responsibility

2.1.1 The responsibility for radiation protection lies with the person (the Responsible Person for the purposes of this Code) in control of the institution, department or practice using the dental X-ray equipment.

2.2 Responsibilities of the Responsible Person

2.2.1 The Responsible Person must be familiar with all requirements of the regulatory authority including registration, licensing, controlled or supervised radiation areas, monitoring, recording of personal doses, reporting, surveying, maintenance and quality control checks.

2.2.2 The Responsible Person must ensure that radiation doses:

(a) are kept as low as reasonably achievable; and

(b) do not exceed the appropriate dose limits specified in Schedule 1.

2.2.3 The Responsible Person must appoint a Radiation Safety Officer (who may also be the Responsible Person) who has sufficient professional and/or technical training to:

(a) supervise radiation protection in order to minimise personal radiation doses;

(b) advise staff on safe working practices in accordance with all legislation and codes of practice;

(c) consult and liaise with the regulatory authority;

(d) ensure that all relevant regulatory matters are duly processed;

(e) arrange for monitoring of areas, equipment and operations as required;

(f) ensure that suitable personal and other monitoring devices are provided where required, kept in good working order, properly used, and calibrated;

(g) arrange for records to be kept of effective doses where determined for individuals;

(h) arrange for any required medical services to be provided and for records to be kept;

(i) record and report to the Responsible Person and the appropriate authorities any unsafe practices or accidents;

(j) prepare local rules for the handling of any foreseeable accidents and emergencies, assemble an emergency kit and take charge of such situations;

(k) maintain current records of all irradiating apparatus and locations;

(l) arrange for any records required by sub-clause (k) to be kept for a period specified by the appropriate authority;

(m) provide advice, instruction and local rules on radiation safety in an easily understandable form and at an adequate level for persons involved in dental radiography;

(n) perform any other tasks that may be necessary to maintain a high standard of radiation safety in the establishment; and

(o) determine which staff are to be designated 'persons occupationally exposed to radiation'.

2.2.4 The Responsible Person must ensure that the Radiation Safety Officer has the authoritative standing to implement this Code.

2.2.5 The Responsible Person must determine the work procedures that are necessary to enable the implementation of this Code.

2.2.6 The Responsible Person must provide all the facilities and/or equipment that are necessary to enable the implementation of this Code.

2.2.7 The Responsible Person must support all the requirements for the implementation of the Radiation Safety Officer's responsibilities.

2.2.8 The Responsible Person must ensure that:

(a) the use of dental X-ray equipment constitutes minimal risks to patients, operators and other staff in the practice as well as to persons who are in or near the premises where the dental X-ray equipment is installed.

(b) the installation and operation of dental X-ray equipment complies with the regulations of the relevant State, Territory or Commonwealth jurisdiction. In most jurisdictions, this includes ensuring that the dental X-ray equipment is used only by operators holding appropriate licences.

(c) adequate X-ray viewing conditions and adequate film or electronic image processing and archiving conditions are provided.

(d) X-ray equipment and processing equipment undergo maintenance on a regular basis and complies with the regulations of the relevant State, Territory or Commonwealth jurisdiction and with the recommendations of the manufacturers.

2.2.9 The Responsible Person must ensure that plans for buildings that are to incorporate dental radiographic facilities, including details of any shielding, are submitted to the regulatory authority before commissioning.

2.2.10 The Responsible Person, in consultation with the regulatory authority, must ensure that appropriate radiation safety assessments are made by an appropriately qualified person for the following circumstances:

(a) before the dental X-ray equipment is put into routine use;

(b) where the dental X-ray equipment is to be replaced or modified, or working procedures are to be modified[2];

[2] 'Modified' means a change in the amount of radiation, the manner of its use or a change in the X-ray equipment or its location. Such modifications may mean the original protection is no longer adequate.

(c) where personal monitoring indicates that the doses received by any person exceed, or are likely to exceed the appropriate dose limits or are higher than normal for no obvious reason, or are higher than average doses received in similar departments and practices;

(d) where changes are to be made in the immediate environs that may result in an increase of occupancy[3];

(e) where an increase in workload in the department or practice is anticipated; or

(f) whenever any servicing is carried out on the X-ray tube assembly.

2.2.11 If at any time a radiation safety assessment indicates that any person has or may have received doses in excess of the relevant effective dose limits, or the relevant dose constraints established, the Responsible Person must notify the regulatory authority.

2.3 PERSONAL MONITORING AND DOSE RECORDS

2.3.1 The Responsible Person must provide personal monitoring for all staff involved in radiography, unless a radiation safety assessment demonstrates that doses are not significant and an exemption is granted by the regulatory authority.

2.3.2 Radiation dose records must be maintained by the Responsible Person for each person occupationally exposed to radiation as required by the regulatory authority.

2.3.3 Radiation dose records must show:

(a) doses assessed during the present period of employment; and

(b) doses assessed as a result of any previous employment in which ionizing radiations were used.

2.3.4 Radiation dose records must be available for inspection by:

(a) the individu-al to whom the record applies; and

(b) the regulatory authority.

2.4 RESPONSIBILITY OF THE CLINICIAN OPERATING THE DENTAL X-RAY EQUIPMENT

2.4.1 Where the clinician operating the dental X-ray equipment is a dentist, the dentist must ensure that:

(a) radiological examinations are carried out properly at all times during the course of dental treatment. This responsibility covers the following components of the examination:

i) determination of clinical need for the examination

ii) selection of the most appropriate method of examination

iii) optimising radiographic techniques

[3] An example would be a store or waiting area becoming an office.

iv) the use of optimal film or electronic image processing techniques

v) interpretation of radiographs

vi) maintenance of radiographic records.

(b) where, if permitted by legislation of the relevant State, Territory or the Commonwealth, a dentist delegates some of the components of conducting an examination to another appropriately authorised person, the dentist must remain ultimately responsible for all of the aspects of the examination specified in 2.2.1.

(c) staff to whom aspects of radiographic examination are delegated are properly trained and that work practices of all staff involved with radiological examinations are reviewed on a regular basis.

2.4.2 Where the clinician operating the dental X-ray equipment is not a dentist the restrictions and responsibilities as specified in the legislation of the relevant State or Territory apply.

2.5 REFERRALS FOR RADIOGRAPHIC EXAMINATION

In cases where patients are referred for radiographic examination, clinical notes must be provided. These notes must contain both the reason for the radiological examination as well as an adequate history. If any radiographs were taken in relation to the condition prior to the referral, these or the reports must also be included where relevant.

2.6 MAINTENANCE OF PATIENT'S RADIOGRAPHIC RECORDS

In order to avoid unnecessary radiation doses, radiographic images and adequate records must be kept for a period of at least 7 years unless the radiographic images are sent to another practitioner. In the case of minors the records must be kept for a minimum of 7 years after they reach adulthood (18 years of age).

2.7 RESPONSIBILITIES OF PERSONS SUPPLYING, INSTALLING AND SERVICING DENTAL X-RAY EQUIPMENT

2.7.1 The supplier is responsible for ensuring that:

(a) dental X-ray equipment complies with the relevant Australian Standards or the requirements of the regulatory authority; and

(b) the purchaser is authorised by the regulatory authority to possess dental X-ray equipment.

2.7.2 The person installing, repairing or modifying dental X-ray equipment must:

(a) be licensed, where required by the regulatory authority;

(b) ensure that the setting for the image receptor sensitivity of newly installed, serviced or modified equipment complies with the sensitivity of the most frequently used image receptors;

(c) ensure that X-ray equipment fitted with an object programmed exposure control (i.e. where the user selects the exposure from an icon showing a representation of the tooth or part to be examined) is adjusted to match the speed of the image receptor in use; and

(d) set any default parameters for digital imaging so that the minimum exposure that is needed to obtain a satisfactory image is used.

2.8 COMPLIANCE TESTING OF X-RAY EQUIPMENT

2.8.1 The regulatory authority may require X-ray equipment to be tested and certified to be in compliance with the relevant Australian Standards and/or local regulations prior to its use on humans. Persons undertaking these tests must be licensed or otherwise authorised by the relevant regulatory authority listed in Annex 2.

2.8.2 Where compliance testing of dental X-ray equipment at regular intervals is required by the regulatory authority, the responsible person must ensure that testing is carried out at the prescribed intervals.

3. Type and frequency of radiographic examination in dental practice

3.1 Clinical Assessment of the Need for Radiography

3.1.1 The nature and extent of an actual or a suspected dental condition, its early detection, treatment and response to treatment must be the primary determining factors in submitting the patient to radiographic examination.

3.1.2 Radiology must not be used as a substitute for a clinical investigation, and therefore radiography must not be undertaken until a medical history has been taken and a preliminary clinical examination has been performed.

3.1.3 Radiology is a most valuable aid to oral diagnosis, but it must be employed in accordance with the dental and general health needs of the individual patient.

3.2 Research Projects Involving the Irradiation of Humans

3.2.1 Where a project is to be undertaken for research purposes on humans the research must conform to generally accepted moral and scientific principles.

3.2.2 To be medically justified, the information gained must be used to affect the care of people discovered to have a particular condition. For each project, there must be full compliance with the NHMRC's *National Statement on Ethical Conduct in Research Involving Humans* (1999) and the relevant requirements of *ARPANSA's Recommendations for Limiting Exposure to Ionizing Radiation and National Standard for limiting Occupational Exposure to Ionizing Radiation.* Radiation Protection Series Publication No. 1 (2002), and approval for a project must be obtained from the regulatory authority, where necessary.

3.2.3 Such projects must be so designed that the frequency of radiographic examinations and the number of films per examination is the minimum necessary and every effort must be made to provide the individual patient with some direct benefit from the examinations made. Recommended dose constraints apply in cases where there is no direct benefit to volunteers.

4. Equipment and site requirements

4.1 Compliance with Australian Standards and Regulatory Authority Requirements

4.1.1 The specifications of Australian Standard AS/NZS 3200.2.201 (refer Annex 2) apply to the following X-ray equipment used for general and specialist dental practice:

(a) X-ray equipment for use with intra-oral image receptors;

(b) X-ray equipment for panoramic radiography; and

(c) dedicated cephalometric X-ray equipment.

4.1.2 Dental X-ray equipment which is in use at the time of introduction of this code, and which does not comply with the relevant requirements of AS/NZS 3200.2.201, must be modified to comply with the requirements, except where otherwise approved by the regulatory authority, or phased out of use on a time scale approved by the regulatory authority. Note that it may not be practical to modify some old equipment.

4.1.3 Dental X-ray equipment must not be used for fluoroscopy.

4.1.4 Equipment designed for intra-oral radiography must not be used for any other type of radiographic examination. Radiography of the mandible, including temporo-mandibular joints, must be conducted only on general purpose medical X-ray equipment or on special purpose equipment designed for such examinations and authorised as required by the regulatory authority.

4.1.5 Hand and wrist radiography (which may be required for bone age determination) must only be performed on medical X-ray equipment or on special purpose equipment designed for such examinations, and operated by appropriately trained and licensed persons.

4.1.6 General purpose medical X-ray equipment must not be used for intra-oral dental radiography.

4.2 Location of X-ray Units and Provision of Structural Shielding

4.2.1 The responsible person must ensure that there is appropriate radiation shielding in the X-ray room and appropriate shielding for operators, such that no person receives a radiation dose in excess of the relevant radiation protection limit.

4.2.2 Approval for the structural shielding and other radiation safety measures may be required by the regulatory authority before X-ray equipment is used on humans. The responsible person must ensure that this approval is obtained where required.

5. Image receptors and film processing

5.1 DIGITAL IMAGING SYSTEMS

5.1.1 A record must be kept of all exposures made using digital equipment in the form of a hard copy of the image, a written diagnostic report or a computer record with appropriate back-up.

5.1.2 The image receptor must be of an appropriate size and compatible with the X-ray unit.

5.1.3 Operators must be appropriately trained in the use of digital imaging systems.

5.2 FILM SIZES AND APPLICATIONS

5.2.1 Films must not have passed the manufacturer's recommended expiry date.

5.2.2 Intra-oral films must comply with the appropriate ISO Standard (currently ISO 3665).

5.3 USE OF HIGH SPEED FILM

5.3.1 The fastest radiographic film consistent with providing the diagnostic information sought ('D' speed or greater) must be used to ensure the least possible radiation dose to the patient (refer also to Safety Guide, Annex 2).

5.3.2 With respect to extra-oral radiography, intensifying screens and an appropriate radiographic film intended for use with the particular type of intensifying screens must be used as the image receptor.

5.3.3 The fastest film-screen combination consistent with the required radiographic quality must be used.

5.3.4 Radiographic film without intensifying screens must not be used for radiological purposes other than for intra-oral dental radiography.

5.4 STORAGE OF UNEXPOSED FILMS

5.4.1 Unexposed X-ray films must be stored in accordance with manufacturer's recommendations, in a container away from excessive heat, humidity or chemical contamination (eg from film processing chemicals), and adequately shielded against ionizing radiation or in an area remote from any X-ray unit .

5.5 PROCESSING OF FILMS[4]

5.5.1 Manual processing of films must be in accordance with the manufacturer's recommendations and must satisfy the following requirements:

(a) Temperature of developing solutions must be measured;

(b) An appropriate time-temperature chart must be used to determine the processing time;

[4] Additional information on film processing is provided in Annex 3.

(c) The temperature must be maintained during processing; and

(d) The time of processing must be measured.

5.5.2 Films must not be processed by sight.

5.5.3 The concentrations of developing solutions must be in accordance with the manufacturer's specifications.

5.5.4 Developer must be replenished or replaced at appropriate intervals to maintain adequate image quality at acceptable patient doses.

5.6 QUALITY ASSURANCE OF PROCESSING

5.6.1 Exposure techniques must not be adjusted to compensate for inadequate film processing.-

5.6.2 An appropriate quality assurance program on film processing must be implemented to ensure that radiographs are of adequate diagnostic quality.

6. Procedures to minimise exposure to ionizing radiation

6.1 Use of Exposure Charts

Where exposure factors for specific examinations are not marked on the unit, a table of appropriate exposure factors must be displayed near the X-ray unit control panel.

6.2 Persons in the Room during Radiography

6.2.1 No person must be present in the room during a radiographic exposure unless:

(a) their presence is necessary for the conduct of the examination; and

(b) they are either

(i) behind a shield;

(ii) wearing a protective apron, or

(iii) are at least 2 metres from the X-ray tube and not in line with the primary beam.

6.2.2 Employees who have no direct involvement in work that requires exposure to radiation must have their exposure controlled such that their doses do not exceed the limit for members of the public.

6.3 Exposure to the Primary X-ray Beam

Under no circumstances must the operator or any member of the dentist's staff be exposed to the primary beam during a radiographic exposure or during testing of the equipment.

6.4 Holding of Image Receptor and Standardisation of Technique by using Image Receptor Holders

The image receptor must not be held in position by the operator or any member of the dentist's staff either by hand or with forceps.

6.5 Holding of X-ray Unit

No person must hold any part of the X-ray tube head during a radiographic exposure.

6.6 Holding of Patients

Neither the operator nor and any member of the dentist's staff must hold patients during radiographic examinations. If parents or other persons are called to assist, they must be provided with protective aprons and be positioned so as to avoid being exposed to the primary X-ray beam. One person must not regularly perform these duties.

6.7 Position of Operator during Exposure

6.7.1 With respect to the use of distance as a means of reducing radiation dose, the operator must stand outside the primary beam and either:

(a) at least 2 metres away from both the X-ray tube head and the patient;

(b) behind structural shielding of an adequate area and thickness;

(c) behind a protective screen; or

(d) wearing a protective apron.

6.7.2 Where a protective screen is provided, the exposure control must be arranged so that it can only be operated from within the protected area.

6.7.3 The operator must be able to observe the patient during dental radiographic procedures.

6.8 PERSONAL MONITORING

6.8.1 Persons involved in dental radiography must make proper use of personal monitoring devices provided by the Responsible Person.

6.8.2 Personal monitors must not be worn when the wearer is undergoing any medical or dental radiography as a patient.

Schedule 1

ARPANSA *Recommendations for limiting exposure to ionizing radiation (2002)* – Dose Limits

Application	Dose Limits[1]	
	Occupational	**Public**
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years[2,3]	1 mSv in a year[4]
Annual equivalent dose in:		
the lens of the eye	150 mSv	15 mSv
the skin[5]	500 mSv	50 mSv
the hands and feet	500 mSv	–

1 The limits shall apply to the sum of the relevant doses from external exposure in the specified period and the 50-year committed dose (to age 70 years for children) from intakes in the same period.

2 With the further provision that the effective dose shall not exceed 50 mSv in any single year. In addition, when a pregnancy is declared by a female employee, the embryo or fetus should be afforded the same level of protection as required for members of the public.

3 (DELETED)

4 In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

5 The equivalent dose limit for the skin applies to the dose averaged over any 1 cm^2 area of skin, regardless of the total area exposed.

_____

NOTE 1: The above dose limits table has been directly extracted from ARPANSA's *Recommendations for limiting exposure to ionizing radiation (1995),* [republished as RPS 1 in 2002]. However, as the Radiation Health Committee now advises that the exceptional circumstances clause is not recommended for use in Australia, note 3 of the table in RPS 1 has been deleted from this Code.

NOTE 2: Exposure to radiation from natural sources is generally excluded from occupational or public exposure, except when the exposure is a direct consequence of a practice or is specifically identified by the appropriate authority as requiring control through the implementation of a program of radiation protection. Medical exposure includes doses received by patients undergoing medical diagnosis or therapy, doses received by volunteers in medical research, and doses received knowingly and willingly by persons other than health care workers as a consequence of their proximity to an exposed patient. Dose limits do not apply to exposures from natural sources, except as described above, or to medical exposures.

References and Further Reading

1. REFERENCES

ICRP (1991) 1990 *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60.

International Organization for Standardization (1996) *Photography-Intra-oral dental radiographic film-Specification* ISO Standard 3665-1996.

Le Heron J. (1997) *Lead Aprons - Should they be used for dental x-rays?* ACPSEM Bulletin May 1997.

National Radiation Laboratory (New Zealand) *Code of Safe Practice for the use of X-rays in Dentistry* NRL C7

National Radiation Laboratory (New Zealand) *Radiation Doses to Patients from Dental Radiography in New Zealand*. Report NRL 1990/6

National Radiological Protection Board (1994) *Documents of the NRPB. Guidelines on Radiology Standards for Primary Dental Care*. Doc. Vol 5, no 3, 1994

National Radiological Protection Board (2001) *Guidance Notes for Dental Practitioners on the Safe Use of X-Ray Equipment*

Standards Australia AS 3200.1 (1990) Approval and Test Specification - *Medical Electrical Equipment Part 1 - General Requirements for Safety*.

Standards Australia AS 3200.1.3 (1996) Approval and Test Specification - *Medical Electrical Equipment Part 1.3 - General Requirements for Safety - Collateral Requirements for Radiation Protection in Diagnostic X-ray Equipment*.

Standards Australia AS 3200.2.201 (1996) Approval and Test Specification - *Medical Electrical Equipment Part 2.201 - Particular Requirements for Safety - Dento-Maxillofacial X-ray Equipment*.

Standards Australia AS 3200.2.7 (1994) Approval and Test Specification - *Medical Electrical Equipment Part 2.7- Particular Requirements for Safety - High Voltage Generators of Diagnostic X-ray Generators*.

Standards Australia AS 3200.2.7 (1994) Approval and Test Specification - *Medical Electrical Equipment Part 2.7- Particular Requirements for Safety - X-ray source Assemblies for Diagnosis Generators*.

Tingey, D.R.C. (1983) *Quality control procedure for dental X-ray film processing*. Report No. ARL/TR059, Australian Radiation Laboratory, Yallambie.

World Health Organization (1977) *Manual on radiation protection in hospitals and general practice* (Vol. 4. 'Radiation protection in dentistry'), WHO, Geneva, Switzerland.

2. FURTHER READING

Australian Dental Association (2000). *The Practical Guides* 6th edition, ADA Inc. (ISBN 0909961 34 4).

Langlais P., O.E. Langland & C.J. Nortjé (1995) *Diagnostic imaging of the jaws*, Lea & Febiger, Baltimore.

National Health and Medical Research Council 1985, *Recommendations for minimizing radiological hazards to patients*, Radiation Health Series No. 14, AGPS, Canberra.

White S.C. & Pharoah M.J. (2000) *Oral Radiology – Principles and Interpretation 4th ed.* Mosby, St Louis.

Glossary

Absorbed dose

The energy absorbed per unit mass by matter from ionizing radiation which impinges upon it. The unit of absorbed dose is the joule per kilogram (J/kg) with the special name gray (Gy).

Beam applicator

An accessory device on dental X-ray equipment used to indicate the position of the useful beam and to establish a definite focus-skin distance.

Collimator

A fixed or adjustable device to limit the useful beam to specific dimensions.

Contrast

The difference in photographic density between various image areas.

Dead-man switch

A switch used to initiate an X-ray exposure which will automatically terminate the exposure when released.

Dose

A generic term for absorbed dose, equivalent dose or effective dose depending on the context in which it is used. As a general rule, absorbed dose or equivalent dose is relevant where reference is made to doses received at a particular point or for a dose to an organ. Effective dose is used when the risk from an exposure needs to be compared to a whole body dose.

Dose rate

The dose per unit time.

Effective dose (E_T)

A measure of dose which takes into account both the type of radiation involved and the radiological sensitivities of the organs and tissues irradiated. The effective dose is given by the expression:

$$E = \sum_T W_T H_T$$

Where H_T is the equivalent dose in organ or tissue T and W_T is the weighting factor for that organ or dose. The unit of effective dose is the same as for equivalent dose, J/kg, with the special name sievert (Sv)

Equivalent Dose (H_T)

A measure of dose in tissues which takes into account the type of radiation involved. The equivalent dose is given by the expression:

$$H_T = \sum_R W_R D_{T,R}$$

where $\mathbf{D_{T,R}}$ is the absorbed dose averaged over the organ or tissue and $\mathbf{W_R}$ is the weighting factor for the radiation type and quality. The unit of dose equivalent is the joule per kilogram (J/kg). The special name of the unit of dose equivalent is the sievert (Sv). (In general for X-rays the absorbed dose is the same as the equivalent dose.)

Exposure (unit)

The amount of ionization in air produced by X-rays or gamma rays. Unit is coulombs per kilogram C/kg. Air kerma is more commonly used.

Exposure

The actuation of X-ray equipment producing radiation.

Exposure factors

The X-ray tube potential in kilovolts (peak) (kV peak) and milliamperes (mA) and the exposure time in seconds (s), or the product of the tube current and exposure time in milliampere seconds (mAs).

Filtration

The modification of the spectral distribution of an X-ray beam as it passes through matter, due to the preferential attenuation of particular photon energies in the radiation beam.

Added filtration: quantity indicating the filtration effected by added filters in the useful beam, but excluding inherent filtration.

Inherent filtration: the filtration effected by the irremovable materials of the X-ray tube assembly through which the radiation beam passes before emerging from the X-ray tube assembly.

Total filtration: the total of inherent filtration and added filtration between the radiation source and the patient or a defined plane.

Focus-film distance

The distance between the point within the X-ray tube from which X-rays originate and the plane in which the film is located.

Focus-skin distance

The distance between the point within the X-ray tube from which X-rays originate and the entrance plane in which the patient's skin is located.

Half value layer

The thickness of a specified material which reduces the exposure or kerma rate in air of a given X-ray beam to half its original value.

Kerma

The Kinetic Energy Released per unit Mass in material by ionizing radiation. The unit of kerma is the joule per kilogram (J/kg). The special name of the unit is the gray (Gy). Kerma is a useful unit because it has almost identical properties to Exposure.

Lead equivalent

At a specified kilovoltage (kV peak) and x-ray beam quality, the thickness of lead effecting the same attenuation as the material under consideration.

Leakage radiation

Ionizing radiation transmitted through the protective shielding surrounding a radiation source.

Optical density

The logarithm to the base 10 of the ratio of incident light to the transmitted light through processed film.

Panoramic radiography

Radiography of the mandible and the maxilla performed by the controlled rotation of an extra-oral X-ray source and an extra-oral image receptor around one or more axes in relation to the patient's head.

Responsible Person

In relation to any radioactive source, radiation apparatus, prescribed radiation facility or premises on which unsealed radioactive sources are stored or used means the person:

(a) having overall management responsibility including responsibility for the security and maintenance of the source, apparatus, or facility;

(b) having overall control over who may use the source or apparatus, or facility; and

(c) in whose name the source, apparatus, or facility, would be registered if this is required.

Scattered radiation

Ionizing radiation resulting from the interaction of ionizing radiation with matter.

Sievert (Sv)

The special name of the unit of equivalent dose and effective dose. It has units of joule per kilogram (J/kg).

Speed or sensitivity of an X-ray film

The reciprocal of the exposure required to produce an optical density of 1.0 above gross fog for specified exposure and processing conditions.

Useful beam

(From a source of ionizing radiation) all ionizing radiation which emerges through the specified aperture of its protective shielding and its beam collimator.

X-ray tube current

The electric current flowing through an X-ray tube during an exposure expressed in milliamperes (mA).

X-ray tube potential difference

The peak value of the potential difference applied to the X-ray tube expressed in kilovolts (peak) (kVp).

Annex 1

Summary of AS/NZ 3200.2.201: 2000.

Approval and Test Specification-Medical Electrical Equipment. Part 2.201 Particular Requirements for Safety - Dento-maxillofacial X-ray Equipment

The following summary of the radiation safety aspects of Australian Standard AS/NZ 3200.2.201 is intended to provide general information on X-ray equipment requirements. It is not intended as a substitute for the standard, which includes many additional requirements and performance criteria.

The standard requires that:

(a) the X-ray equipment must be designed to permit the operator to preset exposure factor(s) without the need for energising the X-ray tube to check on the operation of the equipment;

(b) where the X-ray equipment operates at fixed potential differences and currents, the exposure factors must be indicated in the accompanying documents and on labels attached to the equipment;

(c) the selected tube potential difference, tube current and exposure time or current time product must be indicated by analogue meters, digital displays or scales, or by calibrated permanent markings;

(d) a green indicator on the control panel must indicate when the main switch is in the 'ON' position and the control panel is energised;

(e) a clearly visible amber light must indicate when the X-ray tube is energised;

(f) the 'beam on' indicator must be clearly marked, or its function appropriately set out in the instruction documents. In addition, a signal audible to the operator other than the sound produced fortuitously by switching devices or contactors during the exposure is to indicate either the duration of the exposure or its termination. Both signals are to be at the control panel, or, for remotely controlled equipment, at the position of the operator;

(g) the exposure switch must be arranged so that the X-ray equipment can be operated from a distance of at least 2 metres from the x-ray tube and the patient;

(h) the exposure switch must be of the dead-man type;

(i) all X-ray equipment must be equipped with electronic timers;

(j) the timer must terminate an exposure at a preset time interval or at a preset product of current and time. It must not be possible to initiate an exposure if the timer is set to zero;

(k) it must be possible to alter the timer setting to a higher or lower value after the initial adjustment without initiating an exposure;

(l) where there is an image receptor sensitivity control, the exposure setting and/or the setting for digital radiography must be clearly indicated, and the last selected value must be the default;

(m) the X-ray tube must be surrounded by a protective housing or other protective shielding. For all dental equipment other than that used with intra oral receptors, the kerma in air from leakage radiation from a tube assembly, including cones, diaphragms and collimator, must not exceed 1 mGy in any 1 hour period at a distance of 1 metre from the focal spot; and

(n) the accuracy of the output controls, and requirements for reproducibility and linearity must be that which is given in detail in the standard.

In addition, the standard requires the following for the equipment specified:

1. *For extra-oral X-ray tubes with intra-oral image receptors*:

   (a) the X-ray equipment must be operated at potential differences of between 60 kV (peak) and 90 kV (peak);

   (b) the maximum dimension of the X-ray field at the open end of the beam applicator is not to exceed 60 mm;

   (c) only open ended beam applicators must be used and these must limit the focus - skin distance to not less than 200mm;

   (d) the total filtration must be such as to ensure that the measured half-value layer is equal to or greater than that specified in Table 1; and

   (e) the kerma in air from leakage radiation from a tube assembly, including cones, diaphragms and collimator, must not exceed 0.25 mGy in any 1-hour period at a distance of 1 metre from the focal spot.

2. *For X-ray equipment used for dental panoramic radiography*:

   (a) X-ray equipment used for dental panoramic radiography must be operated at potential differences of between 55 kV (peak) and 125 kV (peak);

   (b) the dimensions of the useful beam at the secondary collimator must be determined by the beam-limiting device at the X-ray tube housing and must not exceed either of the two dimensions of the slot in the secondary collimator or the film height; and

   (c) the total filtration must be such as to ensure that the measured half-value layer is equal to, or greater than, that specified in Table 1.

3. *For X-ray equipment for cephalometric radiography*:

   (a) X-ray equipment for cephalometric radiography must be operated at potential differences of between 60 kV (peak) and 125 kV (peak);

   (b) a beam-limiting device must be provided to restrict the radiation field to the image receptor area. The dimensions of this field must not exceed 240 mm x 300 mm;

   (c) means must be provided to limit the focus-skin distance to not less than 1500 mm;

   (d) the detailed requirements given in the standard for the operation of the light beam collimator must be met; and

   (e) the total filtration must be such as to ensure that the measured half-value layer is equal to, or greater than, that specified in Table 1.

Table 1 Half-value layer of the useful beam at given potential difference

Equipment type	Measured potential kV (peak)	Minimum Permissible first Half-value layer mm Al
Intra-oral receptor	50	Not permitted
	60	1.5
	70	1.5
	>70	See other dental equipment
Other dental equipment	50	1.5
	60	1.8
	70	2.1
	80	2.3
	90	2.5
	100	2.7
	110	3.0
	120	3.2
	125	3.3

Annex 2

Radiation Protection Authorities

Where advice or assistance is required from the relevant radiation protection authority, it may be obtained from the following officers:

COMMONWEALTH, STATE / TERRITORY	CONTACT
Commonwealth	Director, Regulatory Branch ARPANSA PO Box 655 Tel: (02) 9541 8333 Miranda NSW 1490 Fax: (02) 9541 8348 Email: info@arpansa.gov.au
New South Wales	Director Radiation Control Department of Environment and Conservation P.O. Box A290 Tel: (02) 9995 5000 Sydney South NSW 1232 Fax: (02) 9995 6603 Email: radiation@environment.nsw.gov.au
Queensland	Director, Radiation Health Department of Health 450 Gregory Terrace Tel: (07) 3406 8000 Fortitude Valley QLD 4006 Fax: (07) 3406 8030 Email: radiation_health@health.qld.gov.au
South Australia	Director, Radiation Protection Division Environment Protection Authority PO Box 721 Tel: (08) 8130 0700 Kent Town SA 5071 Fax: (08) 8130 0777 Email: radiationprotection@state.sa.gov.au
Tasmania	Senior Health Physicist Health Physics Branch Department of Health and Human Services GPO Box 125B Tel: (03) 6222 7256 Hobart TAS 7001 Fax: (03) 6222 7257 Email: health.physics@dhhs.tas.gov.au
Victoria	Manager, Radiation Safety Program Department of Human Services GPO Box 4057 Tel: (03) 9637 4167 Melbourne VIC 3001 Fax: (03) 9637 4508 Email: radiation.safety@dhs.vic.gov.au
Western Australia	Secretary, Radiological Council Locked Bag 2006 PO Tel: (08) 9346 2260 Nedlands WA 6009 Fax: (08) 9381 1423 Email: radiation.health@health.wa.gov.au
Australian Capital Territory	Manager Radiation Safety Radiation Safety Section ACT Health Locked Bag 5 Tel: (02) 6207 6946 Weston Creek ACT 2611 Fax: (02) 6207 6966 Email: radiation.safety@act.gov.au
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health and Community Services GPO Box 40596 Tel: (08) 8922 7152 Casuarina NT 0811 Fax: (08) 8922 7334 Email: envirohealth@nt.gov.au

Please note: This table was correct at the time of printing but is subject to change from time to time. For the most up-to-date list, the reader is advised to consult the ARPANSA web site (www.arpansa.gov.au).

For after hours emergencies only, the police will provide the appropriate emergency contact number.

Annex 3

Use and Processing of Dental Films

INTRODUCTION

Too great an emphasis cannot be placed on the need for high standards of practice in the use and processing of dental films. The quality of a finished radiograph and its ability to provide the maximum amount of diagnostic information depends upon a number of factors, such as type of film (or film-screen combination), the film size and application, radiographic technique, exposure factors and processing. To produce high quality films it is of the utmost importance that as many of these factors as possible be standardised. Standardisation of processing is best achieved by using automatic processors with temperature control.

1. CHOICE OF FILM

(a) Film Size

The choice of film size that is inappropriate for the particular examination may result in an unnecessary radiation dose to the patient, as the radiograph may have to be repeated due to the distortion of the image.

Consequently, it is recommended that intra-oral films should be used for applications appropriate to their size, as follows:

Size number	*Dimensions (mm)*	*Applications*
0	22 × 35	(i) periapical radiographs of deciduous teeth (ii) bitewing radiographs of deciduous teeth
1	24 × 40	(i) periapical radiographs of permanent incisors and canines (ii) bitewing radiographs of mixed dentitions
2	31 × 41	(i) occlusal views of very small children (ii) periapical radiographs of permanent premolars and molars (iii) bitewing radiographs of permanent dentitions
3	27 × 54	not recommended for use
4	57 × 76	Occlusal views of adults and children

(b) Film Speed

The choice of film speed is also of importance. For a given set of exposure conditions involving selected values of (peak) kilovoltage (kV (peak)), tube current (mA), exposure time, focus-film distance and filtration, the photographic density of a dental radiograph will depend markedly on the speed of the film used. High speed dental films result in the use of a lower mA and exposure time product than films of lesser speed. The selection of the optimum tube current and exposure time product can result in a significant reduction in the radiation dose to the patient and to the dentist and staff. The use of high speed dental films may necessitate a modification of radiographic technique and/or the X-ray unit. The mA and exposure time product may be reduced by decreasing either or both of these operating factors. Many dental X-ray units are designed for operation at fixed mA, and as such, it may be possible for the supplier of the dental X-ray unit to adjust the circuit so that a lower fixed value of mA is obtained. However, the adjustment of mA will most likely affect the kV, hence any adjustment to mA should not be at the expense of causing the X-ray unit to fail a kV accuracy test.

2. FACTORS AFFECTING THE FINAL RADIOGRAPH

High standards of processing contribute to better quality radiographs for diagnostic purposes and to the elimination of one cause of avoidable repeat radiographic examinations which result in additional unnecessary radiation exposure both to the patient and the dentist and staff.

Although patients will vary a great deal and exposures will have to vary to compensate, ALL processing factors should be constant.

(a) General

Automatic processors need to be meticulously maintained. Strict adherence to manufacturers' recommended maintenance schedules is essential for optimal functioning of these devices. Positioning of "daylight" units should be away from bright light sources and/or direct sunlight.

The following sections apply to manual (wet tank) processing techniques, although the principles are still relevant to semi-automatic and automatic processors. In the case of semi-automatic or automatic processors, the manufacturer's instructions should be followed, in order to obtain the best processing results.

To obtain radiographs of a uniform high quality it is important that exposed films be processed under reproducible conditions with respect to:

- concentration of chemical solutions;
- temperature of developer;
- time of development, fixing and washing;
- processing techniques.

It should be noted that the processing solutions should be used as specified by the manufacturer for the type of film employed.

With respect to the time-temperature relationship, the use of a set temperature and a corresponding time of development are essential. It is important that the temperature of the developing solution is measured and a time of development employed appropriate to that temperature. This is calculated from a time-temperature chart supplied by the manufacturer.

In some situations, for example endodontic procedures, rapid processing of the film may be required. This can be achieved by increasing the developer temperature so that development of the film occurs in a substantially shorter time than by using standard techniques, or by the

use of commercially available rapid processing chemistry. To obtain the correct time-temperature relationship, reference should be made to the time-temperature chart as supplied by the X-ray chemical manufacturer. It should be noted that a rapid processing technique will result in radiographs which may be 'grainy' and lacking in contrast, and although suitable for endodontic work, would not be adequate for normal procedures due to the lack of diagnostic information. Care should be taken that the developer temperature has returned to the normal level before further processing using standard techniques is carried out. Conventional film with rapid processing chemistry will generally give better results than instant process films.

(b) Darkroom requirements and procedures

1. Light proof darkroom	-	exclude all extraneous light
2. Ventilation	-	adequate ventilation should be provided
3. Processing unit	-	developer, fixer and wash tanks
4. Safe-lights	-	as recommended by film manufacturer
5. Thermometer	-	not mercury type
6. Timer	-	timer with alarm which is suitable for darkroom use, and includes graduation increments of 30 seconds
7. Film hangers	-	to fit tanks
8. Chemicals	-	developer and fixer; mix to manufacturer's instructions
9. Disposal	-	used chemicals should be safely disposed of

Attention should be directed towards:

- organisation of work in the darkroom to avoid damage to films;
- the use of an appropriate safe-light;
- the proper storage before processing of unexposed and exposed film away from heat, radiation and chemical contamination;
- the use of film on a first-in, first-out basis to minimise use of old stock;
- the regular replenishment or renewal of processing solutions; and
- following the procedures outlined below with respect to developing, fixing and washing and drying of films.

Ventilation of darkrooms. A darkroom should be provided with extraction ventilation providing fifteen air changes per hour. Fresh air should be supplied to the darkroom in such a manner that negative pressure is maintained between the darkroom and other areas thus preventing an outflow of fumes.

Refrigeration of films. It should be noted that unexposed film stored in a refrigerator should be allowed to stand for a few hours to avoid condensation forming and causing the films to stick together. This applies to film stored in sheets in a sealed package, or used in panoramic and cephalometric units. This precaution does not apply to individually wrapped intra-oral and occlusal films.

Storage of Film Processing Chemicals. Film processing chemicals must not be stored in the same refrigerator or cupboard as foodstuffs.

Disposal of used chemicals. Regulations with respect to safe disposal of used processing chemicals may vary between various regions. It is therefore recommended that dentists contact the appropriate authority in their State or Territory for advice.

(c) Developer

1. For manual development, always dilute the developer concentrate as specified by the chemical manufacturer – often 1 part concentrate to 4 parts water. However, for processing units such as the Dry-O-Mat, Procomat, Velopex, Periomat, etc, the developing time is fixed and a special dilution rate must be used depending on the type of processing unit and the type of developer.

2. The developer should be stirred before use with a 'developer only' stirrer.

3. Low levels must be topped up with FRESHLY mixed replenisher. Replace the developer if the total volume of replenishment used exceeds twice the tank volume. Where small volume tanks are used, replenishment is not practical and freshly mixed developing solution should be made up to completely replace the old developer.

4. The developer should be changed at least every 2 weeks or if it becomes contaminated.

5. The volume of the tank should be checked and the developer should be mixed strictly to manufacturer's recommendations. Always mix developer AFTER fixer as contamination of developer is a greater problem and often requires immediate disposal of the developer. Contamination of developer with even a small quantity of fixer will result in fogging of the processed radiograph. This may not occur immediately after mixing but may happen after some days. It is therefore advisable to dispose of contaminated developer immediately after contamination has occurred.

(d) Fixer

1. The fixer should be stirred before use with a 'fixer only' stirrer.

2. Low fixer level must be topped up with FRESHLY mixed replenisher, or for small volume tanks, the old fixer should be completely replaced by freshly mixed fixer.

3. The fixer should be changed when the clearing time is over 2 minutes, or at least every 2 weeks.

4. The volume of the tank should be checked and the fixer be mixed strictly to the manufacturer's instructions. Always mix fixer before developer.

Note: All solutions should be at approximately the same temperature, although only the developer temperature is critical. When solutions are changed, the tanks must be thoroughly cleaned with separate cloths. Steel wool and abrasive powders should not be used.

(e) Processing

1. Check developer temperature, set timer for the recommended time, and place the film in hanger into the developer.

2. Extra-oral films: Agitate the film without lifting film out of solution using a vertical motion when first placed into the solution, and agitate three or four times during the developing period. Agitation for intra-oral films is usually not required.

3. When the timer sounds, quickly remove the film and allow it to drain over the wash tank – NOT OVER the developer.

4. Rinse the film for fifteen seconds in the wash tank and allow to drain back into wash tank.

5. Place the film in the fixer tank and again agitate several times-particularly during the first minute of fixing.

6. Leave the film in the fixer for the time recommended by the manufacturer (normally 4-6 minutes), or at least twice the time it takes to clear the unexposed sections. The film should not be left in the fixer for more than 15 minutes.

7. Allow the fixer to drain back into the fixer tank, and then place the film in the wash tank.

8. Films should be washed in clean running water. The water should be renewed at a rate of approximately 8 times per hour.

9. After 30 minutes, drain the films and hang to dry in a dust free area - warm moving air is most effective.

Note: Steps 1-6 must be carried out under safe-light conditions.

(f) Additional processing hints

1. Keep hands dry when handling films.

2. Touching the emulsion of unprocessed films with certain latex gloves may result in dark stains appearing on the processed film.

3. Avoid splashing chemicals as this may cause contamination of other solutions.

4. Tanks should be covered with lids when not in use as this retards oxidation of the developer and keeps dust out of the solutions. For large developer tanks, a floating lid may be desirable.

(g) Darkroom light-proof test

Turn off all darkroom lights and remain in the completely darkened room for ten minutes. Look around the room for light leaks and mark them with chalk. Repair holes to prevent light leaks.

(h) Safe-light test

Darkroom

1. Physically examine the safe-light filter and housing for cracks or white light leaks. Check that the globe is 25 watts or less, preferably 15 watts.

2. Turn off all darkroom lights, remove a dental film from its packet and place on the workbench.

3. Cover three-quarters of the film with a piece of cardboard and turn on the safe-lights.

4. After 30 seconds move the cardboard so that half of the film is covered.

5. After an additional 30 seconds move the cardboard so that only one-quarter of the film is covered.

6. At the end of a further 30 seconds turn off the safe-lights.

7. Process the film in total darkness.

8. Safe-lights can only be considered safe for the period of exposure which shows no significant. difference in blackness compared with the unexposed area.

9. If the handling time of the films in the darkness is longer than the safe period:

- replace the globe with one of lower wattage; and/or
- direct safe-lights at the wall or ceiling; and/or
- replace the safe-light filter according to the film manufacturer's recommendations.

(i) Self-contained developing systems with an inspection window

1. Develop a film in complete darkness by covering the inspection window with a blackout cover.

2. Remove the cover and develop a second film normally.

3. If there is a significant difference in the blackness of the two films then the effectiveness of the inspection window is unsatisfactory. The lighting in the room should be decreased and the test repeated until there is no significant difference between the blackness of the two films.

Australian Government

Australian Radiation Protection and Nuclear Safety Agency

SAFETY GUIDE

Radiation Protection in Dentistry

Radiation Protection Series Publication No. #

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1. Introduction

1.1 BACKGROUND

With publication of the Code of Practice for Radiation Protection in Dentistry it was found necessary to provide additional explanatory material on certain aspects related to the Code.

The Safety Guide provides information to help obtain a satisfactory radiograph with minimum exposure to radiation of the patient, the clinician and other persons involved with the examination. It includes information on the following responsibilities and protective measures:

- allocation of responsibility;
- need for clinical assessment of the indications for radiography;
- provision of appropriate equipment, film and processing facilities;
- adoption of procedures to minimise exposure to radiation.

1.2 PURPOSE

This Safety Guide has been prepared as a supplement to the Code of Practice for Radiation Protection in Dentistry. It provides advice and guidance on measures that could be employed to assist in meeting the requirements of the Code of Practice.

1.3 SCOPE

This Safety Guide deals with radiographic procedures used in general and specialist dental practice. These include:

- intra-oral radiography: periapical, bitewing and occlusal views;
- panoramic radiography;
- cephalometry;
- other forms of radiography of the complete skull or certain parts of the dento-maxillofacial region;
- hand and wrist radiography for the purpose of the determination of the bone age.

Certain of the above procedures may be restricted or have special regulatory requirements in some States or Territories.

This safety guide should assist responsible persons in ensuring safety in the use of dental X-ray equipment and any person performing a dental radiographic examination (e.g. dentists, radiographers, dental therapists, dental hygienists and dental assistants with extended duties) in dental practice.

1.4 STRUCTURE

This Safety Guide sets out information that should assist in achieving the levels of protection established in the Code of Practice. It does not form part of the material that would be adopted into regulatory frameworks by State, Territory or Commonwealth regulatory authorities.

The meaning of terms used in this Safety Guide is the same as the meaning defined in the Glossary to the Code of Practice.

Material in the Annexes provides clarification and guidance on issues discussed in the Safety Guide.

2. Responsibilities

2.1 Overall Responsibility of the Clinician Operating the Dental X-ray Equipment

The clinician is responsible for implementing procedures for radiographic examinations that embody adequate safeguards to ensure that patients and staff are exposed to the minimum amount of radiation consistent with the production of a radiograph of optimal diagnostic quality. This responsibility also includes measures to minimise radiation exposure to members of the public. Where the operator is a dentist, this responsibility covers the following components of the examination:

- determination of clinical need for the examination
- selection of the most appropriate method of examination
- optimising radiographic techniques
- the use of optimal film or electronic image processing techniques
- interpretation of radiographs
- maintenance of radiographic records.

Subject to legislation of the relevant State or Territory the dentist may delegate some of these components. However, in such cases the dentist remains ultimately responsible for all of the above aspects of the examination. It is also the dentist's responsibility to be aware of the latest developments in all of the above aspects and to ensure that staff to whom aspects of radiographic examination are delegated are properly trained and that work practices of all staff involved with radiological examinations are reviewed on a regular basis.

2.2 Maintenance of Patient's Radiographic Records

Techniques and/or exposure factors which deviate from normal settings should be entered on the patient's record.

If a patient transfers to a different practice the available radiographs or duplicates of the radiographs should be provided to the new practice. In the case of originals, these should be returned to the originating practice if requested.

3. Type and frequency of radiographic examination in dental practice

3.1 CLINICAL ASSESSMENT OF THE NEED FOR RADIOGRAPHY

The nature and extent of an actual or a suspected dental condition, its early detection, treatment and response to treatment must be the primary determining factors in submitting the patient to radiographic examination. The decision to perform a radiographic examination rests upon a professional judgement of the benefits which accrue to the total health of the patient, as opposed to any biological effects which might be caused by the radiation. Particular emphasis should be placed on minimising the radiation exposure of children (see section 6.2). In view of the above principles, the concept of the routine use of X-rays as part of the periodic examination of all patients or group(s) of patients is inappropriate. Radiology is a most valuable aid to oral diagnosis, employed in accordance with the dental and general health needs of the individual patient. No preferred frequency of radiological examinations can be expressed, as it is dependent upon the needs of each particular patient. In addition, the need for radiographic examinations may be reduced by the use of alternative methods such as transillumination as a replacement for bitewing radiographs and the use of electronic apex location in endodontic procedures.

3.2 MEDICO-LEGAL EXAMINATIONS

If it is anticipated that a medico-legal situation might arise, intra-oral views should be taken using double-film packets. Extra-oral radiographs can very easily be copied. Most radiological practices and larger hospitals offer this facility.

When consideration is being given to litigation, repeat radiographic examinations for medico-legal purposes should not be undertaken if clinical indications no longer exist unless a (specialist) consultant considers such a procedure essential for the adequate assessment of long-term disability.

3.3 RESEARCH PROJECTS INVOLVING THE IRRADIATION OF HUMANS

Research that exposes humans to ionizing radiation should conform to the NHMRC's *National Statement on Ethical Conduct in Research Involving Humans* (1999). Volunteers should, where practicable, be over 40 years of age, and preferably be over 50. Persons under the age of 18 should normally not be permitted to be exposed to radiation for dental research.

Exposures should be permitted only when the volunteers understand the risks involved and participate willingly. Researchers have the responsibility to provide dose and risk information to volunteers and to enquire about previous exposure of the volunteer.

There is additional information on requirements for research involving ionising radiation in Radiation Protection Series publication 1 (ARPANSA 2002). In addition, the 1984 NHMRC statement on human research (NHMRC 1984) is being revised and will be re-published in the Radiation Protection Series.

Regulatory Authorities also may require licences for research involving exposure of volunteers. The requirements should be checked with the regulatory authority.

4. Equipment and site requirements

4.1 Compliance with Australian Standards and regulatory authority requirements

The regulatory authority may apply other requirements, and they should be consulted before purchase of second-hand X-ray equipment to ensure that it meets these requirements.

Dental X-ray equipment should only be used for the types of examinations for which the equipment is designed. Failure to do so is likely to expose patients and staff to higher doses of radiation, and result in poor quality radiographs.

Some dental X-ray equipment for intra-oral radiography can be fitted with rectangular beam applicators with dimensions close to those of intra-oral films. These beam applicators, when used in conjunction with particular image receptor holders, result in a substantial dose reduction and are therefore strongly recommended.

4.2 Location of X-ray units and provision of structural shielding

Careful consideration should be given to both the siting of X-ray units and to the provision of structural shielding. These considerations are particularly important when more than one dental X-ray unit is operated in close proximity to occupied areas, when an X-ray unit is used in a small dental surgery, or where cephalometric or panoramic X-ray equipment is used. Advice on structural shielding may be obtained from the regulatory authorities listed in Annex 2 of the Code of Practice.

5. Image receptors and film processing

5.1 DIGITAL IMAGING SYSTEMS

Several digital imaging systems are available for intra-oral and extra-oral radiography. These systems employ sensors to replace conventional films on silver-halide base and should require less exposure than E-speed film. Some digital systems for intra-oral radiography have radiation sensors significantly smaller than conventional films which may limit their use to the imaging of a relatively small area, thus diminishing the dose reduction advantage due to a larger number of exposures being required. The choice of imaging system should result in a net dose benefit to the patient. Exposure times are lower than for conventional films and practitioners using both digital and conventional image receptors should carefully check exposure settings before initiating the exposure. Digital images can be manipulated to compensate for over and underexposure. Overexposure needlessly increases the patient dose without any benefit. Underexposure produces grainy or snowy images and results in loss of diagnostic information. While such manipulation of the image can sometimes be useful in avoiding re-takes, it is preferable to make the correct exposure in the first place to minimise dose and avoid losing detail in the image. It is also important to ensure that the image receptor is compatible with the X-ray equipment.

5.2 FILM SIZES AND APPLICATIONS

It is recommended that intra-oral films be used for applications appropriate to their size. Film sizes and applications are given in Annex 3 of the Code of Practice.

5.3 USE OF HIGH SPEED FILM

For intra-oral radiography no films should be used with speeds lower than that of films of speed group D. E-speed films possess image qualities similar to those of D-speed films and have demonstrated to provide sufficient information with a considerable reduction in dose. Where possible, D-speed films should therefore be replaced with E-speed films. It should be noted that exposure times will be reduced when changing from D speed to E speed films.

For extra-oral radiography such as panoramic and cephalometric radiography, the fastest available film and intensifying screen combination consistent with satisfactory diagnostic results should be used. The speed of the system should be at least ISO 400. The light sensitivity of the film should be correctly matched with the intensifying screens. The use of “rare earth” intensifying screens is strongly recommended.

5.4 PROCESSING OF FILMS

The processing of films is an area where dental practices often fail to pay appropriate attention. The correct processing of exposed films plays a major part in ensuring consistency of results and minimising radiation exposure. The correct processing is best obtained by using automatic processors with developing time and temperature control. The use of such automatic processors is therefore highly recommended.

5.5 QUALITY ASSURANCE IN PROCESSING

To ensure that radiographs of consistent diagnostic quality are obtained, a quality assurance program should be established so as to avoid repeat radiographs due to deterioration or failure of the processing system. High standards of processing will contribute to better quality radiographs for diagnostic purposes as well as the elimination of one cause of avoidable repeat examinations. Unsatisfactory processing of an exposed film will result in a radiograph of less than optimal quality. In particular, a radiograph which has been over-exposed and under-developed will not only be of less than optimal quality but will have been obtained with unnecessary and avoidable radiation exposure. If correct processing techniques are adhered to and the overall density of the radiograph is too high this indicates that the film has been overexposed. Consequently, the tube current and/or the exposure time should be reduced. An example of a quality assurance procedure is described below.

Quality control procedure for dental X-ray film processing

PURPOSE

In order to achieve optimum processing of dental films, there is a need to establish an inexpensive but suitable method of assessing the developing conditions, which can be readily used by dentists in their practices.

By exposing test films and developing one prior to processing normal dental X-ray films, the deterioration of the developer can be observed, and an indication of when the solutions need changing can be ascertained. Sufficient films should be exposed at a given time, so that one film can be developed each day that normal dental films are to be processed, to ensure that the processing chemicals are not exhausted.

If optimum processing of dental X-ray films is achieved, the resultant radiographs will be of sufficient quality that optimum exposure factors can be used and the number of repeat exposures reduced. This procedure will ensure that the radiation doses to patients are kept to a minimum. It is emphasised that there should be, at all times, strict adherence to the film manufacturer's processing specifications.

METHOD

Set up the X-ray unit so that later exposures may be easily reproduced and insure that the processor is operated with fresh developer and optimum development cycle. Care should also be taken not to exceed the heat loading of the x-ray tube at any stage.

(a) To ensure that test film is uniformly exposed:

Place a dental film on a flat surface within the X-ray field and use a focus-film distance of at least 300 mm.

Using appropriate exposure factors expose and then develop the film. The developed film should have an optical density that can be visually assessed. If the field is not uniform or if the field size is not large enough to cover the whole film, increase the X-ray tube-to-film distance and place the film in the most uniform region of the field. Repeat this procedure until a satisfactory result is obtained.

(b) Exposure of test films

Test films, which have a graduated set of density bands can produced by exposing a commercially available step wedge in accordance with the manufacturer's specifications. A step wedge is relatively inexpensive and their use will greatly facilitate the QA procedure.

As an alternative to using a step wedge, the following procedure as outlined by Tingey (1983) may be used.

Expose and process films[1] with varying exposure factors until a density of about 1.0 is obtained. The density of the film can be estimated by placing the developed film on a piece of white, printed paper in a well illuminated room. With a density of 1.0 the printed letters should be just legible.

The exposure time for the test film, described below, is half that required to produce a density of 1.0. If no such setting exists on the equipment, an exposure time as close as possible will suffice. Record the distance and exposure factors so that this exposure may be reproduced.

The test film is exposed in strips so that after processing the resulting image will have four strips of differing densities. The first strip will receive four exposures, the second will have three exposures, and the third will have two exposures, and the fourth, one exposure.

With a film in the X-ray field place a lead sheet of at least 1 mm thickness over three-quarters of the film so that the first strip may be exposed.

Once exposed, reposition the lead sheet so that half the film is uncovered. Repeat the exposure.

Repeat the procedure until all four (strip) quarters have been exposed.

(c) Number of test films to expose.

For the first round of QA, until the rate of deterioration of the developer is established, expose enough films so that there are sufficient available to use one per day to cover a period in excess of the expected developer working life.

Once exposed the films must be stored in a suitable place away from X-rays and chemical contamination (preferably in a refrigerator). It is recommended that the films, stored in a container, be clearly marked as having been exposed to X-rays.

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[1] Any size dental film can be used to produce a test film provided that it is large enough so that four areas can be exposed on it. When a batch of test films is to be exposed, all of the films are to be from a fresh supply and of the same manufacturer's emulsion number and preferably from the same box of films.

Prior to the preparation of the test films mix up fresh chemicals and allow a suitable time period for temperature stabilisation. Ensure that the temperature of the developer complies with that specified by the manufacturer.

(d) Use of the test films

After fresh developer has been made up, develop one test film. This film is used as a reference film to which subsequent developed test films will be compared for the active life of this developer.

At the beginning of each day that normal dental films are to be processed, develop one of the test films.

Compare the test films with the reference film by placing the films on a light box. There may be some variation in density but when there is a one step or greater difference in density the developer is nearing exhaustion and should be replaced and a test film processes. If this film is not satisfactory, the reasons for this, such as temperature change, need to be resolved.

For practices with low x-ray usage, once the working life of the developer has been established - usually 2-4 weeks - the frequency of processing of the test films may be reduced one every two to three days.

5.6 VIEWING OF RADIOGRAPHS

The provision of dedicated viewing facilities is essential to realise the full diagnostic information from radiographs. A specially designed lightbox should be used and installed away from strong sources of ambient light. Significant improvements can also be achieved by mounting radiographs on a mask which eliminates stray light around the radiograph. The facility should include provision for magnification. The incorporation of a high intensity light source for viewing areas of high density on the radiograph may prove useful for extra-oral radiographs and in particular for panoramic radiographs.

6. Procedures to minimise exposure to ionizing radiation

6.1 General Principles

All diagnostic exposures to ionizing radiation should be subject to the following principles of justification and optimisation in a diagnostic context:

For doses received by a patient undergoing medical and/or dental diagnosis, there are two levels of justification. First, the practice involving exposure to radiation should be justified in principle and the expected clinical benefit demonstrated to be sufficient to offset the radiation detriment. Second, each procedure should be subject to a further, case-by-case justification by the clinician who is responsible for the management of the patient and who determines that the exposure is necessary for diagnostic purposes.

Protection should be optimised during radiographic exposures. In the case of diagnostic radiology, there is often scope for dose reduction, through careful choice of exposure and image processing conditions, without loss of diagnostic information. Dose limits are not appropriate because of the individual medical and/or dental requirements of each case. Where guidance dose levels have been recommended by the regulatory authority, they should be followed.

Selection of the most appropriate form of examination is also an important aspect of patient dose reduction.

Repetition of radiological examination due to technical errors. The repetition of a radiograph will result in unnecessary exposure to both the patient and the operator. Repeat exposures may be necessary due to the poor quality of the radiograph or if the radiograph does not provide the clinical information required. The latter cause can be avoided by the careful planning of the examination to fit the clinical problem. Repeat exposures should not be prescribed simply because a radiograph may not be of the best diagnostic quality if the radiograph contains the required information. Care is also necessary to ensure the correct positioning of the patient, image receptor and X-ray tube head. Repeat exposures due to technical errors can be minimised by the correct selection of exposure factors consistent with the region being radiographed, the speed of the image receptor and processing procedures. It is recommended that exposure tables based on the manufacturer's instructions for the particular image receptor are available to assist in maintaining proper exposure.

6.2 Minimising doses to the patient

The use of image receptor holders for intra-oral radiography. The use of image receptor holders that include aligning devices is strongly recommended as these aligning devices assist in correct alignment of the X-ray tube. This facilitates standardising the technique thus reducing the necessity for retakes. Some types of image receptor holders with aligning devices contain an additional collimator; others enable the use of a rectangular beam applicator. In these cases, a substantial radiation dose reduction and consistent high quality radiographs are achievable.

Positioning of the patient for intra-oral radiography. Unless aligning devices are used, the positioning of the patient should be standardised so that consistent radiographic results can be obtained, reducing the necessity for retakes.

Field sizes in cephalometric radiography. For certain diagnostic procedures it is necessary to portray the entire skull. Therefore the Australian Standard AS/NZS 3200.2.201 allows a maximum field size at the image receptor area of 240 x 300 mm. For normal orthodontic use, however, an image of a significantly smaller part of the skull is required. Reduction of the field size to 180 x 240 mm is, for normal orthodontic use, therefore strongly recommended since this will result in a significant dose reduction and an improvement of the image quality of the resulting cephalogram. If the cephalometric X-ray unit is not factory equipped with a collimator resulting in a field size of 180 x 240 mm, it is usually possible to have such an additional collimator retro-fitted.

Protective drapes. Protective drapes do not protect against radiation scattered internally within the body and only provide significant protection in cases where the X-ray beam is directed towards structures outside the dento-maxillofacial area. Even in the latter case the use of a protective drape for gonadal protection could only be regarded as prudent for a small child or for a female patient who is, or may be, pregnant. Although it has been argued in the past that routine use of protective drapes for dental radiography could be justified to allay perceived patient anxiety, their routine use is unnecessary in view of the very low effective doses involved in properly conducted dental radiography. Protection of the thyroid may be relevant for some examinations (see section on children below).

Pregnancy. The National Health and Medical Research Council recommends that precautions be adopted in radiological procedures involving exposure to the lower abdomen and pelvic regions of women of reproductive capacity to ensure that the radiation dose received is as low as possible, and particular care should be taken to avoid the irradiation of the foetus whenever practicable. When radiography of an area remote from the foetus is needed, such as in dental radiography, this can be undertaken with negligible dose to the foetus at any time during pregnancy. Provision of a leaded drape is recommended when the X-ray beam is directed downwards towards the patient's trunk, for instance when taking occlusal views of the maxilla. There is no need on radiation protection grounds to defer dental radiography during pregnancy.

Children. The various factors influencing the dose to adults also apply to children, but the shorter distances between the area irradiated and many of the organs in children will result in higher doses to those organs. This is particularly true for the gonads and the thyroid. In general, it must be remembered that some tissues in growing children are more sensitive to radiation than those of mature persons. Therefore, the need for radiography should be carefully assessed and appropriate protective measures such as leaded drapes and thyroid collars should be considered, particularly during occlusal views of the maxilla where the X-ray beam is directed vertically downwards towards the patient's trunk. However, in the case of panoramic and cephalometric radiography the use of a thyroid collar is discouraged since it may physically interfere with the procedure and can often be detrimental to obtaining an adequate image.

Film type. Use of film of speed D or faster will reduce doses to the patient during dental radiography. Slower film types require more radiation to produce an image and are therefore not permitted by the Code of Practice.

Typical doses. Typical doses from various types of dental radiographic examinations and comparison with other diagnostic radiology procedures can be found in Annex 2.

6.3 MINIMISING DOSES TO THE OPERATOR AND OTHER STAFF

Occupational Exposure. The system of radiation protection recommended in Australia is described in the ARPANSA *Recommendations for limiting exposure to ionizing radiation* and *National standard for limiting occupational exposure to ionizing radiation* (republished 2002). It states that radiation protection for occupational exposure requires justification, optimisation and limitation to be applied to the practice which causes the exposure. Compliance with the occupational limit on effective dose (20 mSv per year, averaged over a period of 5 consecutive calendar years) will ensure that deterministic effects do not occur in most body tissues and organs. It is recommended that dose constraints be used for appropriate work categories in the design of the working environment. That is, for occupations in which the nature of the work requires only minor exposures to radiation, doses should be restricted by design to be less than some value which is lower than the dose limit and which is determined through experience. While dose limits mark the lower bound of unacceptability, dose constraints promote a level of dose control which should be achievable in a well-managed practice.

Holding of image receptor and standardisation of technique by using image receptor holders. Wherever possible the image receptor should be fixed in position by using an image receptor holder; otherwise it should be held by the patient or, exceptionally, if the patient is incapacitated, by an individual not occupationally involved with radiation. Image receptor holders eliminate the need for the patient to hold the image receptor and help in positioning and stabilising the image receptor, and also in standardisation of positioning.

Holding of patients. It may be necessary in some cases that uncooperative patients (eg. a child or incapacitated patient) be restrained during exposure or that the image receptor be held in place. If there is a need to restrain a patient, restraining devices should be used as a first preference, but if this is not possible, the patient should be restrained by someone not occupationally exposed to radiation, such as a member of the patient's family.

Position of operator during exposure. The radiation dose to the operator can be minimised by the use of both distance and position relative to the X-ray tube and the patient and/or by structural shielding. If there is no structural shield and the operator has to remain in the room, the operator should stand at least 2 metres away from the X-ray tube, and outside the primary beam. The area of minimal scatter radiation is reported to be at 45 degrees from the primary beam as it exits the patient.

Personal or area monitoring. Personal monitoring is useful for checking the adequacy of radiation protection. It can be used to document the occupational doses of the wearers, especially when the wearer is accidentally exposed, and to disclose inadequate or improper radiation protection practices. It is advisable for a dentist or any member of the dentist's staff who is likely to be exposed to radiation to wear a personal monitor particularly when new equipment is installed. It may be obligatory in some jurisdictions to wear monitors until it can be shown that the occupational dose of the wearers is either zero or negligible. If personal monitoring is required, monitors should be worn on the body at chest or waist height during the period of occupational exposure. When lead protective aprons are worn, monitors should be worn under the aprons. In some cases, area monitoring using appropriate techniques may obviate the need for the dentist or dentist's staff to wear personal monitors on a routine basis. Advice on radiation protection, including the need for area monitoring

and personnel monitoring, is available from the authorities listed in Annex 2 of the Code of Practice. The limits for occupational exposure to ionizing radiation are given in the ARPANSA Radiation Protection Series publication '*Recommendations for limiting exposure to ionizing radiation* (2002)'. This document supports the principle that radiation exposure be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA) and should be taken as a guiding principle. Personal dose monitors from dental practices typically record an effective dose of less than 0.04 mSv per year so exposure to dental staff is usually well within the prescribed limits. Hence, the recording of effective doses higher than about 0.1 mSv per year by dentists or staff, while well below permitted dose limits, may indicate that a radiation protection practices should be reviewed .

Pregnant operators and other staff. If a member of the dental staff is pregnant then the foetus should be afforded the same level of protection as a member of the public which is set at the rate of 1 mSv per year. This may be achieved by controlling the exposure of the employee such that the dose received by the foetus is less than this public effective dose limit for the remainder of the pregnancy. The low effective doses typically recorded by dental staff are such that it should not normally be necessary to modify work practices during pregnancy. It is prudent to provide a pregnant staff member with a personal dose monitor.

Annex 1

Health Effects of Ionizing Radiation and Standards for Control of Exposure

It is well known that high doses of ionizing radiation can cause harm, but there is continuing scientific uncertainty about effects at low doses. At levels of dose routinely encountered by members of the public and most present-day radiation workers, there is little or no epidemiological evidence of health effects. Radiation protection standards recognise that it is not possible to eliminate all radiation exposure, but they do provide for a system of control to avoid unnecessary exposure and to keep doses in the low dose range.

Extreme doses of radiation to the whole body (around 10 sievert and above), received in a short period, cause so much damage to the body that vital systems cease to function and death may result within days or weeks. Very high doses (between about 1 sievert and 10 sievert), received in a short period, kill large numbers of cells, which can impair the function of vital organs and systems. Acute health effects, such as nausea, vomiting, skin and deep tissue burns, and impairment of the body's ability to fight infection may result within hours, days or weeks. The extent of the damage increases with dose. However, 'deterministic' effects such as these are not observed at doses below certain thresholds. By limiting doses to levels below the thresholds, tissue reactions can be prevented entirely.

Doses below the thresholds for tissue reactions may cause cellular damage, but this does not necessarily lead to harm to the individual: the effects are probabilistic or 'stochastic' in nature. It is known that doses above about 100 millisievert, received in a short period, lead to an increased risk of developing cancer later in life. There is good epidemiological evidence – especially from studies of the survivors of the atomic bombings - that, for several types of cancer, the risk increases roughly linearly with dose, and that the risk factor averaged over all ages and cancer types is about 1 in 100 for every 100 millisievert of dose (i.e. 1 in 10,000 per millisievert).

At doses below about 100 millisievert, the evidence of harm is not clear-cut. While some studies indicate evidence of radiation-induced effects, epidemiological research has been unable to establish that there are effects of statistical significance at doses below a few tens of millisieverts. Nevertheless, given that no threshold for stochastic effects has been demonstrated, and in order to be cautious in establishing health standards, the proportionality between risk and dose observed at higher doses is presumed to continue through all lower levels of dose to zero. This is called the linear, no-threshold (LNT) hypothesis and it is made for radiation protection purposes only.

There is evidence that a dose accumulated over a long period carries less risk than the same dose received over a short period. Except for accidents and medical exposures, doses are not normally received over short periods, so that it is appropriate in determining standards for the control of exposure to use a risk factor that takes this into account. While not well quantified, a reduction of the high-dose risk factor by a factor of two has been adopted internationally, so that for radiation protection purposes the risk of radiation-induced fatal cancer (the risk factor) is taken to be about 1 in 20,000 per millisievert of dose for the population as a whole.

If the LNT hypothesis is correct, any dose carries some risk. Therefore, measures for control of exposure for stochastic effects seek to avoid all reasonably avoidable risk. This is called optimising protection. However, risk in this sense may often be assessed in terms of risk to a population, and may not ensure sufficient protection of the individual. Consequently, the optimisation approach is underpinned by applying dose limits that restrict the risk to individuals to an acceptable level. The fundamental regulatory philosophy is expressed in three principles, based on the recommendations of the International Commission on Radiological Protection (ICRP) , which may be summarised as follows:

Justification: human activities that cause exposure to radiation may be permitted only if they do more good than harm;

Optimisation of protection: exposure to radiation from justified activities should be kept as low as reasonably achievable, social and economic factors being taken into account; and

Limitation of individual dose: doses must not exceed the prescribed dose limits.

Determining what is an acceptable risk for regulatory purposes is a complex value judgement. The ICRP reviewed a number of factors in developing its recommendations, which have in general been internationally endorsed, including by the World Health Organization, the International Labour Organization and the International Atomic Energy Agency. Australia's Radiation Health Committee, now established under the ARPANS Act†, has recommended that the international standards be adopted in Australia. The recommended dose limits are summarised as follows:

Limit on effective dose*

	For occupational exposure	For members of the public
To limit individual risk	20 mSv per year, averaged over 5 years*	1 mSv in a year*

*for details, see ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*

In most situations, the requirements for limiting individual risk ensure that doses are below deterministic thresholds, but for cases where this does not apply, the recommended limits are as follows:

Annual limit on equivalent dose*

	For occupational exposure	For members of the public
To prevent tissue reactions		
in the lens of the eye	150 mSv	15 mSv
in the skin	500 mSv	50 mSv
in the hands and feet	500 mSv	–

*for details, see ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*

In the case of occupational exposure during pregnancy, the general principle is that the embryo or fetus should be afforded the same level of protection as is required for a member of the public. For medical workers, the ICRP recommends that there should be a reasonable assurance that fetal dose can be kept below 1 mGy‡ during the course of the pregnancy. This guidance may be generalised to cover all occupationally exposed pregnant workers by keeping the fetal dose below 1 mSv. A full explanation of radiation protection principles and of the recommended standards for Australia is given in ARPANSA/NOHSC Radiation Protection Series No. 1: *Recommendations for limiting exposure to ionizing radiation (1995)* and *National standard for limiting occupational exposure to ionizing radiation* (both republished in 2002).

† The *Australian Radiation Protection and Nuclear Safety Act (1998).*

‡ The gray (Gy) is a unit of radiation dose. For X-rays and gamma radiation, it is numerically equivalent to the sievert.

Annex 2

Doses and Risks from Dental Radiographic Examinations

Table 1 Typical Doses from Dental Radiographic Examinations

Examination	Effective Dose (mSv)	Equivalent period of natural background radiation[1]
2 × bitewings, 70kV, 200 mm FSD[2], rectangular collimation, E speed film	0.002[3]	8.8 hours
2 × bitewings, 70kV, 200 mm FSD[2], round collimation, E speed film	0.004[3]	17.5 hours
2 × bitewings, 50-60kV, 100 mm FSD[2], round collimation, E speed film	0.008[3,7]	1.5 days
2 × bitewings, 50-60kV, 100 mm FSD[2], round collimation, D speed film	0.016[3,5]	3 days
Dental panoramic, rare-earth intensifying screens	0.007[4]	1.3 days
Dental panoramic, calcium-tungstate intensifying screens	0.014[4]	2.6 days

1. Natural background radiation is approximately 2 mSv per year in Australia
2. X-ray tube focus to skin distance.
3. National Radiological Protection Board, Guidelines on Radiology Standards for Primary Dental Care, Vol 5 No.3 1994. Derived from an effective dose of 0.084 mSv for a full mouth survey involving 20 films exposed at 70 kV with round collimation and using D speed film. (White, SC. Assessment of radiation risk from dental radiography. Dentomaxillofac. Radiol., 21, 118-26 (1992)).
4. National Radiological Protection Board, Guidelines on Radiology Standards for Primary Dental Care, Vol 5 No.3 1994
5. National Radiological Protection Board, Guidelines on Radiology Standards for Primary Dental Care, Vol 5 No.3 1994. The factor of two difference between 70kV sets and 50-60 kV sets is derived from data published by Velders. (Velders, XL. Patient exposure to bitewing radiography. Leiden, University of Amsterdam (1989)).

Table 2 Comparison of doses with other diagnostic radiology procedures and air travel.

Examination	Effective Dose (mSv)	Equivalent period of natural background radiation
Skull	0.1[8]	2.6 weeks
Chest	0.02[9]	3.4 days
Computed tomography: head	2[8]	1 year
Computed tomography: chest	8[8]	4 years
Barium meal	5[8]	2.5 years
Air travel: [6]		
New York to Paris (7 hrs 25 min.)	0.05[7]	9 days
Melbourne to Perth (4hrs)	0.009[10]	1.5 days

6. The radiation dose during air travel is due to increased exposure to cosmic radiation.
7. United Nations Environment Programme, Radiation Doses, Effects, Risks (1985)
8. Perkins, AC, Nuclear Medicine Science and Safety 1995.
9. Cardillo I, Boal TJ, Einsiedel PF, Patient Doses from Chest Radiography in Victoria, Australasian Physical and Engineering Sciences in Medicine, Vol. 4, no. 2, June 1997
10. Wilson OJ, Young BF & Richardson CK, Cosmic Radiation Doses Received by Australian Commercial Flight Crews and the Implications of ICRP 60, Health Physics, vol 66, no 5, May 1994.

Annex 3

ARPANSA Radiation Protection Series Publications

ARPANSA has taken over responsibility for the administration of the former NHMRC Radiation Health Series of publications and for the codes developed under the *Environment Protection (Nuclear Codes) Act 1978*. The publications are being progressively reviewed and republished as part of the *Radiation Protection Series*. All publications listed below are available in electronic format, and can be downloaded free of charge by visiting ARPANSA's website at **www.arpansa.gov.au/pubs.htm.**

All publications listed below are available in electronic format, and can be downloaded free of charge by visiting ARPANSA's website at **www.arpansa.gov.au/codes.htm**.

Radiation Protection Series publications are available for purchase directly from ARPANSA. Further information can be obtained by telephoning ARPANSA on 1800 022 333 (freecall within Australia) or (03) 9433 2211.

RPS 1. Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002)

RPS 2. Code of Practice for the Safe Transport of Radioactive Material (2001)

RPS 3. Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz (2002)

RPS 4. Recommendations for the Discharge of Patients Undergoing Treatment with Radioactive Substances (2002)

RPS 5. Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004)

RPS 6. National Directory for Radiation Protection – Edition 1.0 (2004)

RPS 7. Recommendations for Intervention in Emergency situations Involving Radiation Exposure (2004)

RPS 8. Code of Practice for the Exposure of Humans to Ionizing Radiation for Medical Research Purposes (2005)

RPS 9. Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)

RPS ## Code of Practice and Safety Guide for Radiation Protection in Dentistry (200X)

Those publications from the NHMRC Radiation Health Series and the Environment Protection (Nuclear Codes) Act Series that are still current are:

RADIATION HEALTH SERIES

RHS 2. Code of practice for the design of laboratories using radioactive substances for medical purposes (1980)

RHS 3. Code of practice for the safe use of ionizing radiation in veterinary radiology: Parts 1 and 2 (1982)

RHS 4. Code of practice for the safe use of radiation gauges (1982)

RHS 8. Code of nursing practice for staff exposed to ionizing radiation (1984)

RHS 9. Code of practice for protection against ionizing radiation emitted from X-ray analysis equipment (1984)

RHS 10. Code of practice for safe use of ionizing radiation in veterinary radiology: part 3-radiotherapy (1984)

RHS 13. Code of practice for the disposal of radioactive wastes by the user (1985)

RHS 14. Recommendations for minimising radiological hazards to patients (1985)

RHS 15. Code of practice for the safe use of microwave diathermy units (1985)

RHS 16. Code of practice for the safe use of short wave (radiofrequency) diathermy units (1985)

RHS 18. Code of practice for the safe handling of corpses containing radioactive materials (1986)

RHS 19. Code of practice for the safe use of ionizing radiation in secondary schools (1986)

RHS 21. Revised statement on cabinet X-ray equipment for examination of letters, packages, baggage, freight and other articles for security, quality control and other purposes (1987)

RHS 22. Statement on enclosed X-ray equipment for special applications (1987)

RHS 23. Code of practice for the control and safe handling of radioactive sources used for therapeutic purposes (1988)

RHS 24. Code of practice for the design and safe operation of non-medical irradiation facilities (1988)

RHS 25. Recommendations for ionization chamber smoke detectors for commercial and industrial fire protection systems (1988)

RHS 28. Code of practice for the safe use of sealed radioactive sources in bore-hole logging (1989)

RHS 29. Occupational standard for exposure to ultraviolet radiation (1989)

RHS 30. Interim guidelines on limits of exposure to 50/60Hz electric and magnetic fields (1989)

RHS 31. Code of practice for the safe use of industrial radiography equipment (1989)

RHS 34. Safety guidelines for magnetic resonance diagnostic facilities (1991)

RHS 35. Code of practice for the near-surface disposal of radioactive waste in Australia (1992)

RHS 36. Code of practice for the safe use of lasers in schools (1995)

RHS 37. Code of practice for the safe use of lasers in the entertainment industry (1995)

RHS 38. Recommended limits on radioactive contamination on surfaces in laboratories (1995)

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