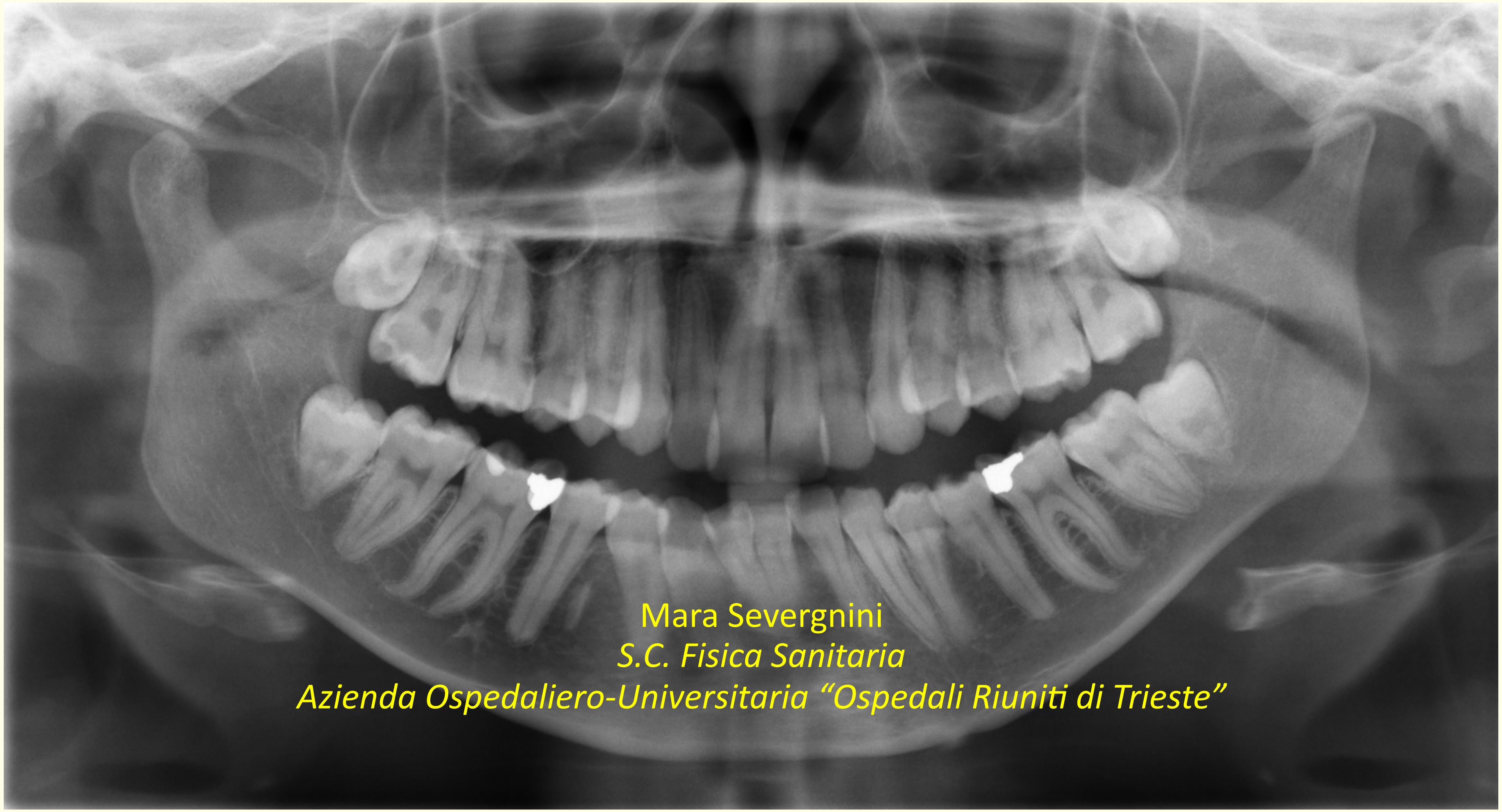
Radiation Protection in Dentistry



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Why radiographs in dentistry?

Radiographs are essential for dentists for:

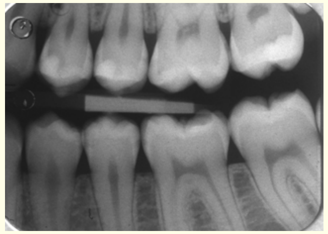
- Diagnosis
- Treatment planning
- Monitoring treatment or lesion development

Drawbacks:

- Sources of exposure for patients and staff
- Need of an appropriate protection

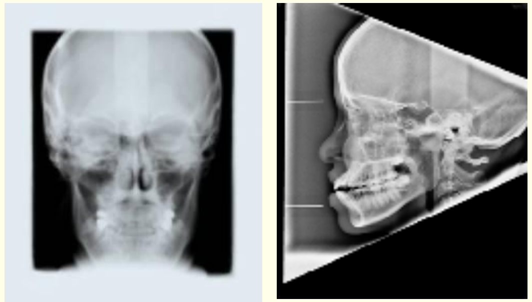
Four types of examination

1) Intraoral radiographs

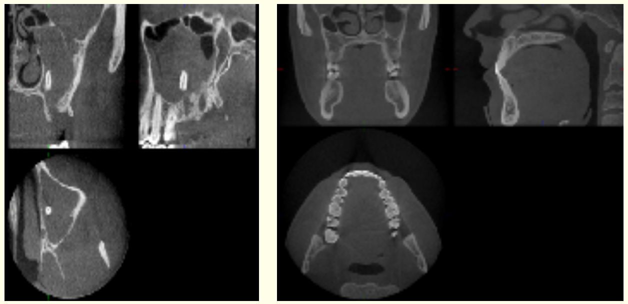


2) Panoramic radiographs

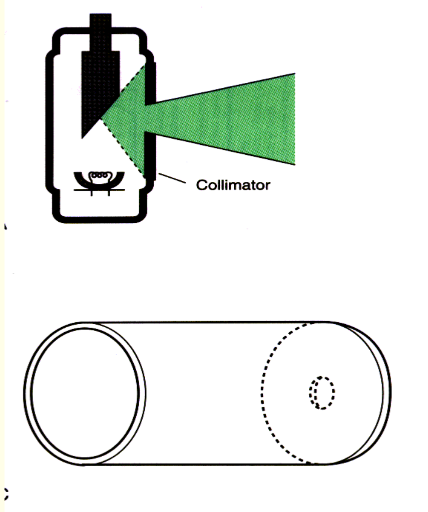
3) Cephalometric radiographs

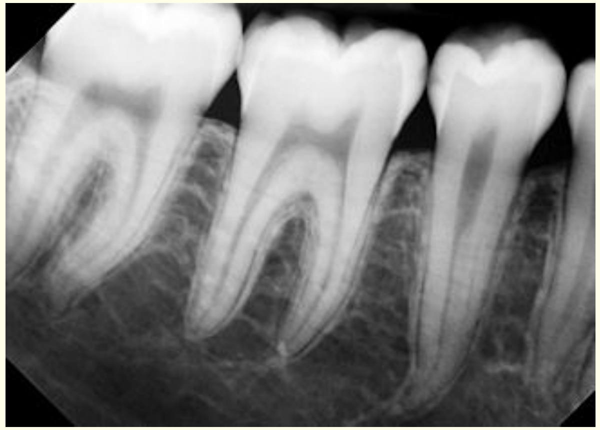


4) Cone-beam imaging



- A) intraoral x-ray examination





Dental X-Ray Equipment

- Dedicated units with low power stationary anode tube
- Tube is deployed on an extendable arm for easier positioning
- Fixed kilovoltage, kVp of 60-70 is normally used
- Tube current usually fixed 7,5-10 mA
- <u>Exposure is normally varied by altering the exposure time</u>
- Lead collimator with central hole
- Spacer Tube (cone, position indicating device)

Dental X-ray equipment

(technical data)

• Exposure time	from 30 ms to 2.5 s
• Tube	Min. 50 kV, Typically 70 kV
• Focal spot size	from 0.4 to 0.7 mm
• Inherent filtration	~ 2 mm Al equivalent
• Focus-skin distance	20, 30, or 40 cm
• Irradiated field	28 cm^2 (with round section of 6 cm diameter collimator)

B) Panoramic examination

- Both film and Tube head rotate around the patient:

  The X-ray tube rotates around the patient head in one direction and the film rotates in the opposite direction, while the patient sits (or stands) in a stationary position.

Panoramic examination, X-ray Unit tube head

1) It consists of a tube head similar to an intraoral x-ray tube head.

2) The collimator used in the panoramic x-ray machine is a lead plate with a narrow vertical slit

3) The Tube head always rotates behind the patient head as the film rotates in front of the patient.

Panoramic examination, Technical data

Focal spot	0.5 mm
kV	60-80 kV (at 2 kV steps)
mA	4-10 mA (4,5,6,8,10 steps)
Exposure time	12 s (standard projection) 0.16-3.2 s (cephalometric projection)
Flat panoramic cassette	15cm x 30cm

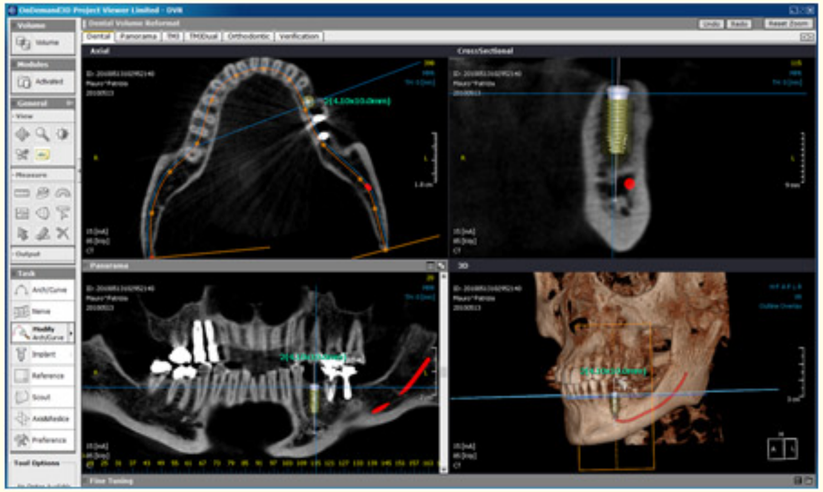
Panoramic examination,
Head positioner and exposure factor

- Head positioner consists of chin rest, notched Bite-block, forehead rest and lateral head supports
- Exposure factors are determined by the manufacturer who suggests the acquisition protocol (kVp and Milliamperage).
- The kVp and milliamperage settings are adjustable and can be varied to accommodate patients of different sizes
- <u>The Exposure time is fixed and can't be changed</u>

D) Cephalometric radiograph

a radiograph of the head, including the mandible, in full lateral view, used to make measurements

E) Cone Beam Computed Tomography (CBCT)



a Cone Beam CT scanner uses a cone shaped x-ray beam rather than a conventional linear fan beam, as in the case of common CT, to provide images of the skull bony structures

Image Receptors in Dental Radiology

- ***Intraoral Radiology***
  - **Small films (2 x 3 or 3 x 4 cm) in light-tight envelopes (no screen)**
  - **Digital intraoral sensors – compared to F film category, the radiation dose is reduced by 60%.**

- ***Panoramic Radiology and Cephalometry***
  - **Screen-film combination**
  - **Digital sensors - compared with screen-film sensitivity class 200, the radiation dose is reduced by 50-70%.**

Digital sensors → Potential Dose reduction 30-60%

CCD (Charge-Couple) or PSP (Photo-Stimulable Phosphor), Software features

Dental Radiology Film Types

- Sensitivity class D
  - Good spatial resolution
  - Typical delivered dose: about 0.5 mGy
  - Typical exposure times: 0.3 - 0.7 s

- Sensitivity class E, E-F, or F
- Good spatial resolution
- Typical delivered dose: about 0.25 mGy
- Typical exposure times: 0.1 - 0.3 s

Similar Image quality of D, E, E-F, F films

Effective dose

Literature Review (A report prepared by the SEDENTEXCT project www.sedentexct.eu)

Table 2.3c: Effective dose from conventional dental imaging techniques in μSv. MSCT = multislice CT.

	Effective dose (μSv)	References
Intraoral radiograph	<1.5*	Ludlow et al 2008
Panoramic radiograph	2.7 – 24.3	Ludlow et al 2008 Okano et al 2009 Garcia Silva et al 2008b Palomo et al 2008 Garcia Silva et al 2008a
Cephalometric radiograph	<6	Ludlow et al 2008
MSCT maxillo-mandibular	280 - 1410	Okano et al 2009 Garcia Silva et al 2008a Loubele et al 2005 Faccioli et al 2009 Suomalainen et al 2009

**Figure for single intraoral radiograph calculated from data for 18 image full mouth intraoral survey and 4 image bitewing examination, both using a photostimulable phosphor plate or F-speed film with rectangular collimation. Substitution of round collimation increased this figure by almost five times, while slower film speeds increased the effective dose still further (Ludlow et al, 2008)*

CBCT Literature Review

(A report prepared by the SEDENTEXCT project www.sedentexct.eu)

Table 2.3a: The range of effective dose and the median values in parentheses from dental CBCT in μSv. Studies are divided into "dento-alveolar" (small and medium FOV) and "craniofacial" (large FOV). The height of the dento-alveolar FOVs is smaller than 10cm allowing imaging of the lower and upper jaws. For the craniofacial FOVs, the height is greater than 10cm allowing maxillofacial imaging.

Dental CBCT unit type	Effective dose (μSv)	References
Dento-alveolar	11-674 (61)	Ludlow et al 2003 Ludlow and Ivanovic 2008 Lofthag-Hansen et al 2008 Hirsch et al 2008 Okano et al 2009 Loubele et al 2009 Roberts et al 2009 Suomalainen et al 2009 Qu et al 2010 Pauwels et al, in press
Craniofacial	30-1073 (87)	Ludlow et al 2003 Tsiklakis et al 2005 Ludlow et al 2006 Ludlow and Ivanovic 2008 Garcia Silva et al 2008a Okano et al 2009 Faccioli et al 2009 Loubele et al 2009 Roberts et al 2009 Pauwels et al, in press

Effective doses and Background Radiation

Table 1. Comparison of Radiation Effective Dose from Various Dental and Medical Image Procedures to Natural Background Radiation

	Estimated effective dose	*Equivalent Amount of Background Radiation*
Natural background radiation	3 mSv/yr	
1 Panoramic X-ray	0.02 mSv	up to 3 days
4 bitewing X-rays	0.005 mSv	0.6 day
Cephalometric X-ray	0.006 mSv	up to 1 day
CBCT (both jaws)	up to 0.6 mSv	up to 30 days
Chest X-ray (single view)	up to 0.01 mSv	1 day
Chest X-ray (2 view)	up to 0.1 mSv	10 days
Head CT	up to 2 mSv	up to 8 months
Chest CT	up to 3 mSv	up to 12 months
Abdominal CT	up to 5 mSv	up to 20 months

Thus the doses from intraoral and cephalometric dental radiological procedures are lower, usually less than one day of natural background radiation.

Doses for panoramic procedures are more variable, but even at the high end of the range they are equivalent to a few days of natural background radiation, which is similar to that of a chest radiograph.

CBCT doses cover a wide range, but may be tens or even hundreds of microSv of effective dose higher than conventional radiographic techniques, depending upon the technique. Rapid technological improvements to CBCT equipment suggest that typical dose ranges are likely to be changed.

Risk projection model in relation to age

Table 2.2: Risk in relation to age. These data are derived from (ICRP 1990) and represent relative attributable lifetime risk based upon a relative risk of 1 at age 30 (population average risk). It assumes the multiplicative risk projection model, averaged for the two sexes. In fact, risk for females is always relatively higher than for males.

Age group (years)	Multiplication factor for risk
<10	x 3
10-20	x 2
20-30	x 1.5
30-50	x 0.5
50-80	x 0.3
80+	Negligible risk

➢Individual risks in dental radiography are small but are greater in the younger groups (below 30 years) in which dental radiography is most frequently performed

Optimization of Protection in Dental Radiology

Facts

1. Very frequent examinations (about 25% of all the radiological examinations)
2. Wide range of delivered doses, that may differ by a factor 2 or 10 or more (entrance doses between 0.5 and 150 mGy)
3. Full mouth examination requires 20 exposures
4. Image Quality often very low due to poor techniques and processing
5. Organ at risk: parathyroid, thyroid, larynx, parotid glands

Patient protection

Can I take measures to promote a good radiation protection practice in dentistry?

- The short answer is YES.
- The most effective way to reduce dose in dental radiography is to avoid unnecessary X ray examinations by justification.
- Routine dental X ray examination for all patients is not justified
- In addition, the patient dose for each X-ray examination should be optimized so that it is As Low As Reasonably Achievable (ALARA) and consistent with producing the required image quality.

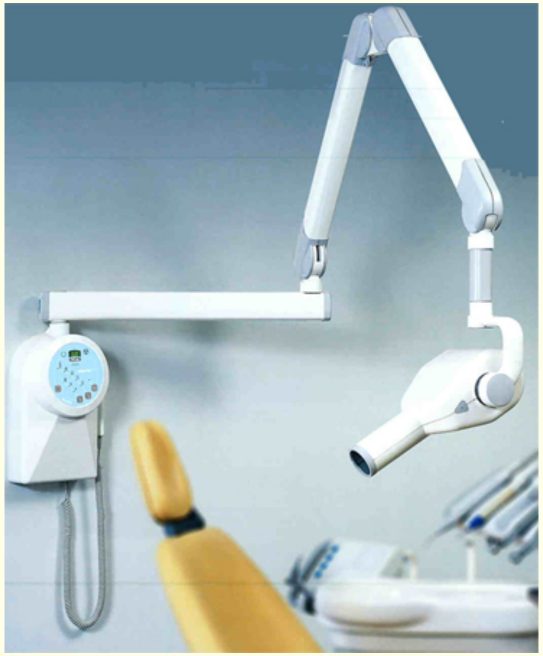
It is important that the equipment is subject to:

- formal acceptance testing,
- routine quality control
- proper maintenance
- standard dose reduction features

Features that contribute to dose reduction

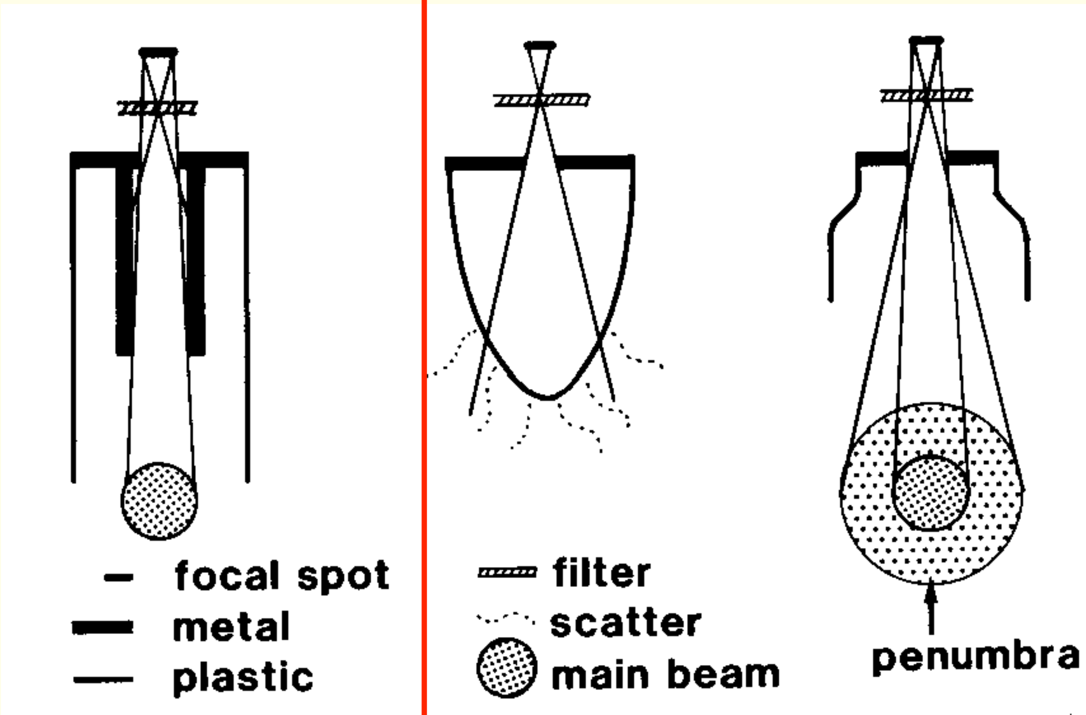
Intraoral equipment:

- Rectangular collimation
- Fastest film
- Digital detectors
- Tube voltage 60-70 kV
- X ray tube filtration
- Minimum focus to film distance (use long collimator)
- Exposure settings



Intraoral x-ray examination

Collimation



Good

Bad

Bad

Effect upon dose of equipment modification when compared with a baseline of a 70 kV AC dental X-ray set with a 60 mm cylindrical beam used with E-speed film

European guidelines on radiation protection in dental radiography Issue n. 136

Equipment factor	Multiplication factor upon dose
Digital system	X 0.5-0.75
Rectangular collimation (30x40mm)	X 0.5
F-speed film	X 0.8
'DC' constant potential set	X 0.8
'short cone' (100mm sources to skin distance)	X 1.5
50 kV set	X 2.0
D-speed film	X 2.0

Intraoral x-ray examination, Cone length and collimation

Cone must be of open ended type

X-ray beam diameter must not exceed 60 mm.

FSD >=200 mm

Features that contribute to dose reduction

Panoramic and cephalometric equipment:

- Fastest screen-film combinations
- Digital detector
- Collimation
- Wedge filters
- Field size limitation
- Paediatric examination mode

Features that contribute to dose reduction

Dental CBCT equipment:

- **Volume of patient imaged**

  Multipurpose dental CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient

- **kiloVoltage and mAs**

  KiloVoltage and mAs should be adjustable on CBCT equipment and must be optimized during use according to the clinical purpose of the examination, ideally by setting protocols with the input of a medical physics expert

- **Choice of voxel size**

  Multipurpose dental CBCT equipment should offer a choice of voxel sizes and examinations should use the largest voxel size (lowest dose) consistent with acceptable diagnostic accuracy

Features that contribute to dose reduction

Dental CBCT equipment:

- **Digital detector**

  Dental CBCT units equipped with either flat panel detectors or image intensifiers need to be optimized in terms of dose reduction before use

- **Number of projections and recostruction algorithm.**

  Research studies should be performed to assess further the effect of the number of projections on image quality and radiation dose

- **Copper filter**

Dental radiography dosimetry

Reference: IAEA Technical Reports series no. 457

A report prepared by the SEDENTEXCT project 2011 , www.sedentexct.eu

- ✓ Intraoral (bitewing projections)

  Incident air kerma, Ki

- ✓ Panoramic

  Air kerma-area product, P_{KA}

- ✓ CBCT (in evaluation…)

  CTDI

  Air kerma-area product, P_{KA}

  New dose index

Dental radiography dosimetry

Reference: IAEA Technical Reports series no. 457

Patient dosimetry

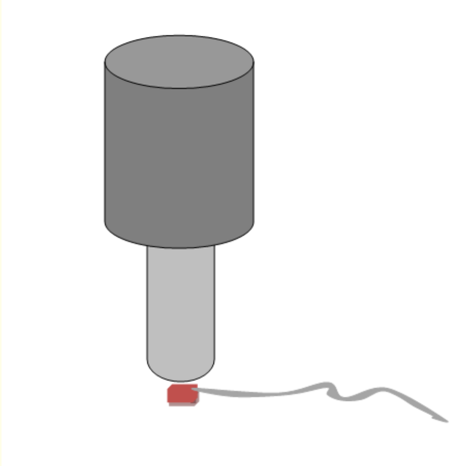
- Exposure settings are normally fixed and do not vary from patient to patient
- Different protocols for types of teeth and adults/paediatric patients
- Patient exposures based on free-in-air measurements
- Use of diagnostic dosimeter or/and TL dosimeters
- TLDs : useful tool for postal dose audits

Measurement with phantoms

Measurements in anthropomorphic phantoms could be performed using TLDs

Dental radiography dosimetry : Bitewing projection

Measurement of incident air kerma with dosimeter



- Position a detector at the centre of the exit of the spacer/director cone.
- Detector should be irradiated totally
- No scattering objects nearby in the beam
- Expose the detector 3 times
- Record temperature and pressure for k_{TP} corrections
- Repeat for all settings used at clinical practice

Dental radiography dosimetry : Bitewing projection

Measurement of incident air kerma with dosimeter

$$K_i = \overline{M}\, N_{K,Q_0}\, k_Q\, k_{TP}$$

$$k_{TP} = \left(\frac{273.2 + T}{273.2 + T_0}\right)\left(\frac{P_0}{P}\right) \quad \text{for IC}$$

k_{TP} = 1.00 for solid state

k_{TP} correction for temperature and pressure

k_Q the correction factor for the beam quality (as deduced by the measured HVL)

Dental radiography dosimetry : Panoramic projection

Measurement of incident air kerma with dosimeter

List of equipment

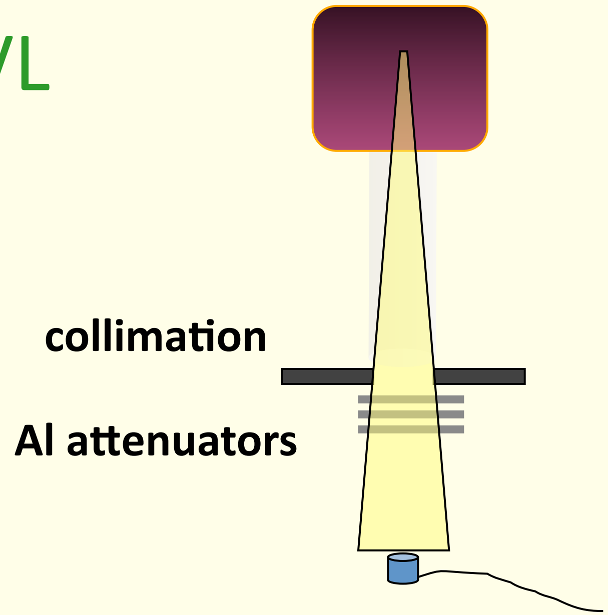
• Calibrated pencil type ionisation chamber (CT chamber) and electrometer;
• Chamber support;
• Thermometer and barometer;
• (TLD dosimeters 1 mm thick and 3 mm diameter)
• Jig for mounting the dosimeters Film and a ruler (for screen-film systems)
• Film and a ruler (for screen-film systems).

Dental radiography dosimetry : HVL

Extracted from

Joint ICTP-IAEA Advanced school on Dosimetry in Diagnostic Radiology: And its Clinical Implementation
11 - 15 May 2009

Donald McLean



HVL measurement

- Set-up the X ray equipment.
- Centre the dosimeter in the X ray beam
- Collimate the beam to achieve conditions for narrow beam geometry.

HVL is used for the determination of the k_Q correction factors of dosimeters & TLDs

Dental radiography dosimetry : HVL

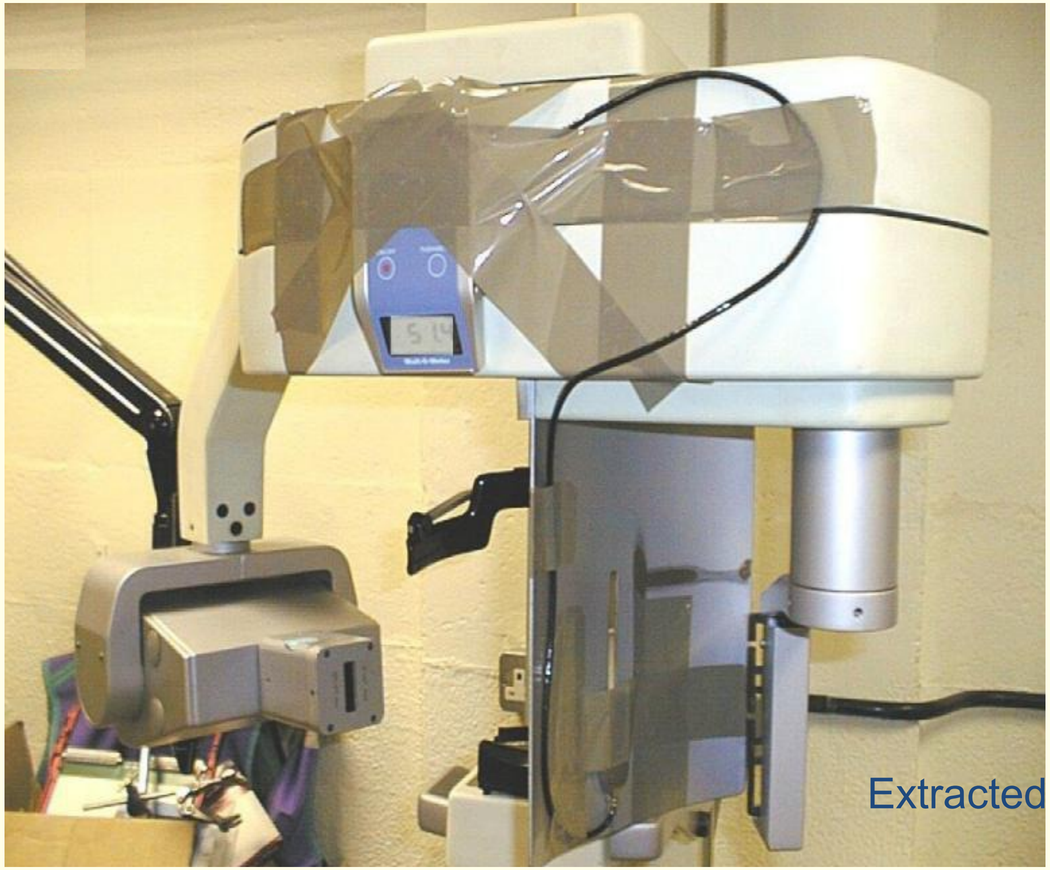
HVL measurement

- For the panoramic unit the tube immobilization might be difficult
- Cephalometric mode could be used
- Otherwise….

Extracted from

Half Value Layer (Set-UP)

OPG



Extracted from

Joint ICTP-IAEA Advanced school on Dosimetry in Diagnostic Radiology: And its Clinical Implementation
11 - 15 May 2009

Dental radiography dosimetry : Panoramic projection

Measurement of incident air kerma with dosimeter

- Position the pencil type chamber in front of the secondary collimator (slit)
- Expose the chamber three times using standard settings of tube voltage, tube load and exposure cycle and record the dosimeter readings *M*1, *M*2 and *M*3.
- Repeat step 3 for other standard settings used in the clinic.
- Record the temperature and pressure.

Extracted from

Joint ICTP-IAEA Advanced school on Dosimetry in Diagnostic Radiology: And its Clinical Implementation
11 - 15 May 2009

Dental radiography dosimetry : Panoramic projection

Measurement of incident air kerma with dosimeter

$$P_{KL} = \overline{M}\ N_{P_{KL},Q_0}\ k_Q\ k_{TP}$$

$$k_{TP} = \left(\frac{273.2 + T}{273.2 + T_0}\right)\left(\frac{P_0}{P}\right)$$

k_{TP} correction for temperature and pressure

k_Q the correction factor for the beam quality (as deduced by the measured HVL)

Extracted from

Joint ICTP-IAEA Advanced school on Dosimetry in Diagnostic Radiology: And its Clinical Implementation
11 - 15 May 2009

Dental radiography dosimetry: Panoramic projection

Measurement of the height of the X ray beam at the secondary collimator slit

- Position a film in front of the collimator slit
- Expose the film to an optical density of less than 0.5 OD.
- Measure the height of the X ray beam on the film using a ruler or scanner. The height is defined as the length between points where the optical density is reduced to half of the maximum optical density.

Dental radiography dosimetry: Panoramic projection

Establishment of the air kerma-area product

both dosimeter & TLD method

air kerma area product

$$P_{KA} = P_{KL}\, H$$

H : height of X-ray beam, as measured by the film

Dose Reference Level (DRL)

European guidelines on radiation protection in dental radiology, Issue N ° 136

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

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

Table 5.7 continued:

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

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

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

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

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

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

Typical doses

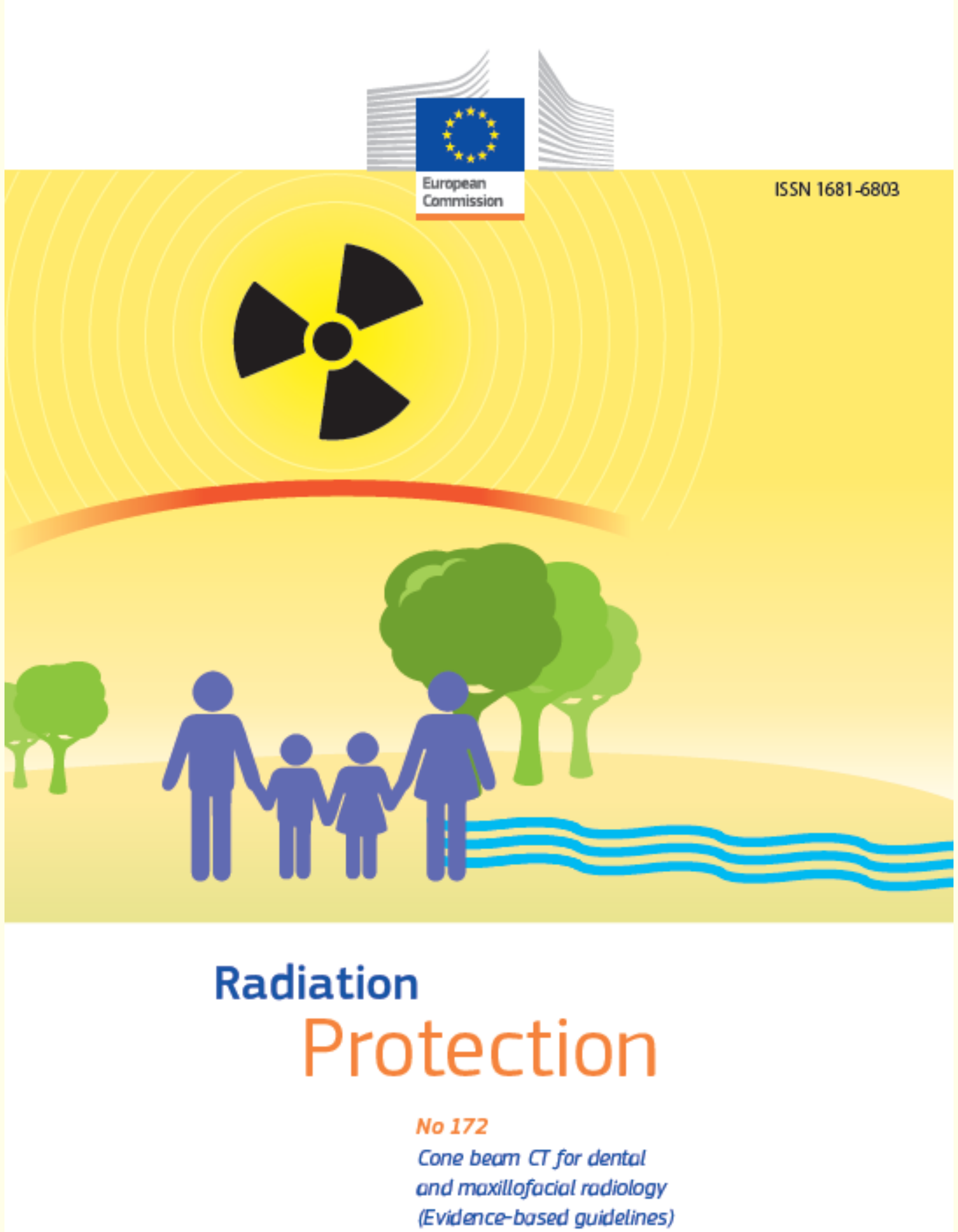
Mean values from various national surveys are in the following ranges:

- 1-8 mGy in terms of entrance surface air kerma for intraoral radiography;
- About 100 mGy*cm^2 in terms of kerma-area product for panoramic radiography;
- 0.25-7 mGy in terms of entrance surface air kerma for cephalometric radiography [EC-RP 136], [UNSCEAR 2000].

Dental radiography dosimetry: CTCB

A report prepared by the SEDENTEXCT project
www.sedentexct.eu

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



Dental radiography dosimetry: CTCB

A report prepared by the SEDENTEXCT project
www.sedentexct.eu

3.1.1 CTDI

For CT scanners the CT dose index (CTDI) is usually used. This is a measurement of the dose integrated across the dose profile along the patient’s length. It is measured using a pencil detector either in air or in a perspex phantom[ix]. Such a dose index has drawbacks for use in dental CBCT units due to the greater beam size and asymmetry of the dose distribution. However, if a CTDI is quoted by the manufacturers, it is suggested that this be measured by the medical physics expert at commissioning for comparison with the specification.

Dental radiography dosimetry: CTCB

A report prepared by the SEDENTEXCT project

Measurements can be performed using an ion chamber or TLDs, within a suitable PMMA phantom (diameter 16cm is recommended). Two CBCT dose indices are currently proposed. Index 1 requires measurements along a diameter of the phantom (Figure 1) and is calculated as the mean of the readings. Index 2 involves measurements at the centre of the phantom and at points around the periphery. Index 1 allows the measurement of an index for on-axis and off-axis exposures, and full and partial dose distributions simply by rotating the phantom in such a way that the isocentre of the x-ray beam lies on the measuring diameter as shown in Figure 1. Index 2 is only suitable for symmetrical dose distributions.

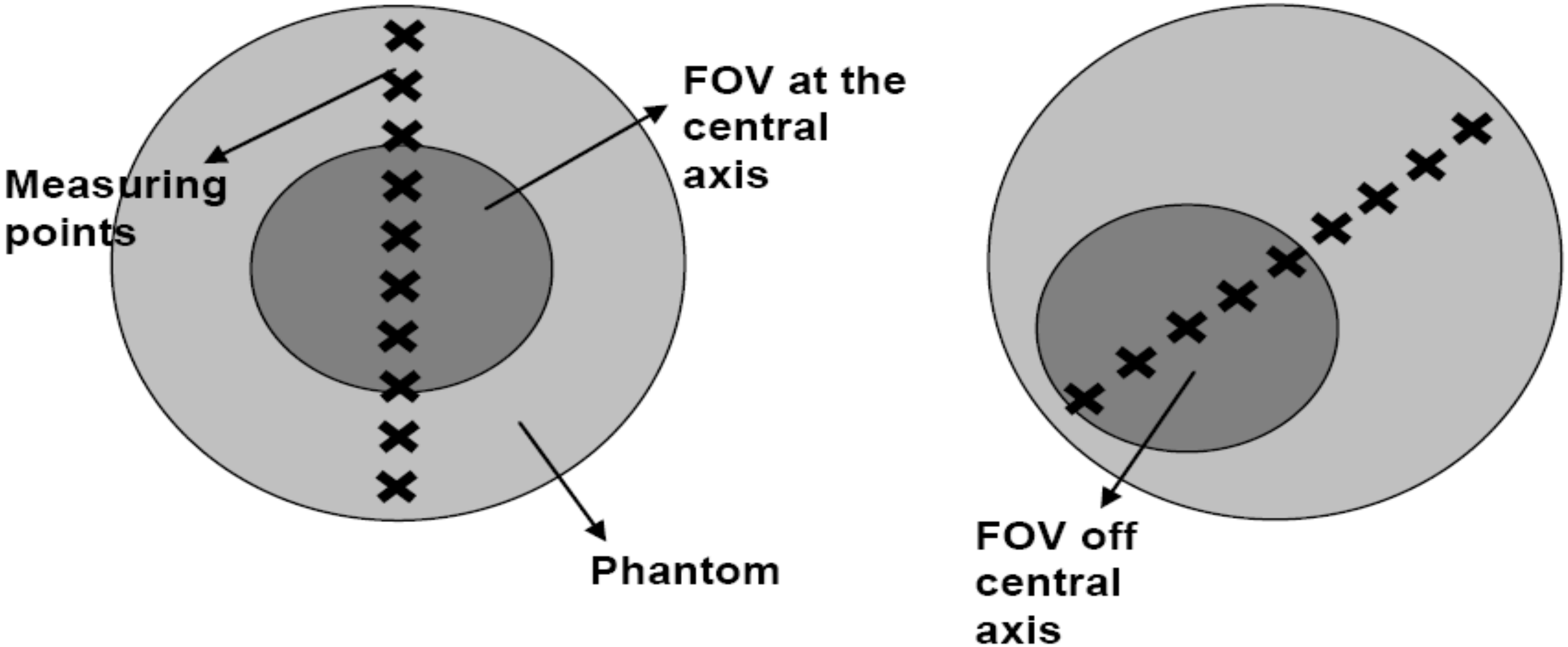


Figure 1. Measurement points for Index 1

Dental radiography dosimetry: CTCB

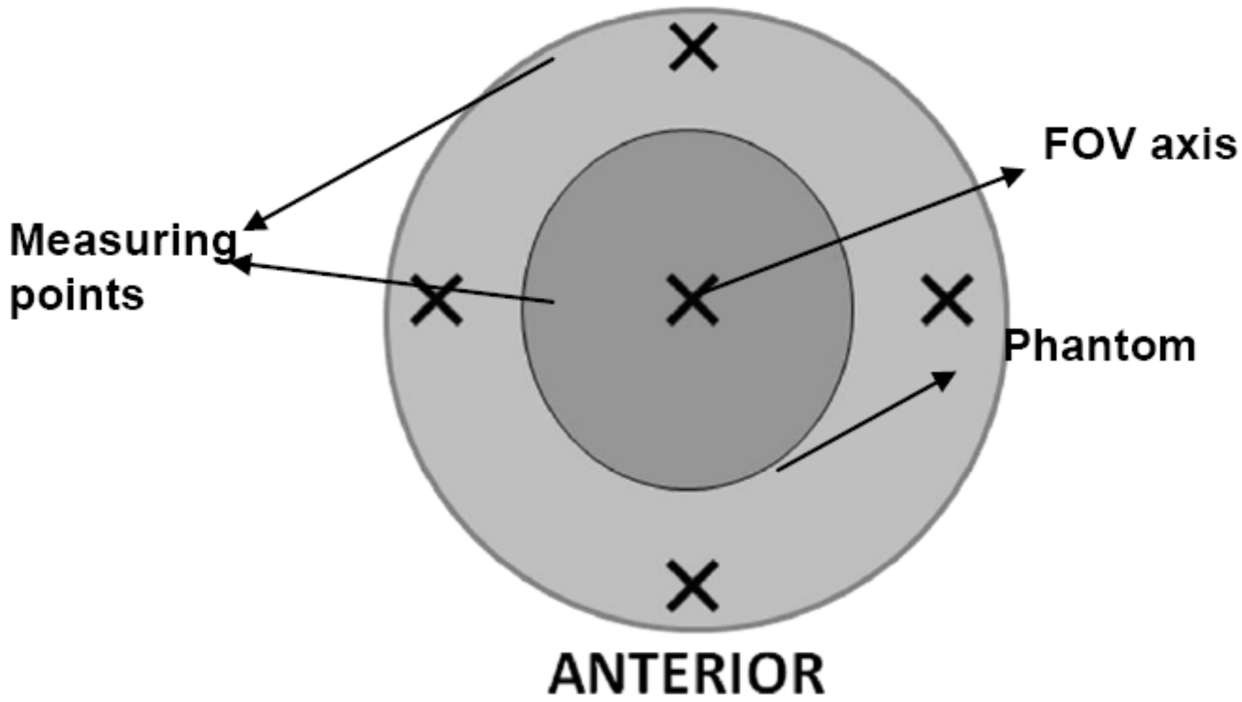


Figure 2 Measurement points for Index 2

Dose Reference Level ?

Based on current national audit data an initial achievable level of 250 mGy cm^2 is proposed and further data is requested so that national reference levels for both adult and child can be set.

It is recommended that clinical dose levels are determined in a practice (by measurement of standard protocols or by patient dose audit if dose index readouts are provided by the equipment) and compared to past results and any national and international levels when set. Dose levels higher than these standards merit investigation as this would suggest that dose is not optimised.

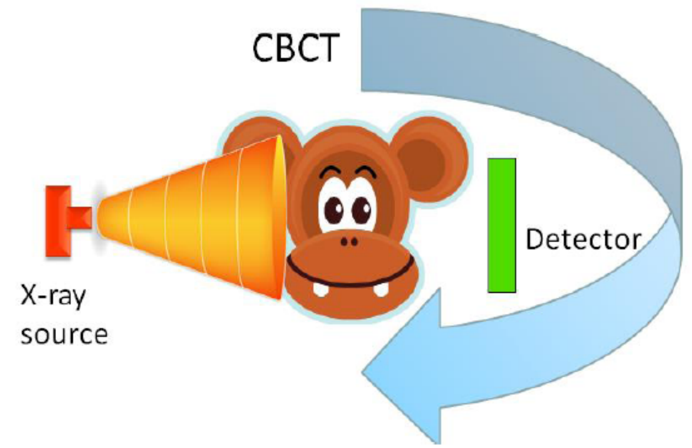
Dental radiography of pregnant patients

- Concerning the dose, there is no controindication to radiography of women who are or may be pregnant providing that it is clinical justified.

- There is no need to use a lead apron. However, the use of lead apron continues to be recommended in some nations to reassure the patient

Children

http://www.pedrad.org



How can Radiation Risk to a Child be Minimized?

The Image Gently Campaign provides guidance to dental practitioners to minimize radiation exposure to children. These involve numerous strategies and include:

- Only perform imaging when there is a clear medical or dental benefit to the child.
- Use the lowest amount of radiation for adequate imaging based on the size of the child.
- Only take images on the indicated area and always using the thyroid collar
- Avoid multiple unnecessary images.
- Use alternative diagnostic studies (such as ultrasound or MRI), if possible.

Children

Table 2. Relative radiation level (RRL) designations for children and adults (after ACR)

Relative Radiation Level	*Effective Dose Estimate Range (mSv)*	
	Adult	*Child*
None	0	0
Minimal	< .1	< .03
Low	.1 – 1	.03 - .3
Medium	1 – 10	.3 – 3.0

Despite several limitations of estimating radiation dose risk, comparison of the radiation Effective Dose from various dental Imaging Procedures (Table 1) to the RRL (Table 2) shows that for children all dental radiographic procedures have minimal risk. For CBCT the risk can vary from low to medium depending on the scanner used.

Lead aprons and thyroid collars

- Vertex examination pregnant patient
- The value of leaded aprons is minimal compared to the benefit of using the E-speed films and rectangular collimation
- Lead aprons should be provided for who is required to support a patient during the radiographic procedure (i.e., a comforter or career).
- Thyroid collars should be used in the examinations where the thyroid may be in the main beam
  - inappropriate for panoramic radiography as it may interfere with the primary beam. In cephalometric radiography lead thyroid prot. Is necessary if the beam does not exclude the thyroid gland.

Thyroid shielding was found to reduce radiation doses by 45% during CT of the head and is strongly recommended, especially in younger groups.

Old equipment

- Move to E-film speed
- 1 mm of aluminium beam filtration should be added to the x-ray tube head
- Exposure setting Optimisation
- Quality assurance

https://rpop.iaea.org

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Thank you
for your attention!