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Joint ICTP/IAEA Advanced School on Dosimetry in Diagnostic Radiology and its Clinical Implementation

11 - 15 May 2009

Dosimetry for Dental Radiography

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Joint ICTP-IAEA Advanced school on Dosimetry in Diagnostic Radiology:
And its Clinical Implementation
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Dosimetry for Dental Radiography

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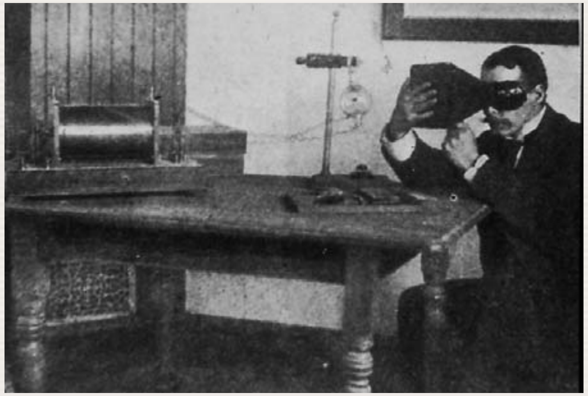
Stories of Kells and Rollins

Kells dental pioneer

- 1880 first to make and use electrified equipment compressed air, electric drill, suction.
- July 1896 demonstrated x-ray technique
- 1912 declared he was “completely immune” to x-rays
- Died 1928 after enduring radiogenic neoplasia for 10-12 years, 35 operations and several amputations.



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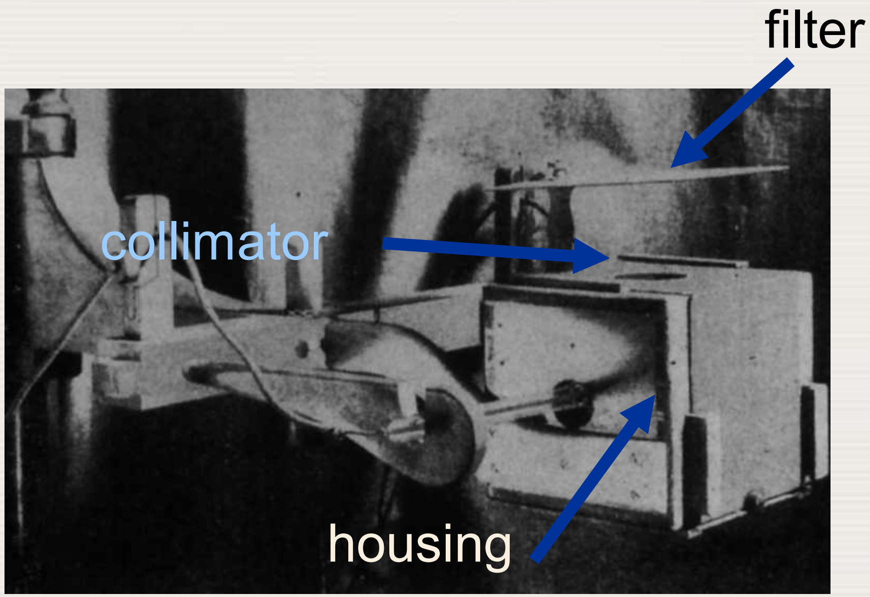
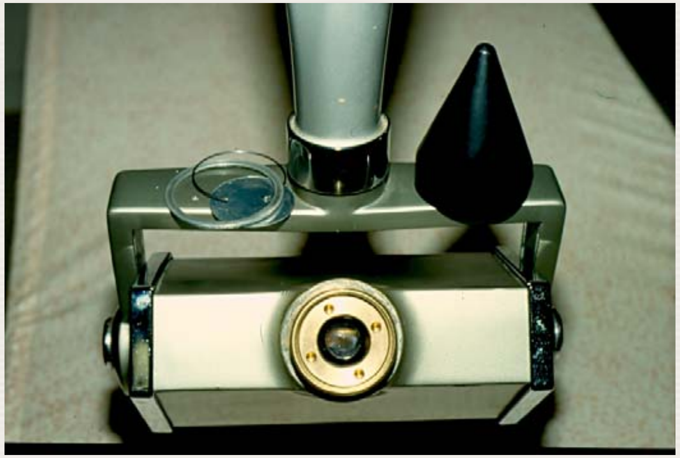
Stories of Kells and Rollins

- **William Herbert Rollins – Scientist/Dentist**
- Boston dental practice by day and researcher by night with over 300 papers published.
- Reported radiation effects on Guinea Pigs (1898 onwards)
- Recommended the use of **filters, housing and collimation** as well as intensifying screens



Beam Collimation (Intra oral Unit)

Cone must be of open ended type



X-ray beam diameter must not exceed 60 mm.

FSD >=200 mm

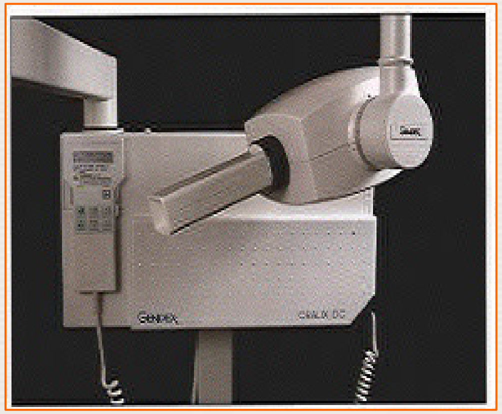
Dental radiography dosimetry

✓Intraoral (bitewing projections)

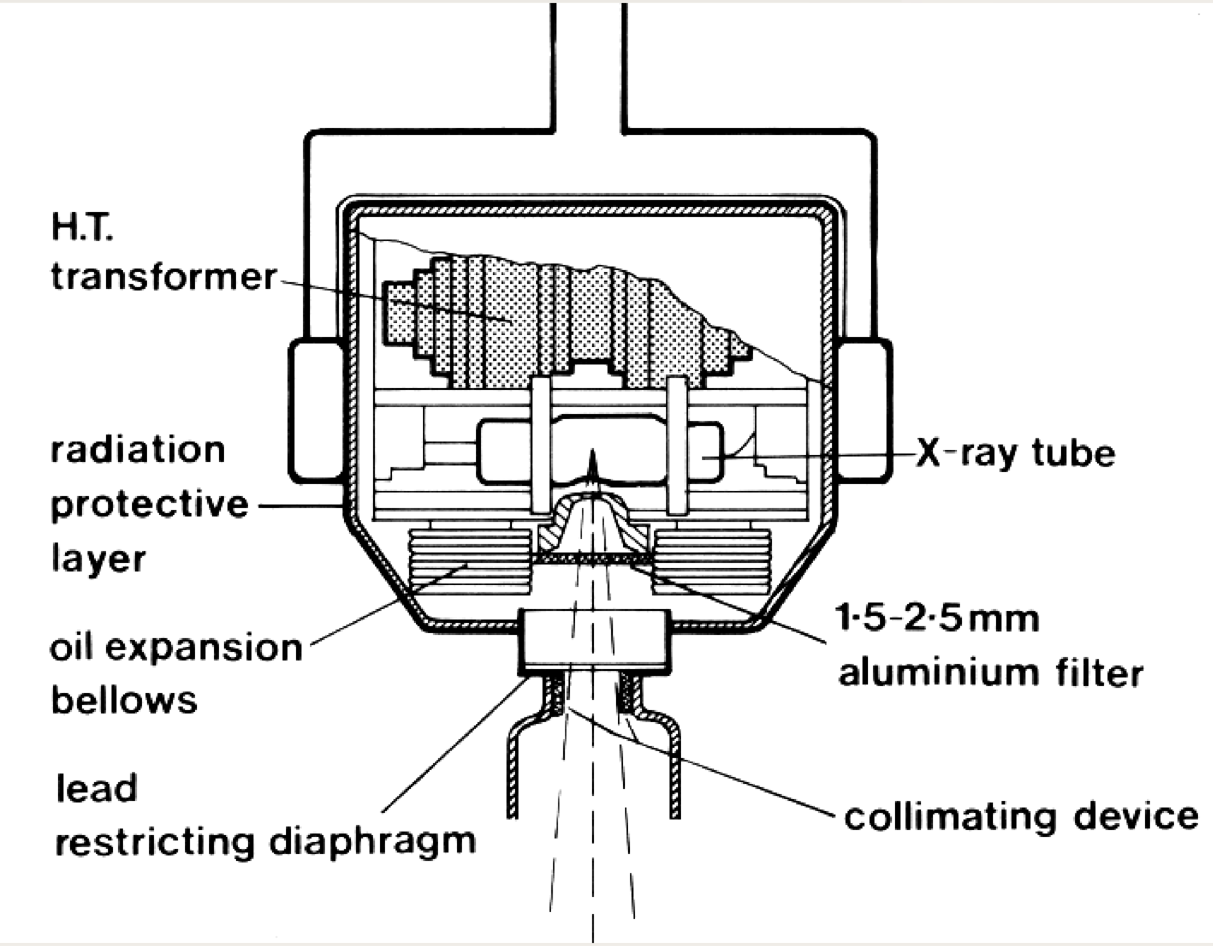
Incident air kerma, K_i

✓Panoramic

Air kerma-area product, P_{KA}



Tube Head



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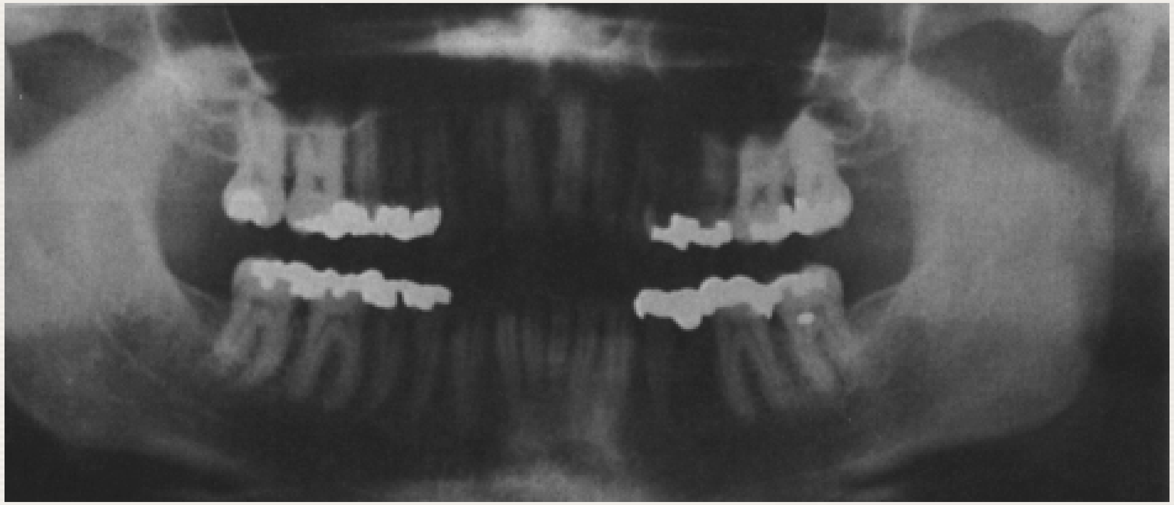
OPG Image



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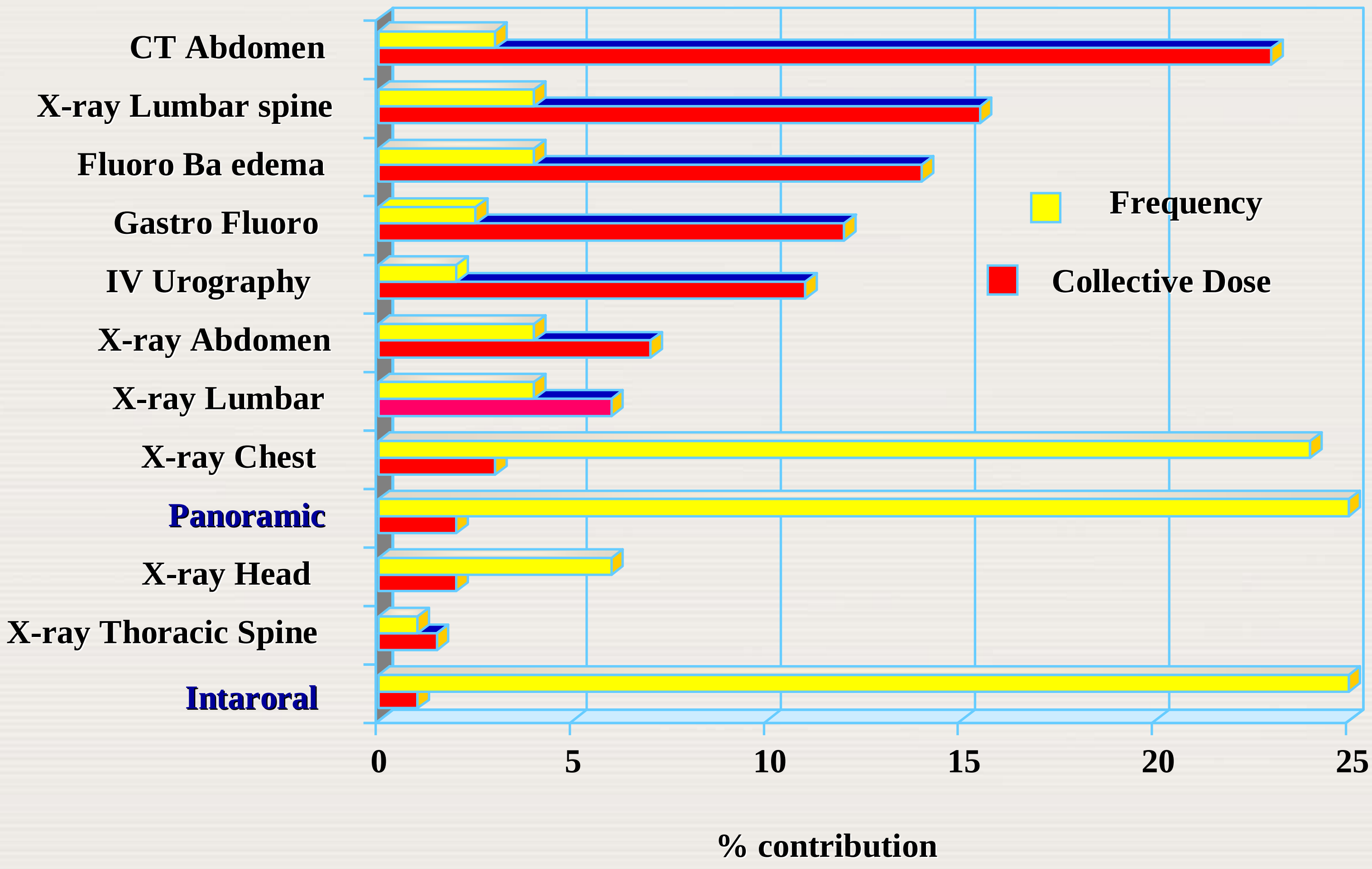
Dental radiography



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Dental radiography dosimetry

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

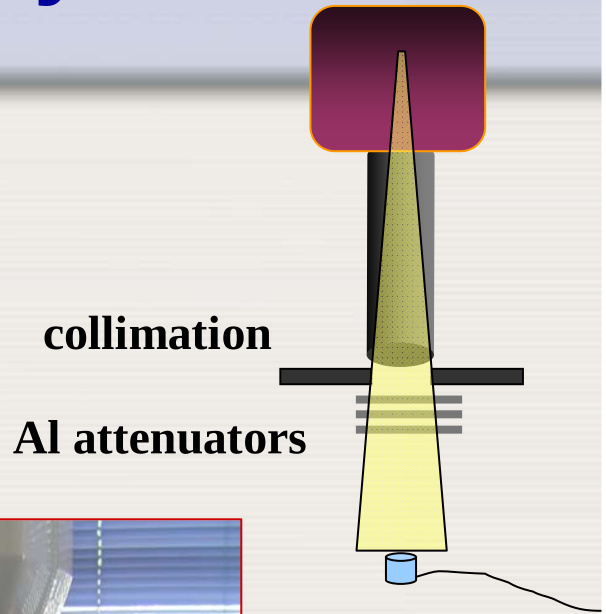
Measurement with phantoms

Measurements in anthropomorphic phantoms are performed using TLDs (are not described in the TRS 457)

Dental radiography dosimetry : HVL

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

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Dental radiography dosimetry : HVL

HVL measurement

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

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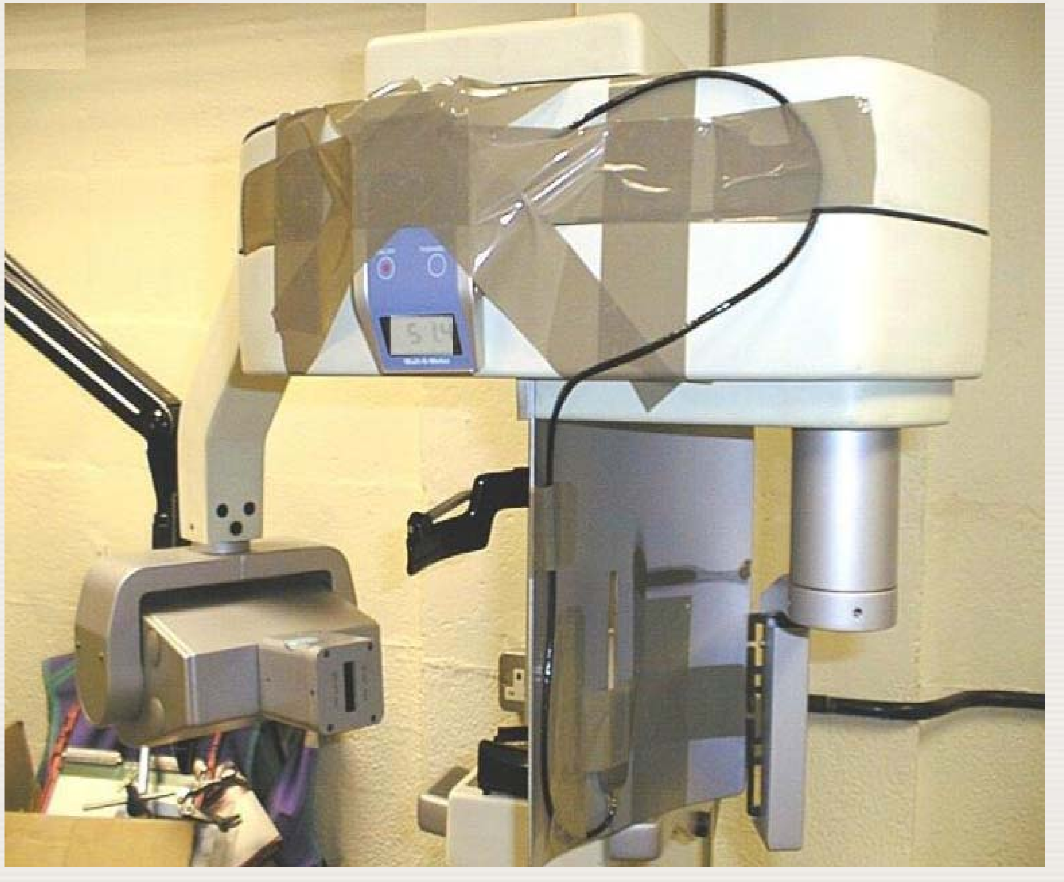
Half Value Layer (Set-UP)

OPG



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Dental radiography dosimetry : Bitewing projection

List of equipment

• Calibrated diagnostic dosimeter;
• Chamber support stand;
• Thermometer and barometer (for measurements with ion chambers);
• Calibrated TL dosimeters (for measurements using TLDs);

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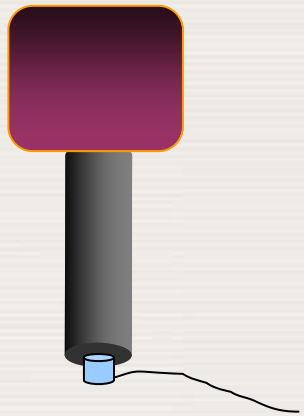
Dental radiography dosimetry : Bitewing projection

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



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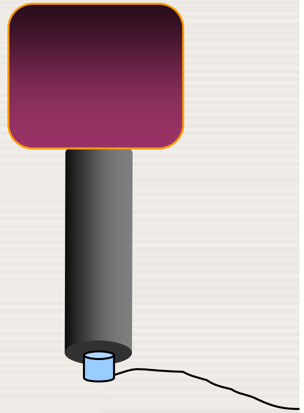
Dental radiography dosimetry : Bitewing projection

Measurement of incident air kerma with dosimeter

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

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

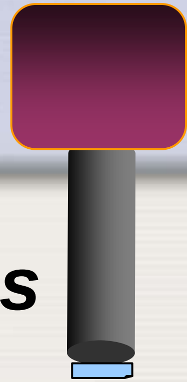
$k_{\mathrm{TP}} = 1.00$ for solid state



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 : Bitewing projection



Measurement of incident air kerma with TLDs

- Position a sachet with three (3) TLD modules at the centre of the exit of the spacer/director cone.
- No scattering objects nearby in the beam
- Another one sachet should be left unexposed (background) M_{01}, M_{02}, $M_{0}3$
- Expose the sachet (M_1, M_2, M_3)
- Repeat for all settings used at clinical practice

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Dental radiography dosimetry : Bitewing projection

Measurement of incident air kerma with TLDs

$$\overline{M}_0 = (M_{01} + M_{02} + M_{03})/3$$

the average background dosimeter reading

$$\overline{M} = \frac{\sum_{i=1}^{3} f_{s,i}\left(M_i - \overline{M}_0\right)}{3}$$

the average background-corrected dosimeter reading

$$f_{si} = \frac{\overline{M}_{calibr}}{M_{i,calibr} - \overline{M}_{0,calibr}}$$

$f_{s,i}$ factors correct for the individual sensitivity of the i-th dosimeter, M_{calibr} and $M_{0,calibr}$ are TLD readings during calibration (TLD group)

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

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

k_f : the correction for the fading effect

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Dental radiography dosimetry : Panoramic projection

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).

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.

Dental radiography dosimetry : Panoramic projection

Measurement of incident air kerma with dosimeter

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

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

k_{TP} correction for temperature and pressure

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

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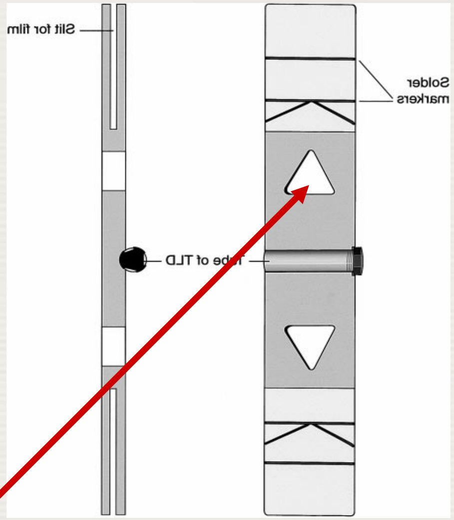
Dental radiography dosimetry : Panoramic projection

Measurement of incident air kerma with TLDs



- A set of TLD with total width three times the slit width. Pack the chips in a tube of PMMA
- Three TLDS for background M_{01}, M_{02} and M_{03}
- Place the jig with PMMA tube at slit
- Expose TLD at standard settings of tube voltage, tube loading and exposure cycle (M_1, M_2, …..M_n)
- Repeat measurements for other standard settings used in the clinic.

Dental radiography dosimetry: Panoramic projection

Measurement of incident air kerma with TLDs

$$\overline{M}_0 = (M_{01} + M_{02} + M_{03})/3$$

the average background dosimeter reading

$$\overline{M} = \frac{\sum_{i=1}^{3} f_{s,i}\left(M_i - \overline{M}_0\right)}{3}$$

the average background-corrected dosimeter reading

$$f_{si} = \frac{\overline{M}_{calibr}}{M_{i,calibr} - \overline{M}_{0,calibr}}$$

$f_{s,i}$ factors correct for the individual sensitivity of the i-th dosimeter, M_{calibr} and $M_{0,calibr}$ are TLD readings during calibration (TLD group)

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

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

k_f : the correction for the fading effect

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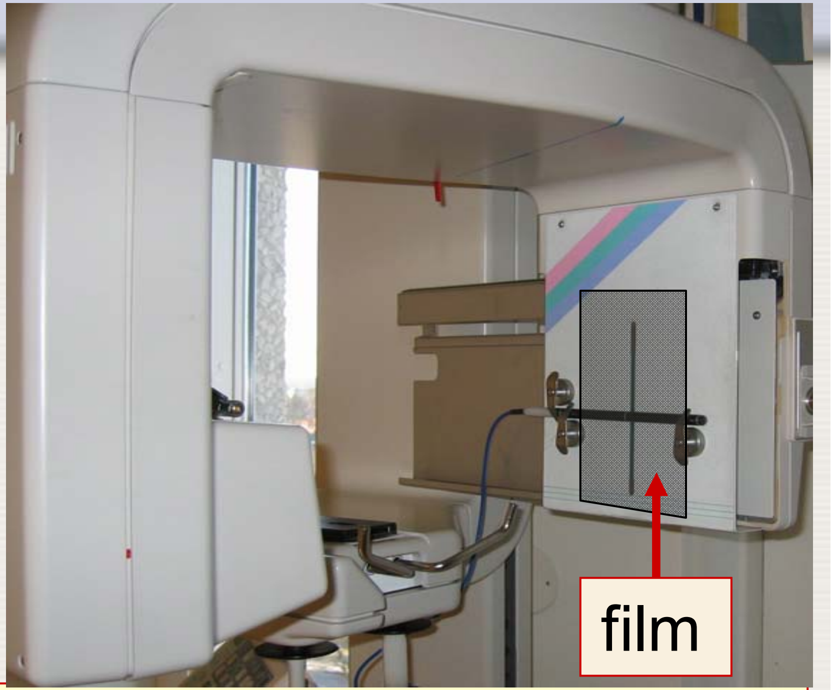
$$P_{KL} = \sum_{i=1}^{n} K_i\,\Delta d$$

Δd : the thickness of the ith TLD

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

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

Dental radiography dosimetry : Uncertainties

Scenario 1 : An instrument in compliance with IEC 61674 is used. No k_{TP} applies but normal pressure at sea level. K_i deduced from reading and calibration coefficient

Scenario 2 : A reference class dosimeter is used with a performance exceeding the requirements of IEC 61674. k_{TP} applies using the actual T & P values.

Scenario 3 : A reference class dosimeter is used. Conditions of exposure are tightly controlled, i.e. in terms of radiation quality, direction of radiation incidence, density of air etc. and where corrections for the relevant influence quantities are made.

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Dental radiography dosimetry : Uncertainties

Influence quantity	IEC 61674 ±L in %	Uncertainty (k=1)/% Scenario 1	Scenario 2	Scenario 3
Intrinsic error, $N_{K,Q}$ or $N_{K,Q0}$*k_Q	5	2,89	1,6	1,6
Radiation quality, i.e. differences between SSDL and user	5	2,89	1,5	0,5
Kerma rate	2	1,15	0,5	0,5
Direction of radiation incidence	3	1,73	1,0	0,5
Air pressure	2	1,15	0,5	0,5
Temperature and humidity	3	1,73	0,5	0,5
Electromagnetic compatibility	5	2,89	1,5	1,0
Field size/field homogeneity	3	1,73	1,0	1,0
Operating voltage	2	1,15	1,2	1,0
Long term stability of user's instrument	2	1.15	1,0	0,5
Relative combined standard uncertainty (k=1)		**6,3**	**3,5**	**2,7**
Relative expanded uncertainty (k=2)		**12,6**	**7,0**	**5,4**

Dental radiography dosimetry : Uncertainties

Table 8.15 (TRS457 p 218) UNCERTAINTY IN THE DETERMINATION OF INCIDENT AIR KERMA FOR A BITEWING PROJECTION USING THE DIAGNOSTIC DOSIMETER.

Source of uncertainty	Uncertainty (k=1)/ %		
	Scenario 1	Scenario 2	Scenario 3
Measurement scenario (see Table 8.2)	6.3	3.5	2.7
Precision of reading	1.0[1)]	0. 6[2)]	0.6[2)]
Uncertainty in measurement position[3)]	1.2	1.2	1.2
Relative combined standard uncertainty (k=1)	6.5	3.7	3.0
Relative expanded uncertainty (k=2)	**13.0**	**7.4**	**6.0**

1) One single reading taken
2) Standard deviation of the mean of 3 readings
3) 2 mm in positioning of a detector at distance 200 mm from the X ray focus

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Dental radiography dosimetry : Uncertainties

UNCERTAINTY IN THE DETERMINATION OF AIR KERMA LENGTH PRODUCT FOR PANORAMIC PROJECTION USING PENCIL TYPE IC

Source of uncertainty	Uncertainty (k=1)/ %		
	Scenario 1	Scenario 2	Scenario 3
Measurement scenario (see Table 8.2)	6.3	3.5	2.7
Precision of reading	1.0[1)]	0. 6[2)]	0.6[2)]
Uncertainty in measurement position[3)]	1.2	1.2	1.2
Relative combined standard uncertainty (k=1)	6.5	3.7	3.0
Relative expanded uncertainty (k=2)	**13.0**	**7.4**	**6.0**

1) One single reading taken
2) Standard deviation of the mean of 3 readings
3) 2 mm in positioning of a detector at distance 200 mm from the X ray focus

For the p_{KA} uncertainty, a 2% of slit height is added (1.2% effect), the U in range 6.4 – 13.2 %

Thanks to

- This presentation was compiled by several authors. Credits belong especially to

- Costas Hourdakis

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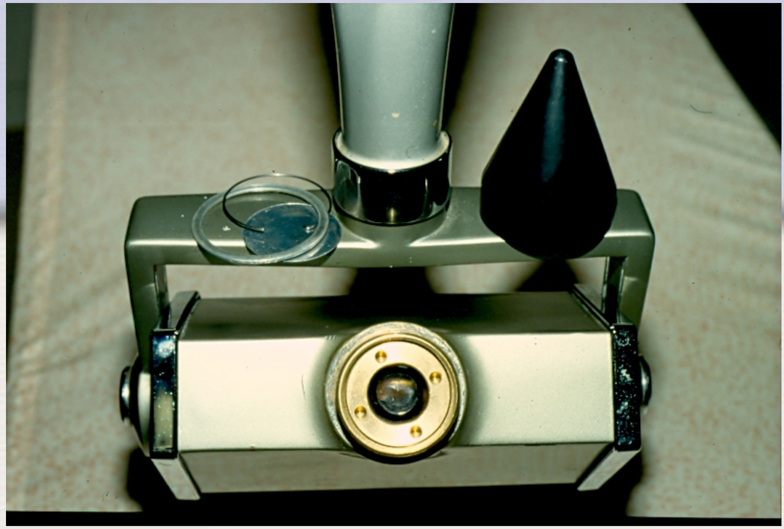

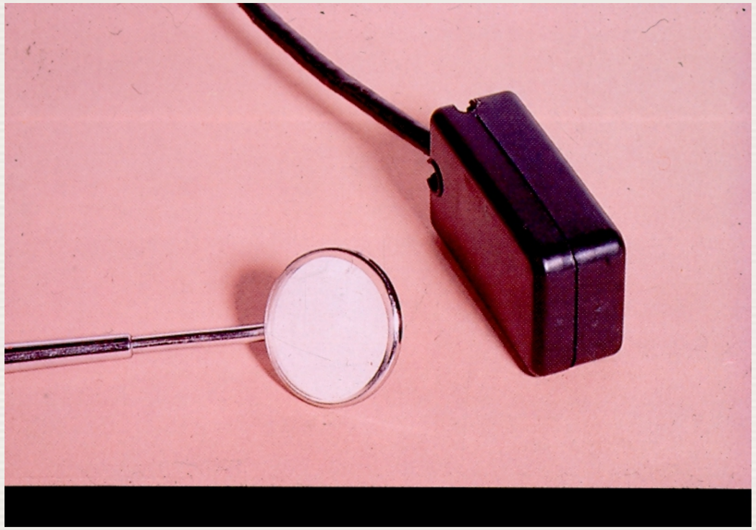

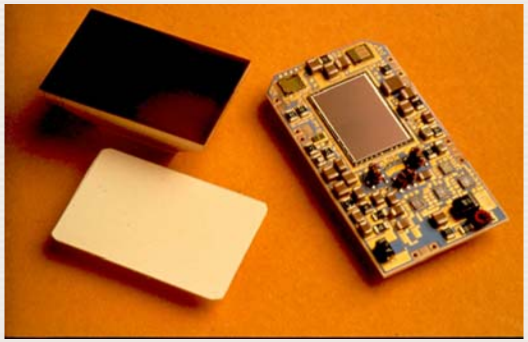

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