Patient exposure to X-rays in dental radiology

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1. Dental X-ray examinations

• Dental X-rays:
  - are the most frequent type of diagnostic X-ray procedures
  - account for more than 21-25% of total X-ray examinations

• Over 500 million dental X-ray examinations performed worldwide every year (UNSCEAR 2000) –

• Individual patient doses are relatively low\(^1\) but collective doses\(^2\) can be significant.

\(^1\) in comparison to diagnostic radiology (radiography, fluoroscopy, mammography, CT...)

\(^2\) Collective dose = Average dose per patient x Total number of patients
2. Dental X-ray Examinations

- Intra Oral X-rays
- Panoramic X-rays (PAN)
- Cephalometric X-rays (CEPH)

- Dental CBCT\(^3\) [3-D]

\(^3\) Cone Beam Computed Tomography
Intra Oral X-rays
(Fixed position - One shot, one image)

- **Bitewing X-rays:**
  Image of the crowns of top and bottom teeth

- **Periapical X-rays:**
  Image of full tooth structure, from crown to root

- **Occlusal X-rays:**
  Image of entire arch of teeth (upper or lower jaw)

- **Fullmouth series:**
  Series of bitewing and periapical X-rays to show all teeth (crowns and roots)

X-ray tube for intra oral imaging

source: IAEA radiation protection of patients [https://rpop.iaea.org](https://rpop.iaea.org)
**Panoramic dental X-rays** *(rotating X-ray assembly)*

**Panoramic view - Image of full mouth**

X-ray assembly (Tube + image receptor) rotates around patient’s head

![Panoramic radiograph](http://pedrad.org/Portals/6/Procedures/What%20Parents%20Should%20Know%20about%20the%20Safety%20of%20Dental%20Radiology.pdf)

Source: www.youngchildrensdentistry.com
Cephalometric X-rays - (Fixed position - One shot, one image)

Image of the entire head

Image receptor
X-ray tube

Cephalometric radiographs
PA position
Profile Position

Courtesy: IAEA radiation protection of patients
https://rpop.iaea.org

miglobaltech.com
Dental Cone Beam Computed Tomography (CBCT)

Dental CBCT:

- is a 3-dimensional (3D) imaging procedure

- was developed to overcome the limitations of 2-Dimensional (2D) imaging.

- is a potential imaging support for:
  • the developing dentition
  • Restoring the dentition, e.g. implants
  • Surgical applications, e.g. trauma, correcting abnormalities...
- Patient positioning: sitting or standing in general
- X-ray beam shape: cone-shaped (small FOV and large FOV)
- Exposure time: About 20 sec / rotation
- 3D images (reconstructed 2-D acquisitions)
- Patient dose: lower than medical CT
Small volume Cone Beam CT  
Large volume Cone Beam CT

Source: IAEA radiation protection of patients https://rpop.iaea.org
- Patient positioning: lying down
- X-ray beam: Fan beam (Thin slices)
- Very quick acquisitions
- Large volumes imaged

But:
- Soft tissues fall down (collapse)
- The Temporomandibular joint (TMJ) not in normal position
- Patient dose: higher than CBCT
3. Justification of dental X-rays and protection of patients

ARE DENTAL X-RAYS NECESSARY?

ANSWER: YES

- NO ALTERNATIVE TO X-RAYS FOR IMAGING INTERNAL DENTAL STRUCTURES.

HOWEVER:

- Dental X-rays are not always justified (~20% unnecessary according to UNSCEAR)
- Patient doses must be kept as low as possible
4. Exposure to dental X-rays

4.1. RADIATION DOSE UNITS

- Absorbed Dose, D

Amount of radiation energy absorbed in a unit mass of biological tissue.

Standard International (SI) unit of D:

The Gray (Gy)

The absorbed dose D does not take into account:

- the type of ionizing radiation involved
- the exposed tissue/organ (muscle, bone, fat, other soft tissues..)
- Equivalent dose, $H$ [for a tissue or organ]

\[ H = D \times W_R \]

$H = \text{product of } D \text{ by a dimensionless radiation weighting factor } W_R$.  

<table>
<thead>
<tr>
<th>Type of radiation</th>
<th>$W_R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-rays</td>
<td>1</td>
</tr>
<tr>
<td>Gamma</td>
<td>1</td>
</tr>
<tr>
<td>Beta particle</td>
<td>1</td>
</tr>
</tbody>
</table>

SI unit of $H$: Sievert (Sv) [$\text{To distinguish it from dose } D$]

$H$ expresses the biological effectiveness of a given type of ionizing radiation.
-Effective Dose, E [whole body]

It is defined as the weighted sum of the equivalent doses $H_T$ in the different organs and tissues of the body to convey a whole body dose:

$$E = \sum W_T H_T = W_1 H_1 + W_2 H_2 + \ldots$$

$W_T$ is the tissue weighting factor for tissue $T$; reflects the sensitivity to ionizing radiation.

Values of $W_T$ for different organs and tissues are shown on Table 1 (next slide)

Unit: $E$ is also expressed in units of Sievert (Sv)

The effective dose $E$ is the quantity that measures the radiation risk associated with exposure to ionizing radiation.
4.2. **Tissue sensitivity: Weighting Factor $W_T$**

<table>
<thead>
<tr>
<th>Organ/Tissue</th>
<th>$W_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>0.12</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.12</td>
</tr>
<tr>
<td>Colon</td>
<td>0.12</td>
</tr>
<tr>
<td>Bone marrow</td>
<td>0.12</td>
</tr>
<tr>
<td>Breast</td>
<td>0.12</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.04</td>
</tr>
<tr>
<td>Esophagus</td>
<td>0.04</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.04</td>
</tr>
<tr>
<td>Liver</td>
<td>0.04</td>
</tr>
<tr>
<td>Bone surface</td>
<td>0.01</td>
</tr>
<tr>
<td>Skin</td>
<td>0.01</td>
</tr>
<tr>
<td>Brain</td>
<td>0.01</td>
</tr>
<tr>
<td>Salivary glands</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Circled in red: organs that are most exposed in dental radiology

5/19/2016
4.3. X-ray machine output (relative to intra-oral X-rays)

# 4.4. Patient dose per procedure for different dental imaging procedures

<table>
<thead>
<tr>
<th>Technique</th>
<th>Effective dose (μSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D Intra-oral radiograph</td>
<td>Up to 1.5 μSv</td>
</tr>
<tr>
<td>2D Cephalometric radiograph</td>
<td>Up to 6 μSv</td>
</tr>
<tr>
<td>2D Panoramic radiograph</td>
<td>2.7 to 24 μSv</td>
</tr>
<tr>
<td>3D CBCT for dento-alveolar imaging</td>
<td>11 to 674 μSv</td>
</tr>
<tr>
<td>3D CBCT for craniofacial imaging</td>
<td>30 to 1073 μSv</td>
</tr>
<tr>
<td>3D Medical CT for dental implant planning scans</td>
<td>280-1410 μSv</td>
</tr>
</tbody>
</table>

4.5. Relative contribution of organ doses (H) to effective dose (E) in dental CBCT

Figure 2.1: Average contribution of organ doses to effective dose calculations for CBCT, adapted from Pauwels et al (2012).
5. X-ray-induced risks

<table>
<thead>
<tr>
<th>X-ray induced risk (per milliSievert)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer</td>
</tr>
<tr>
<td>Hereditable effects</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

(Ref. ICRP 103)
Radiation cancer risk in relation to age

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Multiplication factor for risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>x 3</td>
</tr>
<tr>
<td>10-20</td>
<td>x 2</td>
</tr>
<tr>
<td>20-30</td>
<td>x 1.5</td>
</tr>
<tr>
<td>30-50</td>
<td>x 0.5</td>
</tr>
<tr>
<td>50-80</td>
<td>x 0.3</td>
</tr>
<tr>
<td>80+</td>
<td>Negligible risk</td>
</tr>
</tbody>
</table>

(Ref. ICRP 103)

Children are much more sensitive to X-rays than adults
6. Recommendations for the protection of dental patients, particularly children

- Dental X-rays *should not* be routinely used
- Dental X-rays *should be justified* (i.e. prescribed only when necessary)
- Machines *must undergo* periodical quality control to check image quality and output consistency
- X-ray personnel *should receive training* on patient radiation protection
- Always keep *records* of dental X-ray examinations
- *Discuss* radiation issues with the dentist
- *Read* about dental X-rays
7. Recommended Frequency of dental X-ray examinations

- **intra-oral**: ~ 1 every year or 2 years
- **Panoramic and/or cephalometric**: every 3 to 5 years
- **CBCT**: Only when absolutely necessary, i.e. when 2-D imaging (e.g. PAN) cannot provide required diagnostic information (Follow CDSBC* guidelines)

* College of Dental Surgeons of British Columbia
8. Dental X-ray Guidelines


SC 30 Guidelines cover only 2-D imaging


- Canadian Dental Association

CDA Position on Control of X-Radiation in Dentistry

http://www.cda-adc.ca/_files/position_statements/xRadiation.pdf

- College of Dental Surgeons of British Columbia (CDSBC) - Standards and Guidelines for Dental radiography (Sep 2015)

Additional guidelines for 3-D CBCT


http://www.bccdc.ca/healthenv/Radiation/MedicalXrays/default.htm#Dental
Radiation Protection

No 172

Cone beam CT for dental and maxillofacial radiology
(Evidence-based guidelines)
Some Websites of interest:

www.rpop.iaea.org

www.pedrad.org

http://www.imagegently.org/Procedures/Dental.aspx
RYZ Radiation and Biosafety Consulting Ltd.

www.radsafety.ca

Email: Info@EMFSafety.ca
Telephone: 778 862 5594

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