Diagnostic Imaging
and
Radiation Safety

Anthony Reynolds BA MSc PhD
Registered Clinical Scientist CS03469

Image Diagnostic Technology Ltd.
Who or what is IDT?

Image Diagnostic Technology Ltd aka “IDT Scans”

Specialises in:

- arranging dental CT/CBCT scans
- 3D processing
- radiology reports
- implant simulation
- 3D models
- surgical drill guides

32,000 scans processed since 1991
What can IDT do with my images

- Prepare datasets for planning implants
- Radiology Reports
- Treatment Plans
- 3D Models
- Surgical Drill Guides
Get the most out of your dental CT/CBCT scans

IMPLANT SIMULATION
REFORMAT AN EXISTING SCAN
REQUEST A RADIOLOGY REPORT
REQUEST A NEW DENTAL CT SCAN

Choose a scanning site in the UK or Ireland

SEARCH
Scan Site Search

**Location**

**Keyword**

**A-Z List**

Search

Click the icons for more Information

---

**Dental Practice**

**i-CAT 17-19 CBCT**

**Click Here to Request a Scan**

Oasis Dental Care Heckmondwike
19 Cemetery Road
Heckmondwike
West Yorkshire WF16 9QS

**Prices**

<table>
<thead>
<tr>
<th></th>
<th>GBP</th>
<th>EUR</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Quad</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Arch</td>
<td>£120</td>
<td>£165</td>
<td></td>
</tr>
<tr>
<td>Both Arch</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Table**

<table>
<thead>
<tr>
<th>Name</th>
<th>Distance</th>
<th>Category</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinity House Orthodontics</td>
<td>0.5 km</td>
<td>IDT Scanning Site Partner</td>
<td>i-CAT Classic CBCT</td>
</tr>
<tr>
<td>Oasis Dental Care Heckmondwike</td>
<td>11.5 km</td>
<td>IDT Scanning Site Partner</td>
<td>i-CAT 17-19 CBCT</td>
</tr>
<tr>
<td>Nuffield Health Leeds Hospital</td>
<td>13.4 km</td>
<td>IDT Scanning Site Partner</td>
<td>Toshiba Aquilion ONE medical CBCT</td>
</tr>
</tbody>
</table>
Downloads

Click here to download Lecture Slides

Click here to download our Publications.

For further assistance please contact IDT Scans
Outline of Lectures

✓Introduction / Disclosures

• Diagnostic Imaging in Dentistry
  – Conventional Radiography
  – CT / CBCT Scans

• Radiation Dose and Risk

• Compliance with the Legislation
What do we use dental imaging for?

Review patient anatomy and pathology
  • diagnostic quality images
  • at a low radiation dose

Answer specific clinical questions
  • is caries present
  • how many teeth are present
  • quality and quantity of bone
  • radio-lucencies or radio-opacities
Imaging for specific dental applications

Planning dental implants

Orthodontics

Endodontics

Surgical Planning
**Imaging for Dental Implants**

Need to be able to:

- Review patient anatomy and pathology
  - diagnostic quality images
- Assess bone quantity and quality
  - quantitative assessment
- Decide where implants should go
  - accurate 3D measurements
  - avoid sensitive structures
  - must work mechanically and aesthetically
Restoration-Driven Implant Planning

“Create a model of the desired result, then work backwards to determine how it can be achieved”

- 3D Treatment Planning Software
- Radio-Opaque Scanning Stents
- Surgical Drill Guides
interactive implant planning software

Simplant™ is a trademark of Dentsply Sirona
Why 3D software is important
Software for planning Dental Implants

- Simplant (Dentsply Sirona)
- Blue Sky Plan (Blue Sky Bio) - Macintosh
- Osirix (with Dental3D plugin) - Macintosh
- In Vivo Dental (Anatomage)
- Nobel Clinician (Nobel Biocare)
- coDiagnostiX (Dental Wings)
- ImplantMaster (iDent)
- etc etc
Blue Sky Plan
(Macintosh or PC)

- Free Software produced by Blue Sky Bio
- Can be used with any implant system (but the implants are not realistic)
- Can import DICOM CT or CBCT data
- Can import STL files from optical scanners
- Can be used to design surgical drill guides (but there is a charge to export the STL file)
- Extensive videos available on YouTube
Restoration-Driven Implant Planning

“Create a model of the desired result, then work backwards to determine how it can be achieved”

✓ 3D Treatment Planning Software
- Radio-Opaque Scanning Stents
- Surgical Drill Guides
Advantages of using a Scanning Stent

• Gives inter-arch stability for the patient during the scan
• Opens the bite slightly (a few mm) using occlusal stops
• Shows position and size of the desired restorations
• Shows inter-arch relationship

• If you want a mucosa-supported surgical guide, edentulous patients MUST be scanned wearing a stent
Making a Scanning Stent

- Plastic and clear acrylic does not show up on a CT scan.

- To make it show up, you can:
  - mix barium sulphate with the acrylic
  - paint barium sulphate on the surface
  - use radio-opaque teeth
  - use markers made from a radio-opaque material
    - lab putty
    - gutta percha
    - glass ionomer
  - use a dual-scan technique.
• We recommend using a barium sulphate-acrylic mix for both the radio-opaque teeth and the baseplate.

• Use 15% barium sulphate in the teeth and 10% barium sulphate in the baseplate. This allows the teeth to be picked out separately.

• Do not use too much Barium Sulphate as it will cause an artefact.

• An accurate fitting stent with radio-opaque baseplate is usually the best option for mucosa-supported surgical drill guides.
Good Stent
Bad Stent
Terrible Stent
Dual Scan Technique
Restoration-Driven Implant Planning

“Create a model of the desired result, then work backwards to determine how it can be achieved”

✔ 3D Treatment Planning Software
✔ Radio-Opaque Scanning Stents
  - Surgical Drill Guides
**SIMPLANT drill guide**

Guide resting on:
- Bone
- Mucosa
- Teeth

The SurgiGuide controls:
- Position
- Orientation
- (Depth)

Guiding cylinders

*Simplant™* is a trademark of Dentsply Sirona
Drill Guides can be supported on

Bone
- Bone crest must be clearly visible in the CBCT images and ≥ 3cm long

Mucosa
- Patient must be scanned with a radio-opaque scanning stent in place

Tooth
- Tips of teeth must be clearly visible in the CBCT images
- A recent and accurate plaster cast will be required

Need to think about the Guide before you request the CBCT Scan!
Tooth Supported Guides

- Drill Guide will be supported on patient’s existing teeth
- Need a recent and accurate impression or plaster cast
- Optical (laser) scan of plaster cast (or intra-oral scan)
- Import optical scan into the implant planning software
- Guide will be designed to fit the plaster cast.
Optical Scan of Plaster Cast
Design the Guide
Print it on a 3D Printer
The Ultimate Goal

Place implants so accurately that a (temporary) restoration can be fabricated before the surgery takes place

“The Immediate Smile” – Dentply Sirona
“Teeth in an Hour” – Nobel Biocare
“Smart Implants” – Limplant Ltd
The Ultimate Goal

Place implants so accurately that a (temporary) restoration can be fabricated before the surgery takes place.

- To do this you have to rely on your imaging!
What Imaging Modalities are available?

- Intra-oral radiography
  - Periapicals, bitewings, occlusal views

- Extra-oral radiography
  - AP and Lateral cephs

- Dental Panoramic Tomography (DPT or OPG)

- Cone Beam computed tomography (CBCT)
Intra-oral Imaging

+ Very high resolution (20 lp/mm)
+ Fast, convenient, low dose
- Magnification / Distortion
- No (quantitative) bone quality
- Distance measurements not reliable
Distortion in intra-orals

Solutions:
- bisecting angle
- paralleling technique
**Digital Radiography**

Two types:

- CMOS or CCD detector
- Photostimulable Phosphor Plate (PSPP)
CCD/CMOS Digital imaging

Fig. 6.14  Examples of modern solid-state sensors. A Planmeca dixi\textsuperscript{2} and conventional film packets to show their comparative size. B Gendex Visualix\textsuperscript{®} (kindly provided by Mr R. France). C Kodak RVG 6000.
PSPP Digital imaging

Fig. 7.6 Examples of three phosphor plate readers. A Soredex's Digora® Optime (intraoral), B Durr's Vistascan and C Gendex® DenOptix™.
Extra-oral: Lateral Cephs

+ Good overview
+ Useful for orthodontics
  – Magnification / Distortion
  – Distance measurements not reliable
Conventional Tomography
(tomography by blurring)
Dental Panoramic Tomography (DPT)
Dental Panoramic Tomography (DPT, OPG, OPT)

+ Very good overview
  + Mandibular fractures, unerupted teeth
+ Sufficient detail for caries diagnosis
  – Variable Magnification / Distortion
  – Patient positioning is crucial
Cross-Sectional Imaging

- Linear Tomography
- Complex Motion Tomography (CMT)
- Ultrasound
- Magnetic Resonance Imaging (MRI)
- Computed Tomography (CT or CBCT)
Advanced imaging: Magnetic resonance imaging in implant dentistry
A review

Crawford F. Gray, Thomas W. Redpath, Francis W. Smith, Roger T. Staff

Article first published online: 31 JAN 2003
DOI: 10.1034/j.1600-0501.2003.140103.x
Computed Tomography (CT)  
(tomography by computation)
Panoramic images are perpendicular to the reference axial and intersect it at the curves shown below. Images are numbered from buccal to lingual and are viewed from buccal.
Dental (CB)CT Scans

The dentoalveolar region has high natural contrast.

So we can get away with
- high resolution images
- low radiation dose

We can reduce the dose and get away with images that would not be acceptable for a medical CT scan.
• CBCT is useful for:
  ➢ planning dental implants
  ➢ maxillofacial surgery
  ➢ cleft palate assessment
  ➢ TMJ and airway analysis
  ➢ impacted, supernumerary and abnormal teeth
  ➢ root canals, root fractures etc
  ➢ periapical disease

• CBCT is not good for:
  ➢ dental caries
  ➢ soft tissue tumours
4.18: Where CBCT images include the teeth, care should be taken to check for periapical disease when performing a clinical evaluation (report).

4.19: CBCT is not indicated as a standard method for demonstration of root canal anatomy.

4.20: Limited volume, high resolution CBCT may be indicated, for selected cases where conventional intraoral radiographs provide information on root canal anatomy which is equivocal or inadequate for planning treatment, most probably in multi-rooted teeth.

4.21: Limited volume, high resolution CBCT may be indicated for selected cases when planning surgical endodontic procedures. The decision should be based upon potential complicating factors, such as the proximity of important anatomical structures.

4.22: Limited volume, high resolution CBCT may be indicated in selected cases of suspected, or established, inflammatory root resorption or internal resorption, where threedimensional information is likely to alter the management or prognosis of the tooth.

4.33: Limited volume, high resolution CBCT may be justifiable for selected cases, where endodontic treatment is complicated by concurrent factors, such as resorption lesions, combined periodontal/endodontic lesions, perforations and atypical pulp anatomy.

4.34: Limited volume, high resolution CBCT is indicated in the assessment of dental trauma (suspected root fracture) in selected cases, where conventional intraoral radiographs provide inadequate information for treatment planning.
Grading systems used for levels of evidence [adapted from Scottish Intercollegiate Guidelines Network (SIGN), 2008].

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>At least one meta-analysis, systematic review, or RCT rated as 1++, and directly applicable to the target population; or a systematic review of RCTs or a body of evidence consisting principally of studies rated as 1+, directly applicable to the target population, and demonstrating overall consistency of results</td>
</tr>
<tr>
<td>B</td>
<td>A body of evidence including studies rated as 2++, directly applicable to the target population, and demonstrating overall consistency of results; or extrapolated evidence from studies rated as 1++ or 1+</td>
</tr>
<tr>
<td>C</td>
<td>A body of evidence including studies rated as 2+, directly applicable to the target population and demonstrating overall consistency of results; or extrapolated evidence from studies rated as 2++</td>
</tr>
<tr>
<td>D</td>
<td>Evidence level 3 or 4; or extrapolated evidence from studies rated as 2+</td>
</tr>
<tr>
<td>GP</td>
<td>Good Practice (based on clinical expertise of the guideline group and Consensus of stakeholders)</td>
</tr>
</tbody>
</table>
Cone Beam CT (CBCT) Scanner

GXCB-500™ is a trademark of Gendex Dental Systems of Lake Zurich, USA
What is Cone-Beam CT and How Does it Work?

William C. Scarfe, BDS, FRACDS, MS\textsuperscript{a,*},
Allan G. Farman, BDS, PhD, DSc, MBA\textsuperscript{b}

\textsuperscript{a}Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Room 222G, 501 South Preston Street, Louisville, KY 40292, USA

\textsuperscript{b}Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Room 222C, 501 South Preston Street, Louisville, KY 40292, USA
Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: A systematic review of the literature
DentoMaxilloFacial Radiology

CBCT Special Issue
how CT works...

Godfrey Hounsfield

Allan Cormack

Nobel prize in Medicine,
1979

Animation courtesy of Demetrios J. Halazonetis
www.dhal.com
acquisition

Animation courtesy of Demetrios J. Halazonetis
acquisition

Animation courtesy of Demetrios J. Halazonetis
acquisition

Animation courtesy of Demetrios J. Halazonetis
reconstruction

Animation courtesy of Demetrios J. Halazonetis
volume dataset

Animation courtesy of Demetrios J. Halazonetis
Animation courtesy of Demetrios J. Halazonetis
Animation courtesy of Demetrios J. Halazonetis
Voxels (Volume elements)
Voxels (Volume elements)

512 x 512 x 400 slices ≈ 100 million voxels (200 Mb)

density: 0 - 4095

Animation courtesy of Demetrios J. Halazonetis
cone-beam CT (CBCT)
cone-beam CT (CBCT)

Animation courtesy of Demetrios J. Halazonetis
cone-beam CT (CBCT)

Animation courtesy of Demetrios J. Halazonetis
cone-beam CT (CBCT)

X-ray Tube

Detector
"Sorry mate – no can do!"
CB-500 CBCT Scanner

- Pulsed x-ray tube
- Adjustable collimator: 4 to 8.6 cm height, 8.6 or 15.6 cm width
- Large detector: 8 cm x 8 cm
- Adjustable chair
- Fast scan times: 4.8s to 23s
- Low dose: typical Mx 35µSv, typical Mn 60µSv

Around £90K

Gendex™ is a trademark of Gendex Dental Systems of Lake Zurich, USA
Gendex™ is a trademark of Gendex Dental Systems of Lake Zurich, USA

DP-700 CBCT Scanner

variable mA
fixed scan times
11s for SFOV
45s for MFOV

medium dose
typical Mx 60µSv
typical Mn 100µSv

fixed collimator
4cm x 6cm SFOV
8cm x 6cm MFOV

small detector
no chair

Around £45K
Basic CBCT images

- Panoramic
- Transaxial
- Cross-sectional
Basic CBCT images

Axials

Panoramics

Cross Sections

Sagittal

Coronal
Hyperdontia

Courtesy of Nicolette Schroeder
Third Molars

Courtesy of Barry Dace
Outline of Lectures

✓ Introduction / Disclosures
✓ Diagnostic Imaging in Dentistry
  – Conventional Radiography
  – CT / CBCT Scans
• Radiation Dose and Risk
• Compliance with the Legislation
13.5 \mu Sv/h
Dose Rate at Chernobyl (2017)
• 200m from the reactor
• 1.35 microSievert per hour

Background Dose Rate in the UK (Average)
• 0.25 microSievert per hour

Flight from the UK to Chernobyl
• 3 hours × 5 μSv/hr = 15 μSv

Dental x-ray (intraoral)
• 1 microSievert

CBCT scan (both jaws)
• 100 microSievert
Topics

• What is radiation?
• Sources of radiation
• Is radiation harmful?
• How can I estimate the risk?
What is Radiation?

- Energy travelling through space
- Sunshine is a familiar example
  - A small amount is beneficial
  - Too much can be harmful
Energy depends on the frequency $E = h\nu$
**Gamma Rays and X-Rays**

- Referred to as “Ionising Radiation”
- Can disrupt atoms and turn them into positive and negative ions
- This can cause damage at molecular level.
Sources of Ionising Radiation

1. Environmental (e.g. Radon)
2. Cosmic Rays
3. Radioactive Isotopes
   - inside or outside the body
   - natural or man-made
4. Medical and Dental x-rays

The first 3 make up “Background Radiation”
The first 4 make up “Per-Capita Dose”.
Per-Capita Dose in the UK

Background Radiation: 2.2mSv
Medical and Dental: 0.5mSv
Average Per-Capita Dose: 2.7mSv per person per year
Topics

- What is radiation?
- Sources of radiation
- Is radiation harmful?
- How can I estimate the risk?
What is radon - and how does it work?

In short - Gastein radon therapy stimulates the ability of your own cells to repair themselves. While you swim in thermal water, sweat in a radon vapor bath or relax in the Gastein Healing Gallery, your body absorbs radon through your respiratory passages and skin. In the process, the noble gas emits mild alpha radiation in your body, which in turn activates a special messenger substance, reducing inflammation and promoting natural healing processes. The result: The number of free radicals in your body drops and you have less pain.
Deterministic and Stochastic effects

Deterministic Effects are reproducible
• severity of the effect increases with the dose
• not observed below a threshold dose of about 500mSv

Stochastic Effects are random
• the risk (not the severity) increases with the dose
• known to occur above 20mSv or so
• below about 20mSv we don’t know if they occur or not

Hereditary Effects are random (stochastic) but the incidence in humans is very low.
**Deterministic Effects**

For a high dose of radiation received over a short period of time, we know that the following effects will occur:

- radiation sickness: 1-2Gy (whole body dose)
- skin erythema: 2-5Gy (local dose)
- sterility: 2-3Gy (local dose)
- hair loss: 2-5Gy (local dose)
- death: 3-5Gy (whole body dose)

*We should never see any of these effects in a dental practice!*
Deterministic Effects in Radiation Workers

Dentist (1980s)

Interventional Radiologist (1998)

1 = POSTERIOR SUBCAPSULAR OPACITY
2 = PARANUCLEAR DOT OPACITIES
Vano E et al.; B Jr Radiol 1998; 71:728-733
Dose levels leading to opacities (ICRP 118)

- Lens opacities may occur at doses between 0.2 Gy and 0.5 Gy.
- The severity may increase progressively with dose and time.
- Threshold (1% risk of cataract) is 0.5 Gy acute or chronic exposure.
- Previously cataract was only thought to occur at higher doses and not progress with time.
- Based on exposure over a working lifetime with 15 - 20 y follow-up.

New occupational eye lens limit: 20 mSv per year
(averaged over 5 year, with not more than 50 mSv/year)

Eye Lens Limit is 15 mSv/year for staff and members of the public.
Stochastic Effects

• For a high dose of radiation received over a short period of time, it is very likely (but not certain) that cancer will be induced.

• For a low dose of radiation, we think that cancer may be induced (maybe many years after exposure) but we don’t know for sure.
Should not see in dental practice!

Threshold Dose (about 500 mSv)

Risk Factor = \( \Delta P / \Delta D \)

(about 5% per Sievert)
Effects of Chernobyl Disaster

- 28 workers known to have died from Radiation Sickness (deterministic effect)
- 15 children known to have died from thyroid cancer (stochastic effect)
- An additional 4000 may have died from stochastic effects – we don’t know for sure.

http://www.who.int/ionizing_radiation/chernobyl/backgrounder/en/
Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know


Contributed by Richard Doll, August 29, 2003
Estimated excess relative risk (±1 SE) of mortality (1950–1997) from solid cancers among groups of survivors in the LSS cohort of atomic bomb survivors, who were exposed to low doses (<500 mSv) of radiation (2).

Brenner D J et al. PNAS 2003;100:13761-13766

©2003 by National Academy of Sciences
Schematic representation of different possible extrapolations of measured radiation risks down to very low doses, all of which could, in principle, be consistent with higher-dose epidemiological data.

Brenner D J et al. PNAS 2003;100:13761-13766

©2003 by National Academy of Sciences
The Linear No-Threshold (LNT) Model

Assumes that the risk of producing cancer is proportional to the dose (no safety threshold)

Assumes that cellular damage does not accumulate from one x-ray exposure to the next

Assumes that the risk for a given exposure depends only on the dose for that x-ray exposure and not on the patient’s previous dose history

Assumes that x-ray exposures are independent events.
Criticism of the LNT Model

Doesn’t take dose rate into account

Implies that cells do not have a repair mechanism (if they did, the curve would be less than linear and maybe have a threshold)

Implies that cellular damage does not accumulate from one x-ray exposure to the next (if it did, the curve would be greater than linear)

There is no proof that the LNT model is correct – but it is prudent to use it for Radiation Protection.
The concept of Effective Dose

We know the risks from high doses of radiation
- e.g. Atom Bomb survivors
- Atom Bomb survivors received whole body doses
- Dental patients receive doses to a very small region
- How can we relate the risks?

*Effective Dose* is a way of describing the dose to a limited region in terms of the whole body dose that would result in the same risk to the patient

Effective Dose is a measure of risk!
**Dose Terminology**

**Absorbed Dose**
Energy absorbed by tissue
(Gray, Gy)

**Equivalent Dose $H_T$**
(Sievert, Sv)

**Effective Dose $E$**
(Sievert, Sv)

1 Gray (Gy) = 1 Joule per Kilogram (J/Kg)

Multiply the Absorbed Dose by the Radiation Weighting factor $W_R$ (= 1 for x-rays) to get $H_T$ “Local Dose”

Multiply the Equivalent Dose $H_T$ by the Tissue Weighting factor ($W_T$) for each organ, and add them up to get the Effective Dose $E$ “Whole Body Dose”
### Tissue Weighting Factors from ICRP 103

<table>
<thead>
<tr>
<th>Tissue</th>
<th>w&lt;sub&gt;T&lt;/sub&gt;</th>
<th>ICRP 103</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Salivary glands</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Oesophagus</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Red bone marrow</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Breast</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Bone surface</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Colon</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Ovary</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Bladder</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Testes</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Remainder</td>
<td>0.12</td>
<td></td>
</tr>
</tbody>
</table>
More about Effective Dose

• The Effective Dose calculation takes the size of the region and the body parts irradiated into account.

• It’s tempting to say “My CBCT scanner might deliver a high Effective Dose, but it’s only to a very small region” but this argument is not valid.
To obtain the Effective Dose in practice:

Method 1: Measure it!

1. Measure Absorbed Dose to each organ of interest

2. Apply Radiation Weighting factor to obtain Equivalent Dose for each organ of interest

3. Take the weighted sum of all the Equivalent Doses.

\[ E = \sum_T H_T w_T \]

\( H_T = \) Organ Equivalent Dose
\( w_T = \) Tissue weighting factor

**Unit** = (Sv) Sievert

Effective Dose is proportional to risk of fatal cancer

<table>
<thead>
<tr>
<th>( w_T ) value ICRP103</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
</tr>
<tr>
<td>Salivary glands</td>
</tr>
<tr>
<td>Skin</td>
</tr>
<tr>
<td>Thyroid</td>
</tr>
<tr>
<td>Oesophagus</td>
</tr>
<tr>
<td>Lung</td>
</tr>
<tr>
<td>Red bone marrow</td>
</tr>
<tr>
<td>Breast</td>
</tr>
<tr>
<td>Bone surface</td>
</tr>
<tr>
<td>Liver</td>
</tr>
<tr>
<td>Stomach</td>
</tr>
<tr>
<td>Colon</td>
</tr>
<tr>
<td>Ovary</td>
</tr>
<tr>
<td>Bladder</td>
</tr>
<tr>
<td>Testes</td>
</tr>
<tr>
<td>Remainder</td>
</tr>
</tbody>
</table>
Method 2: Use published data.
Effective dose of dental CBCT—a meta analysis of published data and additional data for nine CBCT units

1J B Ludlow, 2R Timothy, 3C Walker, 4R Hunter, 5E Benavides, 6D B Samuelson and 6M J Scheske

1North Carolina Oral Health Institute, Koury Oral Health Sciences, Chapel Hill, NC, USA; 2Graduate Program in Oral and Maxillofacial Radiology, University of North Carolina, Chapel Hill, NC, USA; 3Department of Orthodontics, University of Missouri, Columbia, MO, USA; 4Private Practice of Orthodontics, Houston, TX, USA; 5University of Michigan School of Dentistry, Ann Arbor, MI, USA; 6University of North Carolina School of Dentistry, Chapel Hill, NC, USA
SEDENTEXCT measured Effective Doses for common CBCT scanners and found they were in the range

20 microSieverts to 370 microSieverts
Effective dose for medium field CBCTs

Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011
Effective dose for small field CBCTs

- 3D Accuitomo 170 4x4 upper...
- 3D Accuitomo 170 6x6 upper...
- 3D Accuitomo 170 6x6 lower...
- Kodak 9000 upper front
- Kodak 9000 lower molar
- Pax-Uni 3D front

Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011
Fig. 1. Ranges of effective dose for the imaging modalities used in implant dentistry.
Method 3: Use the DAP (with caution!)

Cone Beam Computed Tomography
radiation dose and image quality assessments

Sara Lofthag-Hansen
Department of Oral and Maxillofacial Radiology
Institute of Odontology at Sahlgrenska Academy

UNIVERSITY OF GOTHENBURG

REGION VÄSTRA GÖTALAND
Gothenburg 2010
Effective Dose (µSv) = 0.1 x DAP (mGy.cm²) for Maxilla
Effective Dose (µSv) = 0.15 x DAP (mGy.cm²) for Mandible
Effective Dose (µSv) = 0.125 x DAP (mGy.cm²) for Mn & Mx

Multiply the DAP by 0.1 to 0.15 to get a ROUGH estimate of the Effective Dose
Results of Monte Carlo calculations

i-CAT 17-19

Effective dose-DAP relationship:

- Effective dose (μSv) = 0.130 x DAP (mGycm²), r²=0.994
Use the DAP with caution!

- Same DAP
- Different Dose
How accurate do we need to be?

A factor of 2 change in risk is unlikely to bring about a change in the patient’s management.

A factor of 10 would be in line with estimates of risk in other areas.
Table 2—Descriptions of risk in relation to the risk of an individual dying (D) in any one year or developing an adverse response (A)

<table>
<thead>
<tr>
<th>Term used</th>
<th>Risk range</th>
<th>Example</th>
<th>Risk estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>≥1:100</td>
<td>(A) Transmission to susceptible household contacts of measles and chickenpox&lt;sup&gt;6&lt;/sup&gt; (A) Transmission of HIV from mother to child (Europe)&lt;sup&gt;7&lt;/sup&gt;</td>
<td>1:1-1:2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A) Gastrointestinal effects of antibiotics&lt;sup&gt;8&lt;/sup&gt;</td>
<td>1:6</td>
</tr>
<tr>
<td>Moderate</td>
<td>1:100-1:1000</td>
<td>(D) Smoking 10 cigarettes a day&lt;sup&gt;9&lt;/sup&gt; (D) All natural causes, age 40&lt;sup&gt;9&lt;/sup&gt;</td>
<td>1:200</td>
</tr>
<tr>
<td>Low</td>
<td>1:1000-1:10 000</td>
<td>(D) All kinds of violence and poisoning&lt;sup&gt;9&lt;/sup&gt; (D) Influenza&lt;sup&gt;10&lt;/sup&gt; (D) Accident on road&lt;sup&gt;9&lt;/sup&gt;</td>
<td>1:3300</td>
</tr>
<tr>
<td>Very low</td>
<td>1:10 000-1:100 000</td>
<td>(D) Leukaemia&lt;sup&gt;9&lt;/sup&gt;</td>
<td>1:12 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Playing soccer&lt;sup&gt;9&lt;/sup&gt; (D) Accident at home&lt;sup&gt;9&lt;/sup&gt; (D) Accident at work&lt;sup&gt;9&lt;/sup&gt; (D) Homicide&lt;sup&gt;9&lt;/sup&gt;</td>
<td>1:25 000</td>
</tr>
<tr>
<td>Minimal</td>
<td>1:100 000-1:1 000 000</td>
<td>(D) Accident on railway&lt;sup&gt;9&lt;/sup&gt;</td>
<td>1:26 000</td>
</tr>
<tr>
<td>Negligible</td>
<td>≤1:1 000 000</td>
<td>(A) Vaccination associated polio&lt;sup&gt;10&lt;/sup&gt; (D) Hit by lightning&lt;sup&gt;9&lt;/sup&gt; (D) Release of radiation by nuclear power station&lt;sup&gt;9&lt;/sup&gt;</td>
<td>1:43 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1:100 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1:500 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1:1 000 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1:10 000 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1:10 000 000</td>
</tr>
</tbody>
</table>
## Risk Bands

<table>
<thead>
<tr>
<th>Negligible</th>
<th>&lt; 1 in a million risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal</td>
<td>1 in 100,000 to 1 in a million risk</td>
</tr>
<tr>
<td>Very Low</td>
<td>1 in 10,000 to 1 in 100,000 risk</td>
</tr>
<tr>
<td>Low</td>
<td>1 in 1,000 to 1 in 10,000 risk</td>
</tr>
</tbody>
</table>

Department of Health (1995)

*Dental x-rays are in the range “Negligible” to “Minimal”*
ICRP 103:

“Effective dose is not recommended for epidemiological evaluations, nor should it be used for detailed specific retrospective investigations of individual exposure and risk.”

- But we use it anyway!
What is the Risk from an Intraoral x-ray?

- Assume adult patient, F speed, rectangular collimation
- Effective Dose might be 2 microSieverts (worst case)
- Risk that patient might develop fatal cancer in 20 years time

  - $= 5\% \ (1 \text{ in } 20) \ \text{per Sievert} \ \text{(from ICRP103)}$

  - $= 1 \text{ in } 20 \text{ million for } 1 \text{ microSievert}$

  - $= 2 \text{ in } 20 \text{ million for } 2 \text{ microSieverts}$

  - $= 1 \text{ in } 10 \text{ million for } 2 \text{ microSieverts}$

  Health & Safety people would call this a “Negligible Risk”
Table 2—Descriptions of risk in relation to the risk of an individual dying (D) in any one year or developing an adverse response (A)

<table>
<thead>
<tr>
<th>Term used</th>
<th>Risk range</th>
<th>Example</th>
<th>Risk estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>≥1:100</td>
<td>(A) Transmission to susceptible household contacts of measles and chickenpox(^8)</td>
<td>1:1-1:2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A) Transmission of HIV from mother to child (Europe)(^7)</td>
<td>1:6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A) Gastrointestinal effects of antibiotics(^8)</td>
<td>1:10-1:20</td>
</tr>
<tr>
<td>Moderate</td>
<td>1:100-1:1000</td>
<td>(D) Smoking 10 cigarettes a day(^9)</td>
<td>1:200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) All natural causes, age 40(^9)</td>
<td>1:850</td>
</tr>
<tr>
<td>Low</td>
<td>1:1000-1:10 000</td>
<td>(D) All kinds of violence and poisoning(^9)</td>
<td>1:3300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Influenza(^10)</td>
<td>1:5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Accident on road(^9)</td>
<td>1:8000</td>
</tr>
<tr>
<td>Very low</td>
<td>1:10 000-1:100 000</td>
<td>(D) Leukaemia(^9)</td>
<td>1:12 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Playing soccer(^9)</td>
<td>1:25 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Accident at home(^9)</td>
<td>1:26 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Accident at work(^9)</td>
<td>1:43 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Homicide(^9)</td>
<td>1:100 000</td>
</tr>
<tr>
<td>Minimal</td>
<td>1:100 000-1:10 000</td>
<td>(D) Accident on railway(^9)</td>
<td>1:500 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A) Vaccination associated polio(^10)</td>
<td>1:1 000 000</td>
</tr>
<tr>
<td>Negligible</td>
<td>≤1:1 000 000</td>
<td>(D) Hit by lightning(^9)</td>
<td>1:10 000 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(D) Release of radiation by nuclear power station(^9)</td>
<td>1:10 000 000</td>
</tr>
</tbody>
</table>
What is the Risk from a CBCT scan?

- Assume adult patient, dento-alveolar scan, both jaws
- Effective Dose might be 100 microSv (worst case)
- Risk that patient might develop fatal cancer in 20 years time
  
  = 5% (1 in 20) per Sievert (from ICRP103)
  
  = 1 in 20 million for 1 microSv
  
  = 100 in 20 million for 100 microSv
  
  = 1 in 200,000 (roughly) for CBCT scan

  Health & Safety people would call this a “Minimal Risk”

* If your patient is a child the risk is 3x more
# Risk varies with 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>

5% per Sievert at age 30
What is the Dose from a Dental CT or CBCT Scan?

- **Medical CT Scanner (using dental protocol):**
  - About 300 µSv per jaw (20 x OPG)

- **Cone Beam CT:**
  - About 50 µSv per jaw (3 x OPG)
  - Equivalent to about 8 days of Background Radiation (per jaw)
  - Carries a theoretical risk of about 1 in 200,000 of inducing a fatal cancer (1 in 400,000 per jaw)
  - On top of 1 in 3 risk we all have already
  - Much safer than smoking, driving or playing soccer!
**CBCT Scans**

**Risk**
- Exposure to ionising radiation
- Might induce a cancer
- Might induce a hereditary defect

**Benefit**
- Accurately pre-plan the treatment
- Less risk of damaging a critical structure
- Reduce operating time
- Improved aesthetic results

**Clinical Decision**
The Risk of Not Having a CBCT Scan

Fig. 1. Outline of common complications during implant surgery.
Take the CT Scan first, do the surgery second (not the other way around)!
Benefit versus Risk

Risk of losing your luggage: about 6 per thousand
Risk of fatal cancer: about 1 per 20 million

Not Recommended!
# Typical Doses from Dental X-Rays

<table>
<thead>
<tr>
<th></th>
<th>Effective Dose (µSv)</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoral (F speed, rect coll)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Intraoral (E speed, round coll)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Lateral Ceph</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Panoramic</td>
<td>3 to 24</td>
<td></td>
</tr>
<tr>
<td>Cone Beam CT</td>
<td>19 to 1073</td>
<td></td>
</tr>
<tr>
<td>Medical CT (using dental protocol)</td>
<td>280 to 1410</td>
<td></td>
</tr>
</tbody>
</table>
### Typical Doses from Dental X-Rays

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Effective Dose (µSv)</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoral (F speed, rect coll)</td>
<td>2</td>
<td>1 in 10 million</td>
</tr>
<tr>
<td>Intraoral (E speed, round coll)</td>
<td>6</td>
<td>1 in 3.3 million</td>
</tr>
<tr>
<td>Lateral Ceph</td>
<td>10</td>
<td>1 in 2 million</td>
</tr>
<tr>
<td>Panoramic</td>
<td>3 to 24</td>
<td>1 in 6.7 million to 833 thousand</td>
</tr>
<tr>
<td>Cone Beam CT</td>
<td>19 to 1073</td>
<td>1 in 1.05 million to 19 thousand</td>
</tr>
<tr>
<td>Medical CT (using dental protocol)</td>
<td>280 to 1410</td>
<td>1 in 71 thousand to 14 thousand</td>
</tr>
</tbody>
</table>
Risks from Dental x-rays

- Zero risk of Deterministic Effects
- Negligible to Very Low risk of radiation induced cancers
- Negligible risk of serious hereditary disease in an individual’s descendants
If everyone in the UK had a dental CBCT scan every year ...

- There might be 160 extra cancer deaths per year (if LNT is correct)

- Compared to 155,000 cancer deaths from other causes

http://www.cancerresearchuk.org/aboutcancer/statistics/mortality
Quiz - True or False?

1. Medical CT scanners should never be used for dental CT scans.  
   NEVER SAY NEVER

2. Radiation damage is cumulative.  
   NOT FOR DIAGNOSTIC X-RAYS

3. The risk of cancer increases with the number of scans.  
   TRUE AS FAR AS WE KNOW

4. The CBCT scan was non-diagnostic but I shouldn’t repeat it because of the dose.  
   FALSE

5. My patient has had several CBCT scans already - she shouldn’t have any more.  
   FALSE
Outline of Lectures

☑ Introduction / Disclosures
☑ Diagnostic Imaging in Dentistry
  – Conventional Radiography
  – CT / CBCT Scans
☑ Radiation Dose and Risk
  • Compliance with the Legislation
Annals of the ICRP

PUBLICATION 103

The 2007 Recommendations of the International Commission on Radiological Protection

Editor
J. VALENTIN

PUBLISHED FOR

The International Commission on Radiological Protection

by

ELSEVIER
Framework for Radiation Protection

- Based on the Recommendations of the International Commission for Radiation Protection (ICRP)
  - an advisory body with no formal powers
- European Directives for Radiation Safety
- National Legislation
  - Ireland
  - England, Scotland, Wales
  - Northern Ireland
- Local Rules / Written Procedures at each hospital or dental practice
- Each healthcare professional has an individual responsibility
European Directives for Radiation Safety

- Basic Safety Standards Directive
  - 96/29/Euratom of 13 May 1996

- Medical Exposure Directive
  - 97/43/Euratom of 30 June 1997

Both Replaced by

- Basic Safety Standards Directive (revised)
  - 2013/59/Euratom of 5 December 2013
  - National legislation to be enacted by 5 February 2018
Transposition into National Law

Two separate bodies of legislation:

• Radiation Safety for Workers and the Public
  – based on 96/29/Euratom of 13 May 1996

• Radiation Safety for Patients
  – based on 97/43/Euratom of 30 June 1997

• New legislation has come into force in Great Britain and Northern Ireland but not in the Republic of Ireland yet.
In the UK

Radiation Safety for Workers and the Public
• Ionisation Radiations Regulations 1999 – “IRR99”
• Enforced by Health and Safety Executive
• Revised legislation “IRR 2017” came into force on 6 February 2018.

Radiation Safety for Patients
• Ionising Radiation (Medical Exposure) Regulations 2000 (amended in 2006 and 2011) – “IR(ME)R 2000”
• Enforced by Care Quality Commission (CQC)
• Revised legislation “IR(ME)R 2017” came into force on 6 February 2018.
Legislation versus Guidelines – what’s the Difference?

“Legislation” refers to Criminal Law
• Example: it is an offence not to register with HSE if you own an x-ray machine

“Guidelines” refer to Best Practice and are often relevant in Civil Law
• Can I defend myself if a patient sues me?
• What if I’m investigated by the GDC?

You won’t go to jail for not complying with the Guidelines, but compliance puts you in a stronger position.
Ionising Radiation Regulations 2017 (IRR 2017)

- Regulates all use of radiation in the workplace (industry as well as medicine and dentistry)
- Not directly concerned with patient exposures (unless accidental)
- Regulated by Health and Safety Executive (HSE) not Department of Health or Care Quality Commission.
IRR 2017 - New System of Authorisation

• Under IRR99 employers had to notify HSE 28 days in advance of commencing work with ionising radiation.

• Under IRR 2017 you just have to register in advance (doesn’t specify how much in advance).

• Graded system under IRR2017 (based on level of risk):
  – Notification: work with radionuclides only
  – Registration: work with radiation generators including x-ray tubes. Costs £25 to register (for all sites under one Employer).
  – Consent: administering radiopharmaceuticals to patients (costs £25 per Employer)

• Must re-register (and pay a new fee) after a material change (such as change of Employer’s name or address)
**IRR 2017 - New System of Authorisation**

- Employers (e.g. dental practice owners) had to register and pay £25 fee by 5 February 2018.

- Associates (working at someone else’s practice and following the owner’s rules and regulations) do not have to register.

- If you should have registered but haven’t already done so you can register online here: [https://services.hse.gov.uk/bssd/](https://services.hse.gov.uk/bssd/)
A Risk Assessment is required before commencing new activities involving ionising radiation.

1. Look for the hazards
2. Decide who may be harmed and how
3. Decide if existing control measures are adequate or if more are needed
4. Record the findings of the Risk Assessment
5. Review the Assessment periodically (e.g. once per year) and revise if necessary.
Sources of Radiation

• **Primary Beam**
  – only the patient should be exposed to the primary beam.

• **Tube Leakage**
  – must be less than 1mGy/hour at 1 meter
  – tests are performed to ensure this.

• **Scattered Radiation**
  – radiation scattered from the patient
  – staff can protect themselves through Distance, Shielding, Time.
Hierarchy of Control Measures

Control Measures should be considered in this order:

1. Engineering Controls
   - Beam collimation, shielding, warning devices

2. Systems of Work
   - Controlled Areas
   - Local Rules

3. Personal Protective Equipment (should be a last resort)
   - Lead aprons
Staff Protection

Based on 3 principles:

- **Distance**
  - the further you are from the source the less radiation you receive
  - follows Inverse Square Law \((1/d^2)\)

- **Shielding**
  - fixed (built into the walls)
  - a mobile shield
  - Protective equipment (e.g. lead apron for staff)

- **Time**
  - shorter exposure to radiation results in less dose.

*Staff are present 8 hours a day so it is vital to protect them.*
Protecting Members of the Public

• Adequate shielding needs to be built into the walls, ceilings, floors, doors, windows of rooms containing x-ray equipment
  – if you have windows in the doors make sure they contain lead

• Think carefully about the best locations for waiting rooms, toilets etc

• Think how to prevent members of the public from walking into a Controlled Area
  – warning signs
  – radiographer stands at the door
  – good building design ensuring the public have no reason to walk past a Controlled Area.
Dose Limits

• Dose Limits are set so that risks to staff are comparable with other industries e.g. manufacturing, trade, service, government.

• Risk of death in “safe industries” is approximately 1 in 20,000 per year

• Risk from 1mSv is approximately 1 in 20,000

• Risk to staff in a dental practice would normally be much lower than this.
**Dose Limits for Workers and the Public**

<table>
<thead>
<tr>
<th>Annual Dose limits (mSv)</th>
<th>Adults (over 18 yrs)</th>
<th>Trainee (under 18 yrs)</th>
<th>Other persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
<td>20</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Lens of the eye</td>
<td>150</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>Skin</td>
<td>500</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Hands etc.</td>
<td>500</td>
<td>150</td>
<td>50</td>
</tr>
</tbody>
</table>

Women of reproductive capacity 13 mSv averaged over the abdomen in any consecutive 3 months

**IRR 2017: Dose Limit to Lens of Eye is now 20mSv/year for Adults and 15mSv/year for Trainees/Other Persons**
**Classified Persons**

Employees must be “classified” if they are likely to receive:

- An Effective Dose of more than 6mSv per year, or
- An Equivalent Dose to lens of eye of more than 15mSv per year, or
- An Equivalent Dose to extremities of more than 150mSv per year (skin, hands, forearms, feet or ankles)

If they are Classified they must have

- An appointed doctor
- A passbook if they work in another Employer’s controlled environment.

*People who work in dental practices are not normally “Classified”!*
Controlled Areas

An area is *Controlled* if “special procedures designed to restrict significant exposure” are necessary.

**Workloads up to 100 intra-orals or 50 DPTs:**
- Within the primary x-ray beam until sufficiently attenuated
- Within 1.5m of the x-ray tube and patient in any other direction.

**Dental CBCT:**
- Usually the entire room is a Controlled Area while the power is on.
Controlled Areas

Radiation Protection Advisor (RPA) will advise on:

- **Room Shielding**
- **Controlled / Supervised Areas**
- **Warning Signs**
- **Local Rules**

For dental radiography, a Controlled Area only exists while the power is on.
Local Rules

Work in a Controlled Area must be carried out according to Local Rules.

Local Rules should be on display in each room where x-ray equipment is used.

Employees must read Local Rules and sign an undertaking that they have been read.

Some dental practices put the Local Rules on their website.
Radiation Protection Advisor

- Dental Practices must appoint a suitable RPA
- Must consult RPA to ensure observance of IRR 2017
- RPA should review radiation safety for each new x-ray installation and at least every 3 years for existing installations
  - e.g. adequate shielding
  - designation of controlled areas
  - training of operators
  - local rules / written procedures
Radiation Protection Advisor

- RPA is generally a physicist with certification from HSE-approved Assessing Body
- Usually an outside consultant
- Should be available for consultation (otherwise, get a different one)
- A list of RPAs is available at www.rpa2000.org.uk
Radiation Protection Supervisor (RPS)

- Where work is subject to Local Rules, employer must appoint a Radiation Protection Supervisor (RPS)
- Usually a member of staff who can command authority (e.g. a dentist)
- Should be trained to have knowledge of the Regulations and understand the precautions to be taken
- Legal responsibility remains with the employer.
Outside Workers

An Outside Worker is someone who carries out work in the Controlled Area of an Employer other than their own

- Now includes both Classified and Non-Classified workers (used to be just Classified workers)
- May include Agency Staff e.g. radiographers
- Includes service engineers, contractors etc
- You are responsible for their safety
- In the case of an engineer you can hand responsibility over temporarily through a Handover Procedure.
### Part 1: CUSTOMER – Handover of controlled area and equipment to Company Representative

<table>
<thead>
<tr>
<th>FACILITY / DEPARTMENT</th>
<th>CONTROLLED AREA / ROOM</th>
<th>EQUIPMENT</th>
</tr>
</thead>
</table>

**COMPANY CARRYING OUT WORK**

- ID SEEN: [YES] [NO]
- CALL REFERENCE NO:

**REASON FOR HANDBACK**

**IDENTIFY KNOWN HAZARDS WITH CONTROLLED AREA OR EQUIPMENT**

**Customer:** As an authorised representative of the customer, I hereby hand over the controlled area and equipment as above.

**Company:** As an authorised representative of the company, I accept responsibility of the controlled area and equipment for the reason stated above. Risk assessment will be made using the information provided and company procedures followed.

**Customer Representative:** Signature: ____________________________

**Date:** ____________________________

**Time:** ____________________________

**Company Representative:** Signature: ____________________________

**Date:** ____________________________

**Time:** ____________________________

### Part 2: COMPANY REPRESENTATIVE – Handover of controlled area and equipment to customer

#### CATEGORY OF WORK

- [ ] Routine service
- [ ] Fault diagnosis / repair
- [ ] Installation of part(s)
- [ ] Upgrade / Modification
- [ ] Incident response
- [ ] Hazard Notice response
- [ ] Clinical protocol changes
- [ ] Other

**Could this work have implications for radiation safety or patient dose or image quality?**

- [ ] Shielding
- [ ] Beam quality / filtration / grid
- [ ] Dose curve / protocol
- [ ] DAP / skin dose indicator
- [ ] None of the above

**Could this work have any other implications?**

**See visit/service report for details.**

1. Equipment is OPERATIONAL following work as indicated above and on the visit/service report.
2. Equipment is PARTIALLY OPERATIONAL limitations may exist, refer to visit/service report.
3. Equipment is NOT OPERATIONAL and MUST NOT BE USED.

**Company Representative:** Signature: ____________________________

**Date:** ____________________________

**Time:** ____________________________

**Customer Representative:** Signature: ____________________________

**Date:** ____________________________

**Time:** ____________________________

### Part 3: CUSTOMER – Returning equipment to use

1. I confirm the above company provided information and associated service report have been reviewed and carried out appropriate checks in accordance with the Ionising Radiation Regulations. I confirm all required local procedures have been completed.

   - [ ] 1. I am satisfied that the equipment is in a satisfactory condition for use in medical exposure.
   - [ ] 2. I am NOT satisfied that the equipment is satisfactory for use in medical exposure.

**Reason:** ____________________________

**Actions Taken:** ____________________________

**Customer Representative:** Signature: ____________________________

**Date:** ____________________________

**Time:** ____________________________

---

Version 4, © April 2010

AXREM, Rotterwick House, 3 Thomas More Street, London E1W 1YZ
Ionising Radiation (Medical Exposure) Regulations 2017


• Medical exposures (e.g. patients)
• Enforced by Care Quality Commission www.cqc.org.uk
• In Northern Ireland: enforced by Regulation and Quality Improvement Authority www.rqia.org.uk

IR(ME)R 2000 was replaced by IR(ME)R 2017.
Principles of Patient Protection

• Justification (benefits must outweigh the risks)

• Optimisation (keep doses As Low As Reasonably Practicable) (consistent with the intended diagnostic purpose)

• Dose Constraints
  - (20 mSv per year for Classified Persons)
  - (1 mSv per year for members of the public)
  - (no dose limits for medical exposures)
  - (must set limits for research programs)
  - (must set limits for carers and comforters)


**Duty Holders under IR(ME)R 2000**

**The Employer**
- provides a framework of policies and procedures

**The Referrer** (“Prescriber” in most EU countries)
- must supply sufficient clinical information to allow the exposure to be justified

**The Practitioner**
- is responsible for justifying the exposure in terms of benefits versus risks

**The Operator**
- is responsible for carrying it out safely.
Employer

The **Employer** is the legal person responsible for compliance with IRR 2017 and IR(ME)R 2017.

The Employer could be:
- An NHS Trust
- The owner of a dental practice
- The owner of an x-ray repair and servicing company
- etc.

The Employer must create a framework for Radiation Protection through written policies and procedures.
Practitioner

• Practitioner must decide if the exposure is justified (i.e. the benefits must outweigh the risks)
• Must take into account the objectives of the exposure and the characteristics of the patient
• Is there another way to obtain the required information?
• What do the Referral Guidelines say?
• Urgency of the procedure (e.g. pregnant women may prefer to postpone it).
Justifying the Exposure

• There must be procedures to ensure that a clinical evaluation of the outcome of the exposure is carried out and recorded

• If it is known, prior to the exposure, that no clinical evaluation will occur then the procedure cannot be justified and the exposure must not take place

• If exposure will not change the patient’s management it cannot be justified and must not take place.
Informed Consent

Wherever practical and prior to an exposure, the patient must be provided with information relating to benefits and risks.

- For dental radiography, leaflets in the waiting room would meet this requirement in practice.
Referrers may prescribe (request) x-ray examinations.

They must be registered health care professionals.

They must provide sufficient clinical information to substantiate the need for an x-ray examination.

A history and clinical examination of the patient is essential prior to any request for an exposure.

Previous x-ray examinations should also be investigated.

“Routine” x-rays are not allowed.
Operator

- *Operators* are responsible for carrying out the exposure safely.
- They should ensure the dose from the exposure is as low as reasonably practicable and consistent with the intended diagnostic purpose
  - *dose should not be so low as to give non-diagnostic images*
- There should be written protocols in place for each type of examination
- If the dose is above the Diagnostic Reference Levels (DRL) the reason should be recorded.
Medical Physics Expert (MPE)

Under IRR 2017 dental practices have to appoint an RPA

Under IR(ME)R 2017 they have to appoint an MPE (who will often be the same person):
- MPE to be available for consultation on Optimisation
- Give advice on radiological equipment
- Setting of local DRLs
- Establish and maintain QA programme

A list of RPAs and MPEs is available at www.rpa2000.org.uk
Optimisation

Want to Optimise

Benefit to Patient*
Risk to Patient

* not to the dentist!
**Practical ways to Reduce the Risk**

CBCT Scans:

1. **Reduce the Height (vertical collimation)**

   Reduces the risk without loss of benefit in most cases.

<table>
<thead>
<tr>
<th>Dose</th>
<th>Full face 13cm height x 16cm diameter 83 microSieverts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Both arches 8cm height x 16cm diameter 56 microSieverts (interpolated)</td>
</tr>
<tr>
<td></td>
<td>Mandible 6cm height x 16cm diameter 45 microSieverts</td>
</tr>
</tbody>
</table>

Absorbed Dose outside primary beam is effectively zero
2. Reduce the mAs (tube current, scan time)

- Reducing the mAs may have a negative impact on image quality

- On some scanners, the voxel size is linked to the mAs
3. Reduce the Width (horizontal collimation)

- Absorbed Dose outside primary beam is not zero (about 50% from SEDENTEXCT measurements)
- There may be some loss of benefit
The Absorbed Dose to the left side of the patient is not zero (maybe around 50% of the Absorbed Dose to the right side).
**Dose Reference Levels**

- Local DRLs should be set for each type of x-ray procedure.
- Local DRLs should not normally exceed National DRLs.
- For intra-orals the National DRL is 1.7 mGy in the UK (entrance dose) 4 mGy in Ireland.
- For DPTs the National DRL is 67 mGy.cm for children and 93 mGy.cm² for adults (Dose Area Product, DAP).
- We don’t have a DRL for CBCT yet.
Automated Dose Reporting

CT/CBCT equipment installed after 5 Feb 2018 must have the capacity to transfer all dose related parameters to the patient’s exposure record.
**Accidental or Unintended Exposures**

- “Significant events” (not defined) must be analysed, recorded and reported (including near misses)
- Includes equipment or procedural failures
- Duty of candour to disclose “clinically significant” (not defined) events to patient, referrer, practitioner “professionals involved with the care of the patient”
- If not in patient’s best interests to inform patient then representatives must be informed instead.
Guidance on investigation and notification of medical exposures much greater than intended.

16 January 2017

Table 1 – Examples of unintended medical exposures that require notification

<table>
<thead>
<tr>
<th>All Modalities</th>
<th>When to notify (what constitutes an exposure much greater than intended)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrong patient exposed</td>
<td>All cases – regardless of dose</td>
</tr>
<tr>
<td>Wrong examination including incorrect body part or modality.</td>
<td></td>
</tr>
<tr>
<td>Low dose examinations, where the intended dose is less than 0.5mSv, to include DEXA, skull, dentition, chest, in-vitro nuclear medicine</td>
<td>When the total exposure is at least 20 times greater than the intended dose.</td>
</tr>
</tbody>
</table>

https://www.cqc.org.uk/guidance-providers/ionising-radiation/reporting-irmer-incidents
Summary of Changes in IR(ME)R 2017

- Evolution of IR(ME)R 2000, not revolution
- Now covers non-medical imaging using medical radiological equipment (replaces “medico-legal exposures”)
- Doses to “comforters and carers” must be justified and optimised and are subject to constraints
- “Outside Workers” now includes non-classified workers
- Clarification of Medical Physics Expert (MPE) role
- Equipment QA is now addressed in IR(ME)R instead of IRR.
Training Requirements – IRR 2017 and IR(ME)R 2017

• Employers must maintain an up-to-date record of training, available for inspection, with date and nature of training recorded.
Practitioners must have received adequate training both in radiation safety and clinical aspects (e.g. selection criteria)

- for dentists this would normally be a degree course
- must keep up to date with CPD
Operator Training

*Operators* must have received adequate training specific to the tasks that they undertake

- *dental nurses, hygienists, therapists etc required to take x-rays* would normally require the [Certificate in Dental Radiography](#) or equivalent

- *must receive training on practical aspects of operating the equipment*

- *must keep up to date with CPD*
Referrer Training

There are no specific requirements in IR(ME)R 2017 for Referrer training, however, many people believe that training of Referrers would be beneficial, especially for Dental CBCT.
SHORT COMMUNICATION

Basic training requirements for the use of dental CBCT by dentists: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology

J Brown¹, R Jacobs², E Levring Jäghagen³, C Lindh⁴, G Baksi⁵, D Schulze⁶ and R Schulze⁷

¹King’s College London—Dental Institute, Dental Radiology, Guy’s Hospital, London, UK; ²OMFS IMPATH Research Group, Department of Imaging and Pathology, Faculty of Medicine, University of Leuven, Leuven, Belgium; ³Oral and Maxillofacial Radiology, Department of Odontology, Umeå University, Umeå, Sweden; ⁴Department of Oral and Maxillofacial Radiology, Faculty of Odontology, Malmö University, Malmö, Sweden; ⁵Department of Oral and Maxillofacial Radiology, Ege University, School of Dentistry, Bornova, Izmir, Turkey; ⁶Dental Diagnostic Center, Freiburg, Germany; ⁷Department of Oral Surgery (and Oral Radiology), University Medical Center of the Johannes Gutenberg—University Mainz, Mainz, Germany
Friday 15 March 2019  £300

Dental CBCT Course for Referrers

Cone Beam Computed Tomography (CBCT) is increasingly common in hospital and general dental practice. This course is based on the Level 1 training criteria published in the latest European EADMFR guidelines. Upon completion participants will have fulfilled their legal and ethical responsibilities.

The course is hosted by the RCS and the British Society of Dental and Maxillofacial Radiology and is delivered by experienced consultant dental maxillofacial radiologists.
Friday 19 October 2018 £400

Basics of Dentoalveolar CBCT Interpretation

This hands-on course is designed to train dentists to interpret and write reports on CBCT scans limited to dento-alveolar regions. The course content is modified from the “Level 2” training criteria published in the latest European guidelines.

This course is jointly hosted by the British Society of Dental and Maxillofacial Radiology (BSDMFR) and the Royal College of Surgeons of England and is delivered by experienced consultant dental maxillofacial radiologists.
Dental Cone Beam CT Radiological Interpretation PG Cert

Online Course

Radiology Reports

• IR(ME)R 2017 requires a *clinical evaluation* of the outcome of each exposure (other than for carers and comforters) and that this must be *recorded*.

• There is no legal requirement to send the images to a Radiologist for reporting

• If you have received sufficient training, it is good practice to report on the images yourself

• If you haven’t received sufficient training, or if you suspect pathology may be present, it is good practice to send the images to a Specialist in Dental and Maxillofacial Radiology for a Report.
Due Diligence

• “In any proceedings against any person for an offence consisting of the contravention of these Regulations it is a defence for that person to show that the person took all reasonable steps and exercised all due diligence to avoid committing the offence”

• Document everything!
Guidance Documents

- New Approved Code of Practice L121 (costs £27) [www.hse.gov.uk/pubns/priced/l121.pdf](www.hse.gov.uk/pubns/priced/l121.pdf)
- Revised Medical and Dental Guidance Notes – to be published.
- IR(ME)R Companion Guide – to be published.
Medical and Dental Guidance Notes

• Provide general guidance on good practice
• Not an attempt to interpret legal requirements
• Following the guidance is not compulsory but should be sufficient to comply with the law
• Covers IR99, IR(ME)R 2000, equipment
• To be revised for IRR 2017 and IR(ME)R 2017
Radiation Protection

European guidelines on radiation protection in dental radiology

The safe use of radiographs in dental practice

Issue N° 136