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”

Specialising in:

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

Since 1991
Get the most out of your dental CT/CBCT scans

Choose a scanning site in the UK or Ireland
Scan Site Search

Location  Keyword  A-Z List

Wakefield  20 km  Search

Click the icons for more information.

<table>
<thead>
<tr>
<th>Name</th>
<th>Distance</th>
<th>Category</th>
<th>Equipment</th>
</tr>
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<tbody>
<tr>
<td>Trinity House Orthodontics</td>
<td>0.5 km</td>
<td>IDT Scanning Site Partner</td>
<td>i-CAT Classic CBCT</td>
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<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>
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<td>Nuffield Health Leeds Hospital</td>
<td>13.4 km</td>
<td>IDT Scanning Site Partner</td>
<td>Toshiba Aquilion ONE medical CBCT</td>
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Outline of Presentation

✓ Introduction / Disclosures
• Imaging for Dental Implants
  – Conventional Radiography
  – CT / CBCT Scans
• IR(ME)R Regulations
• Radiation Dose and Risk
• Rogues Gallery
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”

- Radio-Opaque Scanning Stents
- 3D Treatment Planning Software
- Surgical Drill Guides
SIMPLANT™ is a trademark of DENTSPLY Implants
Guide resting on:
• Bone
• Mucosa
• Teeth

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

SIMPLANT™ is a trademark of DENTSPLY Implants
Software for planning Dental Implants

- SIMPLANT (DENTSPLY Implants)
- Blue Sky Plan (Blue Sky Bio)
- Osirix (with Dental3D plugin)
- In Vivo Dental (Anatomage)
- Nobel Clinician (Nobel Biocare)
- coDiagnostiX (Straumann, 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/CBCT data
- Can import STL files from optical scanners
- Can be used to design surgical drill guides
- Very powerful software, but not very user friendly!
Osirix with Dental3D plugin
(Macintosh only)

- Free Software
- Can be used with any implant system (but the implants are not realistic)
- Can import DICOM CT/CBCT data
- Can import STL files from optical scanners
- Can be used to design surgical drill guides
- Not as complete as Blue Sky Plan, but more user friendly.
Surgical Drill Guides
Drill Guides can be supported on

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

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

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

Need to think about the Guide before you request the CT Scan!
The Ultimate Goal

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

“The Immediate Smile” – DENTSPLY Implants
“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!
Which Imaging Modalities are best?

✔ Intra-oral radiography
  • Occlusal films, bitewings, periapicals

✗ Extra-oral radiography
  • AP and Lateral cephs

✗ Conventional tomography
  • Dental Panoramic Tomography (DPT)
  • Linear / Complex Motion Tomography (CMT)

✗ Magnetic Resonance Imaging

✔ Medical computed tomography (CT)

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

+ Very high resolution (20 lp/mm)
+ Fast, convenient, low dose
  – No bone width
  – No (quantitative) bone quality
  – Magnification / Distortion
Distortion in intra-orals

Solutions:

- bisecting angle (X)
- paralleling technique (√)
Extra-oral: Lateral Cephs

+ Good overview
  – Width and height on midline only
  – No (quantitative) bone quality
Conventional Tomography
(tomography by blurring)
Dental Panoramic Tomography (DPT)
Dental Panoramic Tomography (DPT, OPG, OPT)

- Very good overview
- No bone width
- No (quantitative) bone quality
- Variable magnification => distortion
- Patient positioning is crucial
**DPTs are useful for:**

- Overall status of teeth and supporting bone
- Anatomical anomalies and pathological conditions
- Triage between:
  - Sites where placing implants will be straightforward
  - Sites where grafting or distraction will be needed
  - Sites where implants are not advisable

**Measurements from DPTs are not accurate:**


- Errors as large as 30% in estimating bone height from DPTs
- Bone width cannot be estimated at all.
Cross-Sectional Imaging

- Linear Tomography
- Complex Motion Tomography (CMT)
- Magnetic Resonance Imaging (MRI)
- Computed Tomography (CT or CBCT)
Magnetic Resonance Imaging

- no radiation dose
- no metallic artefact
- large, expensive machine
- teeth generate no signal
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.
S L Rothman, N Chaftez, M L Rhodes, M S Schwarz and M S Schwartz

CT in the preoperative assessment of the mandible and maxilla for endosseous implant surgery. Work in progress.

Radiology July 1988 168:171–175
Why 3D software is important
**Dental (CB)CT Scans**

- Bony anatomy of Mandible, Maxilla, Zygomatic Arches

- Useful for:
  - impacted, supernumerary and abnormal teeth
  - root canals, root fractures
  - planning dental implants
  - periapical disease
  - cleft palate assessment
  - TMJ and airway analysis
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.
Medical CT Scanner
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
how CT works...

Godfrey Hounsfield

Allan Cormack

Nobel prize in Medicine, 1979
detectors

dx-ray source
acquisition
acquisition
acquisition

Animation courtesy of Demetrios J. Halazonetis
reconstruction
volume dataset

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)
cone-beam CT (CBCT)

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

Animation courtesy of Demetrios J. Halazonetis
cone-beam CT
(CBCT)
CB-500 CBCT Scanner

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

Around £90K

i-CAT™ is a trademark of Imaging Sciences International LLC of Hatfield, USA
**DP-700 CBCT Scanner**

- **You Get What You Pay For!**

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

- **no collimator**
- **fixed field sizes**
  - 4cm x 6cm
  - 8cm x 6cm

- **long scan times**
  - 11s to 45s

- **Higher doses**
  - typical Mx 60µSv
  - typical Mn 100µSv

- **small detector**

- **no chair**

- **Around £45K**
Cannot fit mandible into 8cm Field Of View
Toshiba Aquilion ONE medical CT Scanner

320 detector rows

operates in cone beam mode

volume capture
24cm x 16cm max

0.5s scan time

Effective doses
typical Mx 70µSv
typical Mn 160µSv

Around £1M

Aquilion™ is a trademark of Toshiba Medical Systems Corporation
Basic CT images

Axials

Panoramics

Cross Sections

Sagittal

Coronal
Panoramic

Cross-sectional

Transaxial
Segmentation
Hyperdontia

Courtesy of Nicolette Schroeder
Take the CT Scan first, do the surgery second (not the other way around)!
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
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Transposition into UK Law

Ionisation Radiations Regulations 1999 – “IRR99”
- Exposure of members of the public (e.g. staff and visitors)
- Enforced by Heath and Safety Executive (HSE)

- Medical exposures (e.g. patients)
- Enforced by Care Quality Commission (CQC)
Principles of Radiation Protection

• **Justification** (benefits must outweigh the risks)

• **Optimisation** (keep doses As Low As Reasonably Achievable)

• **Dose Limits**
  - (20 mSv per year for members of the public)
  - (no dose limits for medical exposures)
Duty Holders under IR(ME)R 2000

The Employer
• provides a framework of policies and procedures

The Referrer
• 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
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
<table>
<thead>
<tr>
<th>Instruction type</th>
<th>Role</th>
<th>Training content</th>
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<tbody>
<tr>
<td></td>
<td><strong>The Prescriber</strong></td>
<td>Justification and referral criteria for dental CBCT&lt;sup&gt;5,13&lt;/sup&gt;</td>
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<tr>
<td></td>
<td></td>
<td>Radiation physics in relation to CBCT equipment</td>
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<tr>
<td></td>
<td></td>
<td>Radiation doses and risks involved with CBCT</td>
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<tr>
<td></td>
<td></td>
<td>Radiation protection in relation to CBCT equipment, including justification (referral/selection criteria) and relevant aspects of optimization of exposures</td>
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<td></td>
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<td>CBCT equipment and apparatus, technical background information</td>
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<tr>
<td></td>
<td></td>
<td>CBCT image acquisition, digital imaging and communications in medicine standard and processing</td>
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<tr>
<td>Theoretical instruction</td>
<td><strong>The Practitioner</strong></td>
<td>Justification and referral criteria for dental CBCT&lt;sup&gt;5,13&lt;/sup&gt;</td>
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<td>CBCT image acquisition, digital imaging and communications in medicine standard and processing</td>
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<td>Practical instruction</td>
<td>Principles of CBCT imaging</td>
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<td>Use of different CBCT equipment</td>
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<td>CBCT imaging techniques and measures for dose reduction</td>
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<td>Use of software to optimize patient dose and image interpretation</td>
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<td>Quality assurance for CBCT</td>
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<td>Care of patients undergoing CBCT</td>
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<td>Radiological interpretation</td>
<td>Principles and practice of interpretation of dentoalveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (e.g. smaller fields of view) and of the facial skeleton (e.g. larger fields of view)</td>
<td>Principles and practice of interpretation of dentoalveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (e.g. smaller fields of view) and of the facial skeleton (e.g. larger fields of view)</td>
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<td>Normal radiological anatomy on CBCT images</td>
<td>Normal radiological anatomy on CBCT images</td>
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<td>Artefacts on CBCT images</td>
<td>Artefacts on CBCT images</td>
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<td>Radiological interpretation of disease affecting the teeth and jaws and facial skeleton on CBCT images</td>
<td>Radiological interpretation of disease affecting the teeth and jaws and facial skeleton on CBCT images</td>
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<td></td>
<td>Interpretation of a received report</td>
<td>Interpretation of anatomy and disease in adjacent structures to the teeth and their supporting structures and of the facial skeleton. Writing a structured radiological report&lt;sup&gt;14,15&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Saturday 19 November 2016

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 25 November 2016

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.
A Common Sense Approach to Radiation Safety
The Problem

• Under IR(ME)R 2000 we have a duty to ensure the benefits of exposing the patient to radiation outweigh the risks.

• But how do we know what the risks are?

• How do we manage the tradeoffs between benefits and risks?
How do we know that exposure to radiation results in harm?

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 but the incidence is very low
Dr Mihran Kassabian (1870–1910)
Deterministic Effects

- Severity
- Dose
- Threshold Dose (about 500 mSv)

Stochastic Effects

- Probability
- Dose
- Risk Factor = ΔP / ΔD (about 5% per Sievert)
Estimated excess relative risk ($\pm 1$ 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
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

a = LNT model
d = threshold model
**The Linear No-Threshold (LNT) Model**

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

Implies 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

Implies that cells do not have a repair mechanism

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

Siegel JA, Pennington CW, Sacks B, Welsh JS.

Abstract

This paper examines the birthing process of the linear no-threshold model with respect to genetic effects and carcinogenesis. This model was conceived >70 years ago but still remains a foundational element within much of the scientific thought regarding exposure to low-dose ionizing radiation. This model is used today to provide risk estimates for cancer resulting from any exposure to ionizing radiation down to zero dose, risk estimates that are only theoretical and, as yet, have never been conclusively demonstrated by empirical evidence. We are literally bathed every second of every day in low-dose radiation exposure due to natural background radiation, exposures that vary annually from a few mGy to 260 mGy, depending upon where one lives on the planet. Irrespective of the level of background exposure to a given population, no associated health effects have been documented to date anywhere in the world. In fact, people in the United States are living longer today than ever before, likely due to always improving levels of medical care, including even more radiation exposure from diagnostic medical radiation (eg, x-ray and computed tomography imaging examinations) which are well within the background dose range across the globe. Yet, the persistent use of the linear no-threshold model for risk assessment by regulators and advisory bodies continues to drive an unfounded fear of any low-dose radiation exposure, as well as excessive expenditures on putative but unneeded and wasteful safety measures.
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!
More about Effective Dose

The Effective Dose calculation takes the size of the region and the body parts irradiated into account.
<table>
<thead>
<tr>
<th>Organ</th>
<th>$w_T$ value ICRP103</th>
</tr>
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<tbody>
<tr>
<td>Brain</td>
<td>0.01</td>
</tr>
<tr>
<td>Salivary glands</td>
<td>0.01</td>
</tr>
<tr>
<td>Skin</td>
<td>0.01</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.04</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>0.04</td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
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<tr>
<td><strong>Red bone marrow</strong></td>
<td>0.12</td>
</tr>
<tr>
<td>Breast</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Bone surface</strong></td>
<td>0.01</td>
</tr>
<tr>
<td>Liver</td>
<td>0.04</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.12</td>
</tr>
<tr>
<td>Colon</td>
<td>0.12</td>
</tr>
<tr>
<td>Ovary</td>
<td>0.08</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.04</td>
</tr>
<tr>
<td>Testes</td>
<td>0.08</td>
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<tr>
<td><strong>Remainder</strong></td>
<td>0.12</td>
</tr>
</tbody>
</table>
Effective dose for large field CBCTs

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

- 3D Accuitomo 170 8x8
- 3D Accuitomo 170 10x10
- NewTom VGi small field HR
- Picasso Trio high dose
- Picasso Trio low dose
- ProMax 3D high dose
- ProMax 3D low dose
- Scanora 3D upper
- Scanora 3D lower
- Scanora 3D upper+lower
- Veraviewpocs3D

Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011
Effective dose range for dental cone beam computed tomography scanners

Ruben Pauwels\textsuperscript{a,\,*}, Jilke Beinsberger\textsuperscript{a,1}, Bruno Collaert\textsuperscript{b,2}, Chrysoula Theodorakou\textsuperscript{c,d,3}, Jessica Rogers\textsuperscript{e,3}, Anne Walker\textsuperscript{c,3}, Lesley Cockmartin\textsuperscript{f,4}, Hilde Bosmans\textsuperscript{f,5}, Reinhilde Jacobs\textsuperscript{a,6}, Ria Bogaerts\textsuperscript{g,7}, Keith Horner\textsuperscript{d,8}, The SEDENTEXCT Project Consortium\textsuperscript{9}

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\textsuperscript{f} Department of Radiology, University Hospital Gasthuisberg, Leuven, Belgium
\textsuperscript{g} Department of Experimental Radiotherapy, University Hospital Gasthuisberg, Katholieke Universiteit Leuven, Belgium

Eur J Radiol 81,2,267-271 (February 2012)
Fig. 1. Ranges of effective dose for the imaging modalities used in implant dentistry.
## Typical Doses from Dental X-Rays

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Effective Dose (µSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoral (F speed, rect coll)</td>
<td>2</td>
</tr>
<tr>
<td>Intraoral (E speed, round coll)</td>
<td>6</td>
</tr>
<tr>
<td>Lateral Ceph</td>
<td>10</td>
</tr>
<tr>
<td>Panoramic</td>
<td>3 to 24</td>
</tr>
<tr>
<td>Cone Beam CT</td>
<td>19 to 1073</td>
</tr>
<tr>
<td>Medical CT (dental protocol)</td>
<td>280 to 1410</td>
</tr>
<tr>
<td>Source of exposure</td>
<td>Dose</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Dental x-ray</td>
<td>0.005 mSv</td>
</tr>
<tr>
<td>100g of Brazil nuts</td>
<td>0.01 mSv</td>
</tr>
<tr>
<td>Chest x-ray</td>
<td>0.014 mSv</td>
</tr>
<tr>
<td><strong>Transatlantic flight</strong></td>
<td><strong>0.08 mSv</strong></td>
</tr>
<tr>
<td>Nuclear power station worker average annual occupational exposure (2010)</td>
<td>0.18 mSv</td>
</tr>
<tr>
<td>UK annual average radon dose</td>
<td>1.3 mSv</td>
</tr>
<tr>
<td>CT scan of the head</td>
<td>1.4 mSv</td>
</tr>
<tr>
<td>UK average annual radiation dose</td>
<td>2.7 mSv</td>
</tr>
<tr>
<td>USA average annual radiation dose</td>
<td>6.2 mSv</td>
</tr>
<tr>
<td>CT scan of the chest</td>
<td>6.6 mSv</td>
</tr>
<tr>
<td>Average annual radon dose to people in Cornwall</td>
<td>7.8 mSv</td>
</tr>
<tr>
<td>CT scan of the whole spine</td>
<td>10 mSv</td>
</tr>
<tr>
<td>Annual exposure limit for nuclear industry employees</td>
<td>20 mSv</td>
</tr>
<tr>
<td>Level at which changes in blood cells can be readily observed</td>
<td>100 mSv</td>
</tr>
<tr>
<td>Acute radiation effects including nausea and a reduction in white blood cell count</td>
<td>1000 mSv</td>
</tr>
<tr>
<td>Dose of radiation which would kill about half of those receiving it in a month</td>
<td>5000 mSv</td>
</tr>
</tbody>
</table>

What is the Risk from an Intraoral x-ray?

- Assume adult patient, F speed, rectangular collimation
- Effective Dose might be 2 microSieverts approx.
- 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 microSievert

  = 2 in 20 million for 2 microSieverts

  = 1 in 10 million for 2 microSieverts

Health & Safety people would call this a “Negligible Risk”
Cancer: science and society and the communication of risk

Kenneth C Calman

BMJ VOLUME 313 28 SEPTEMBER 1996

This article is based on the Calum Muir lecture, delivered in Edinburgh in September 1996.

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The Risk from an Intraoral x-ray

Lightning: the risk is negligible
# Typical Doses from Dental X-Rays

<table>
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<tr>
<th>Procedure</th>
<th>Effective Dose (µSv)</th>
<th>Risk</th>
<th>Risk Category</th>
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<tr>
<td>Intraoral (F speed, rect coll)</td>
<td>2</td>
<td>1 in 10 million</td>
<td>Negligible</td>
</tr>
<tr>
<td>Intraoral (E speed, round coll)</td>
<td>6</td>
<td>1 in 3.3 million</td>
<td>Negligible</td>
</tr>
<tr>
<td>Lateral Cephalometric (Lateral Ceph)</td>
<td>10</td>
<td>1 in 2 million</td>
<td>Negligible</td>
</tr>
<tr>
<td>Panoramic</td>
<td>3 to 24</td>
<td>1 in 6.7 million to 833 thousand</td>
<td>Negligible to Minimal</td>
</tr>
<tr>
<td>Cone Beam CT</td>
<td>19 to 1073</td>
<td>1 in 19 thousand</td>
<td>Minimal to Very Low</td>
</tr>
<tr>
<td>Medical CT (using dental protocol)</td>
<td>280 to 1410</td>
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**Risk varies with Age**

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<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>
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5% per Sievert at age 30
The Risk of Not Having a CBCT Scan

Fig. 1. Outline of common complications during implant surgery.
How can we estimate the Effective Dose in practice?

kVp, mAs etc
• only works for comparing scans on the same machine

Dose Length Product (DLP)
• works very well for comparing medical CT scanners

Dose Area Product (DAP)
• works reasonably well for comparing different CBCT scanners
Dose Area Product (DAP) for Cone Beam CT Scanners

Multiply DAP by 0.1 for Maxilla or 0.15 for Mandible to get the Effective Dose in microSieverts (µSv)

Accuracy: ±50%

Mn 45µSv
CBCT 45µSv
**Practical ways to Reduce the Dose**

1. Reduce the Height (vertical collimation)

Reduces the risk without loss of benefit in most cases.
2. Reduce the Width (horizontal collimation)

- Reducing the beam height by 50% reduces the dose by 50%
- Reducing the beam width by 50% reduces the dose by 50% at most (and there may be some loss of benefit)
“Sorry mate – no can do!”
More practical ways to Reduce the Dose

3. 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
Moving the patient to the side (without reducing the Field Of View) does not reduce the dose.
The impossible dream

High Resolution

Low Noise

Low Dose
A good scanner will offer a range of doses and field sizes to suit the imaging task at hand.
Quiz – True or False?

1. There’s no dose to the parts of the patient that I can’t see in the images.  
   NOT ALWAYS TRUE

2. The smaller the Field Of View (FOV) the lower the dose.  
   USUALLY BUT NOT ALWAYS

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

4. The dose from a Small Field Of View (SFOV) scanner is so low that scanning both halves of the mandible separately is better than scanning the whole mandible on a LFOV machine.  
   FALSE

5. My CBCT scanner runs at 85kVp instead of 120kVp so that means a lower patient dose.  
   FALSE
True or False?

6. The smaller the Field Of View, the better.  NOT ALWAYS
7. The smaller the voxel size, the better.  NOT ALWAYS
8. The shorter the scan time, the better.  NOT ALWAYS
9. Radiation damage is cumulative.  NOT FOR DIAGNOSTIC X-RAYS
10. The risk of cancer increases with the number of scans.  TRUE AS FAR AS WE KNOW
11. The CBCT scan was non-diagnostic but I shouldn’t repeat it because of the dose.  FALSE
12. My patient has had several CBCT scans already - she shouldn’t have any more.  FALSE