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Some Facts about Cone Beam CT that May Not Be True

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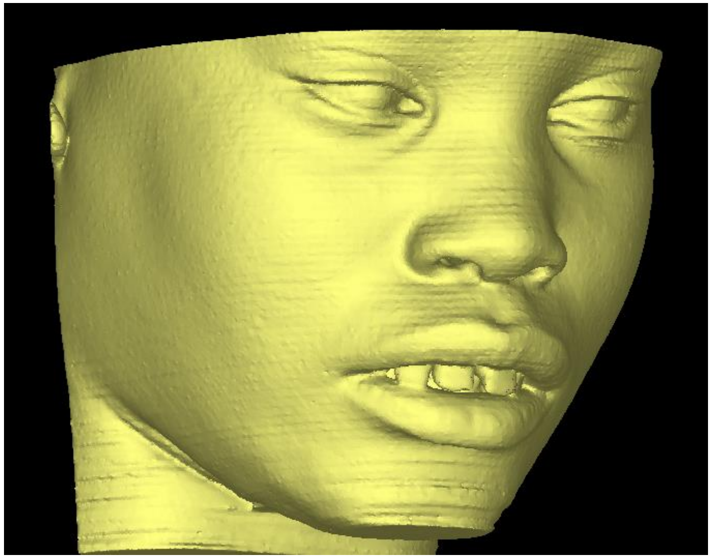
Registered Clinical Scientist CS03469

Image Diagnostic Technology Ltd.

Who or what is IDT?

Image Diagnostic Technology Ltd aka "IDT Scans"

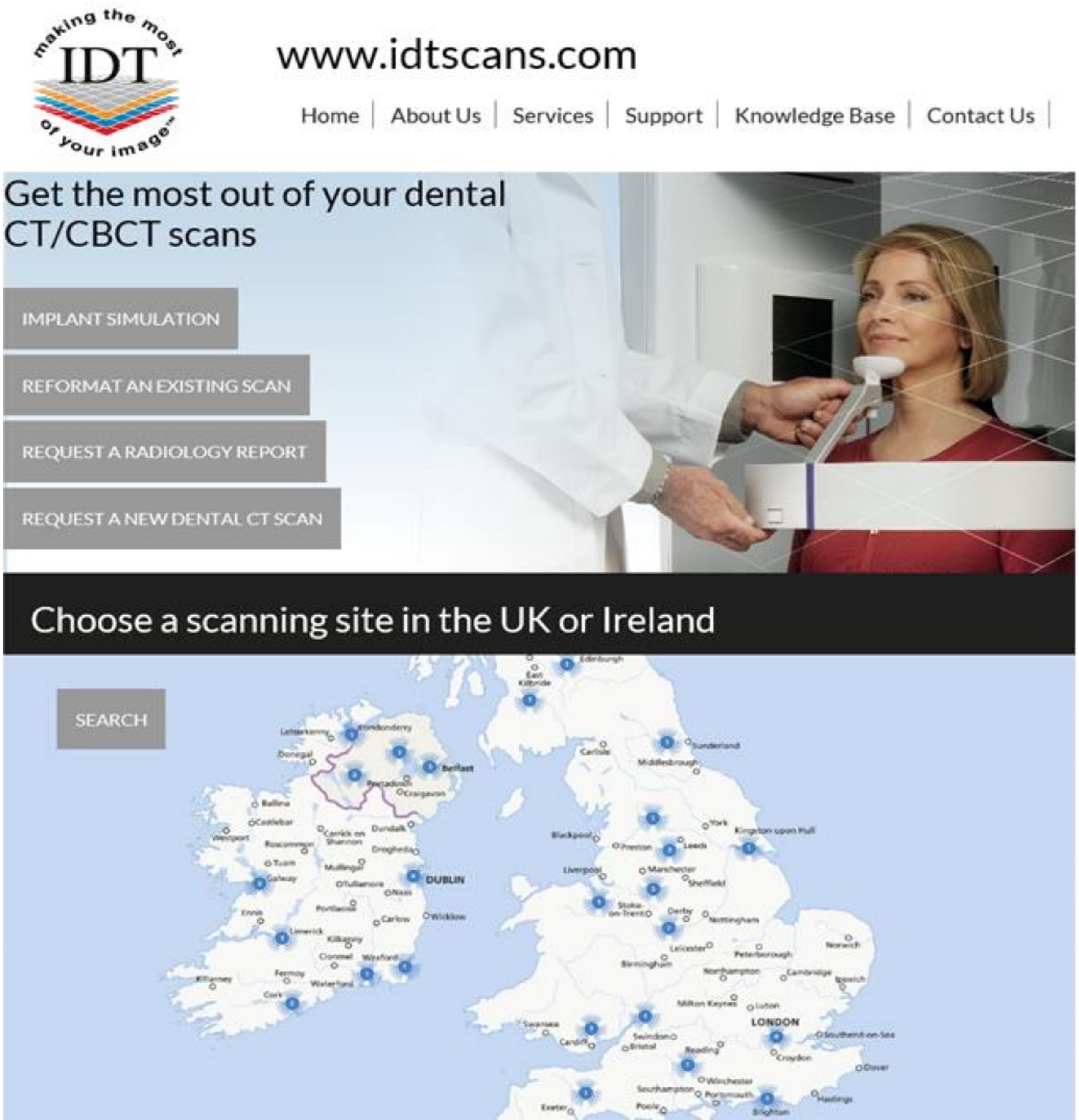


Specialises in:

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

31,500 scans processed since 1991

FOV, kVp, mAs, DAP, DLP, Effective Dose recorded for last 10,000 scans



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“Half of the lies about CBCT are not true”

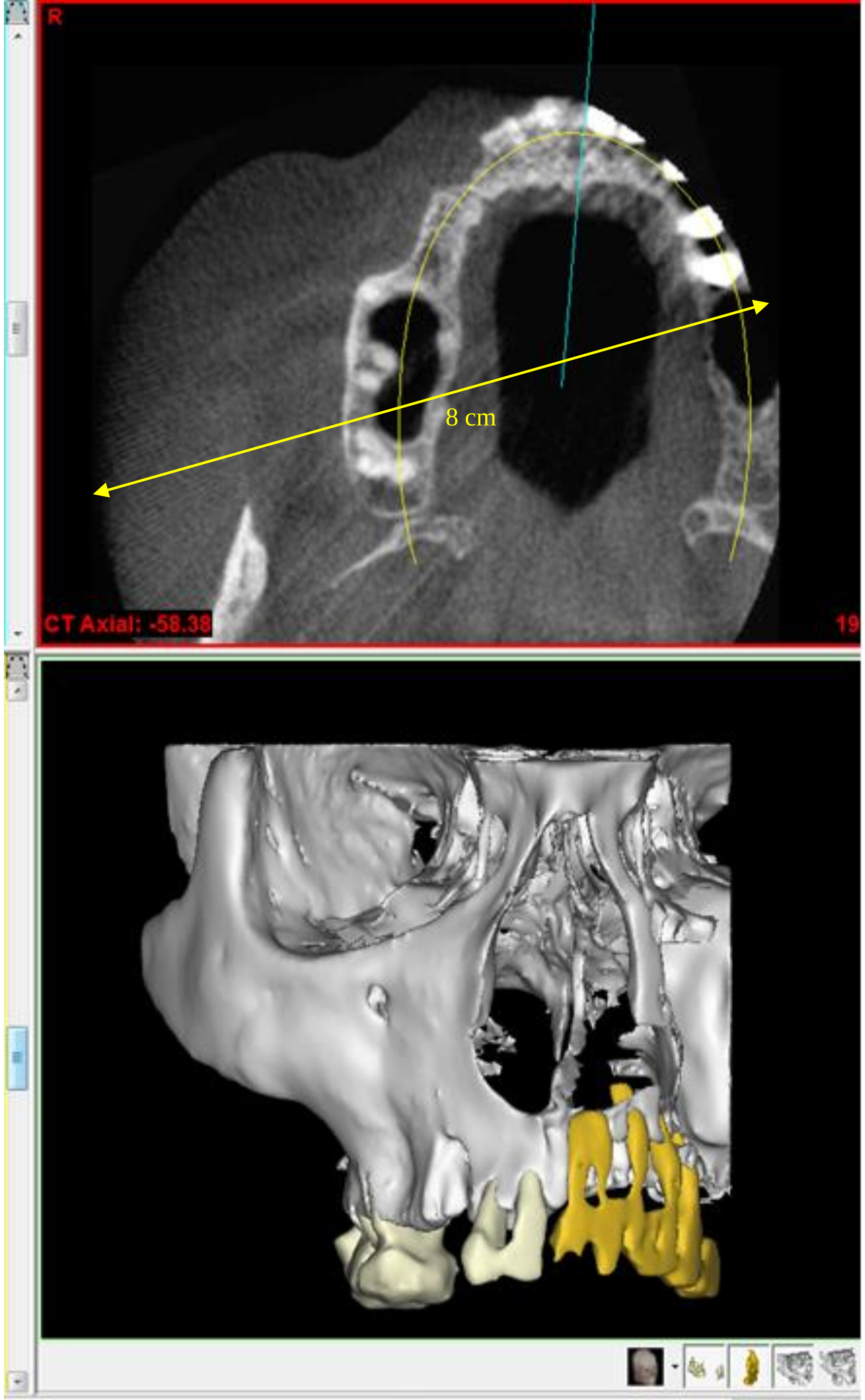
To challenge some fundamental concepts that many people accept without questioning.

- **Do they agree with Physics principles?**
- **Are they supported by the literature?**

“Confessions of an ex-CBCT salesman”

To challenge some fundamental concepts that many people accept without questioning.

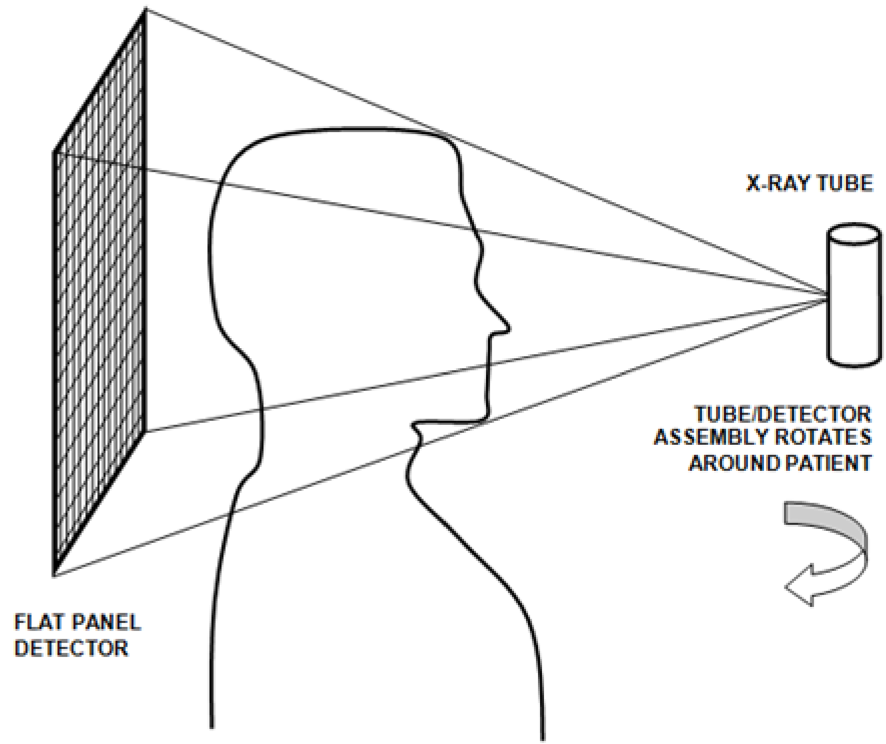
- **Do they agree with Physics principles?**
- **Are they supported by the literature?**



Fact #1:

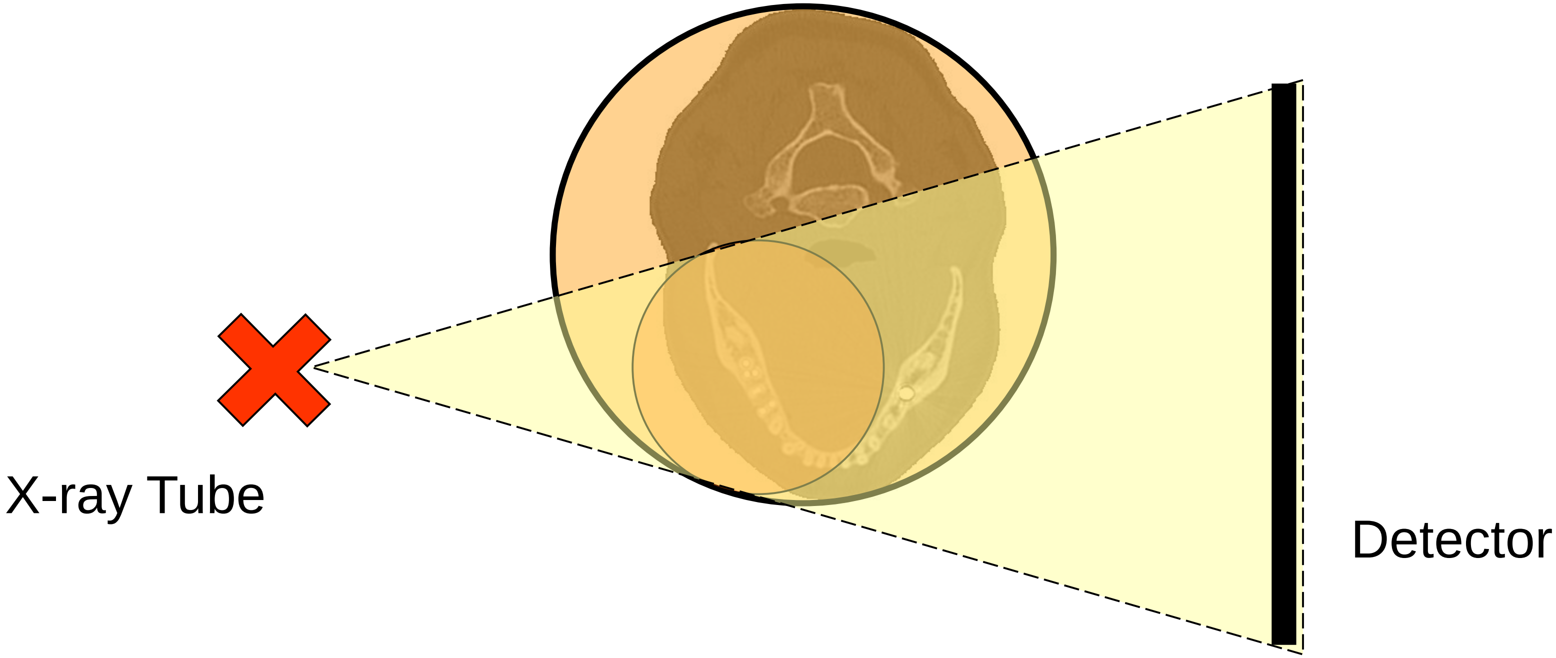
Scanning only one side of the patient is a good way to reduce the radiation dose.

Cone Beam CT (CBCT) Scanner

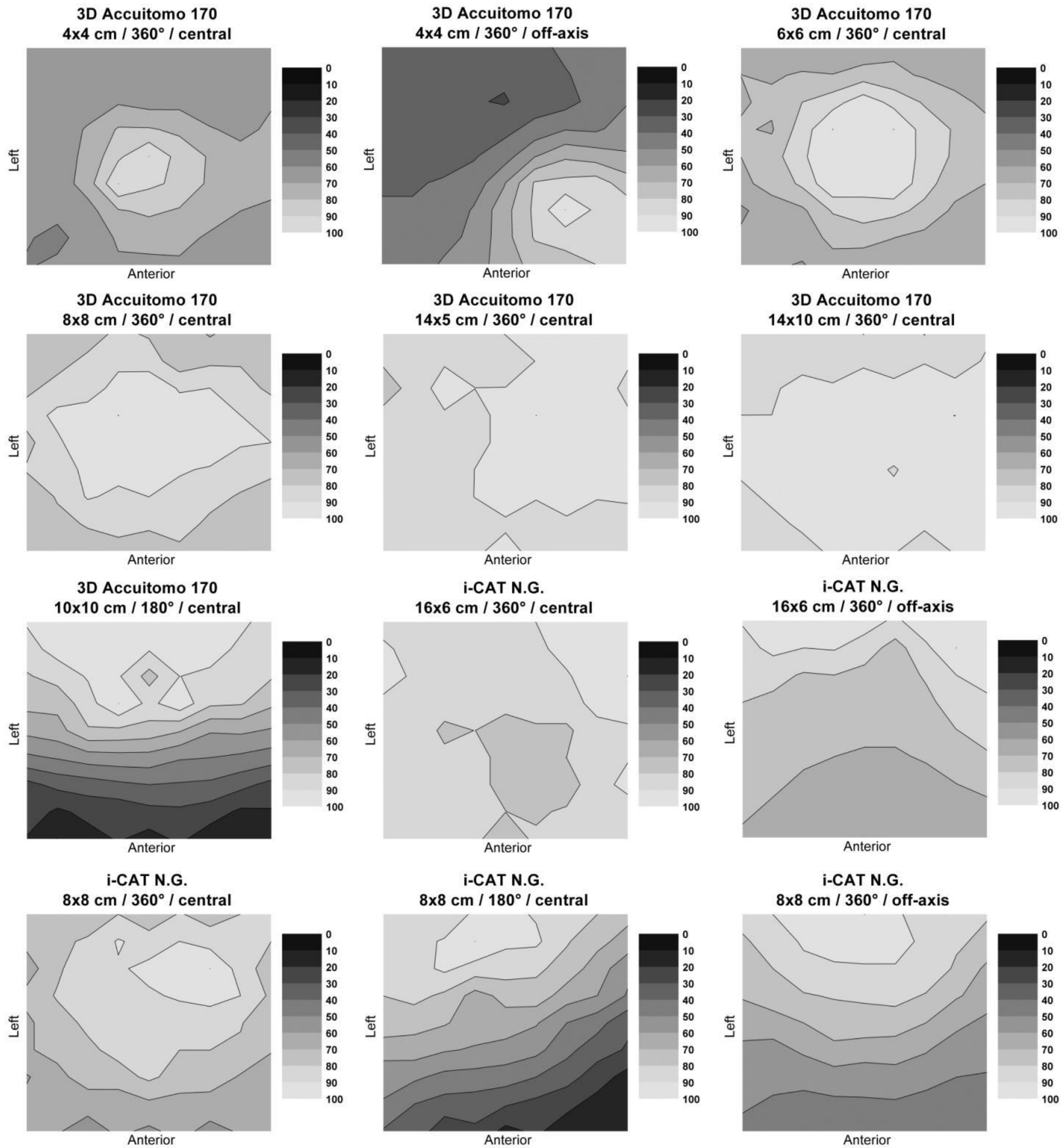


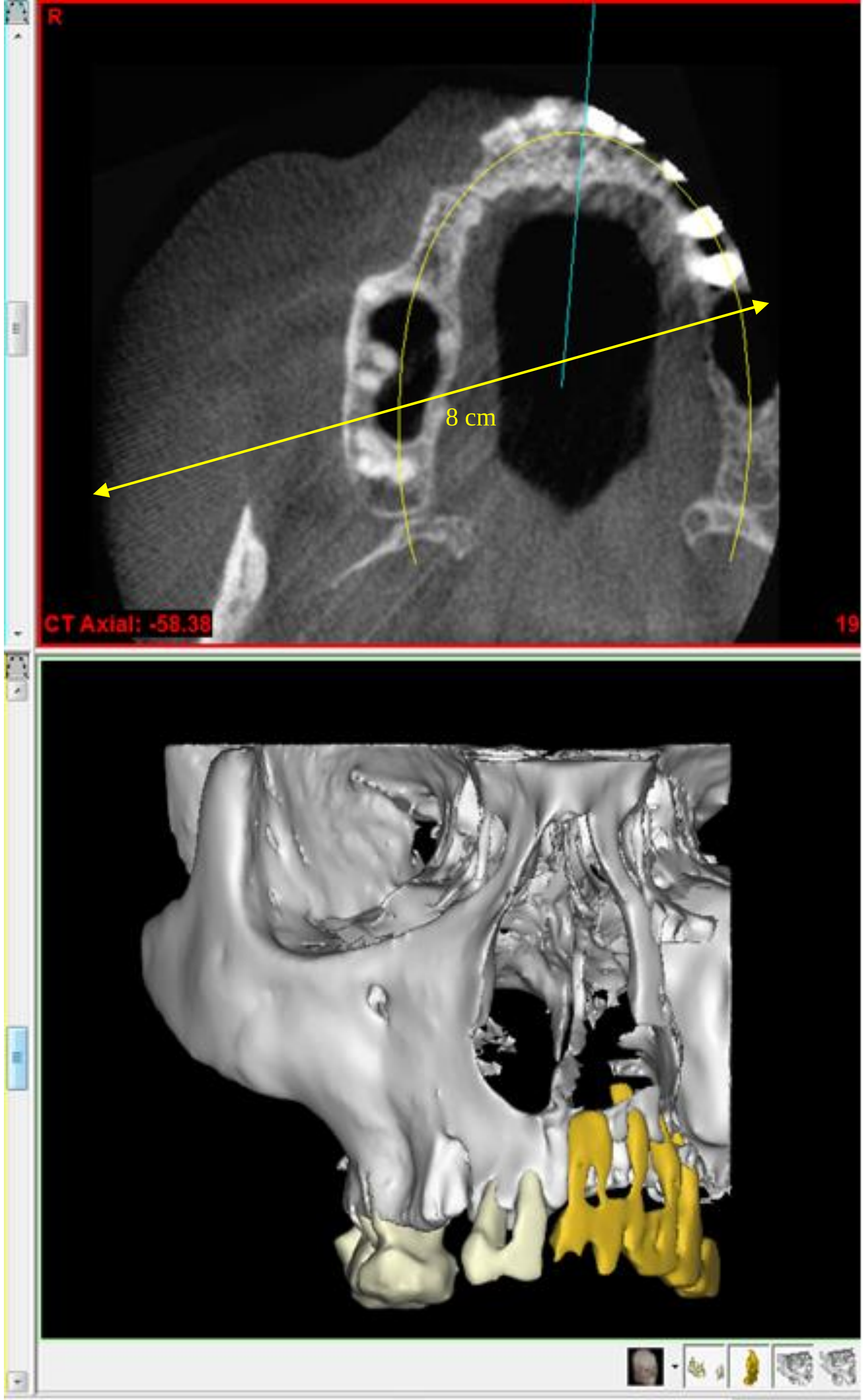
GXCB-500™ is a trademark of Gendex Dental Systems of Lake Zurich, USA

What happens in a Small Field Of View scan

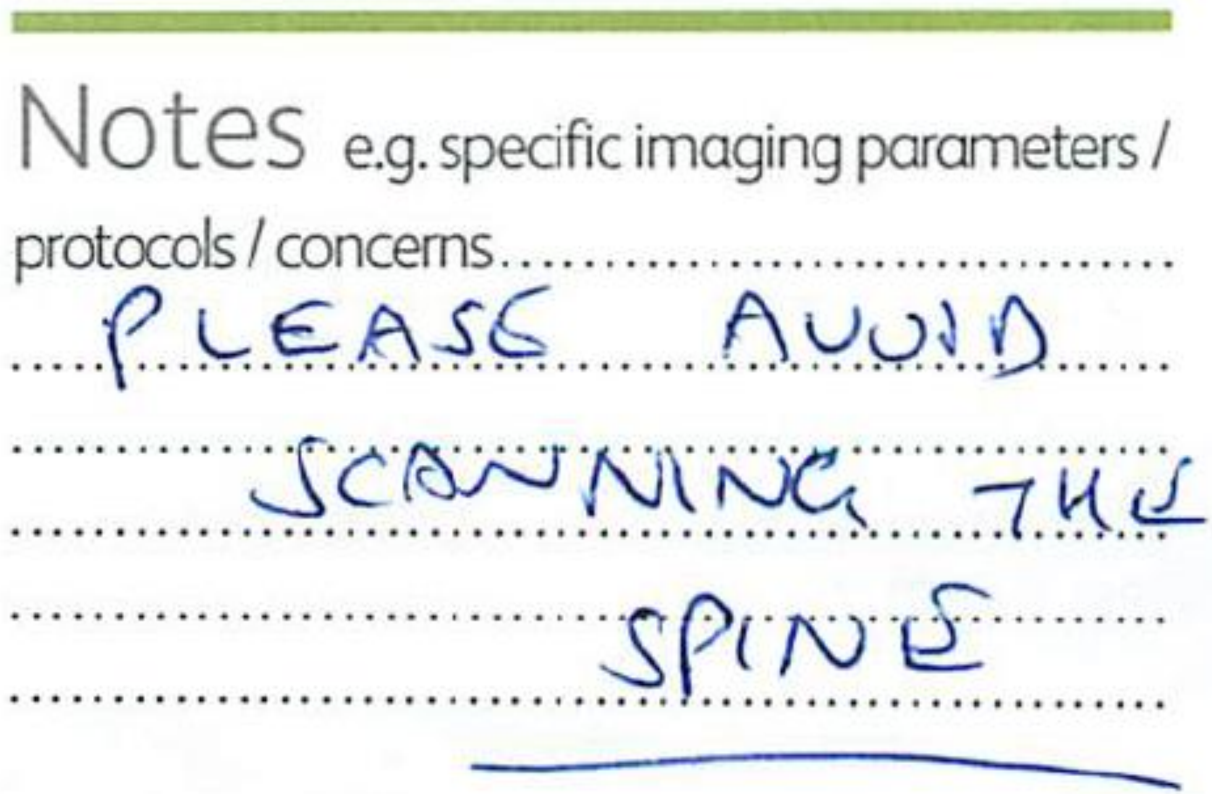


How much dose do points outside the primary beam receive?


3D Accuitomo 170
4x4 cm / 360° / central
3D Accuitomo 170
4x4 cm / 360° / off-axis
3D Accuitomo 170
6x6 cm / 360° / central
3D Accuitomo 170
8x8 cm / 360° / central
3D Accuitomo 170
14x5 cm / 360° / central
3D Accuitomo 170
14x10 cm / 360° / central
3D Accuitomo 170
10x10 cm / 180° / central
i-CAT N.G.
16x6 cm / 360° / central
i-CAT N.G.
16x6 cm / 360° / off-axis
i-CAT N.G.
8x8 cm / 360° / central
i-CAT N.G.
8x8 cm / 180° / central
i-CAT N.G.
8x8 cm / 360° / off-axis
Left
Anterior
0
10
20
30
40
50
60
70
80
90
100



The Absorbed Dose to the left side of the patient is not zero (maybe around 50% of the Absorbed Dose to the right side).


Notes e.g. specific imaging parameters / protocols / concerns

PLEASE AVOID SCANNING THE SPINE

"Sorry mate – no can do!"

Fact #1 Revisited:

1. **If I can't see it in the images it didn't receive any dose.**
   FALSE

2. **If I can't see it in the images I don't have to report on it.**
   TRUE
   (benefits the dentist not the patient)

Why do we want to reduce the Dose?

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

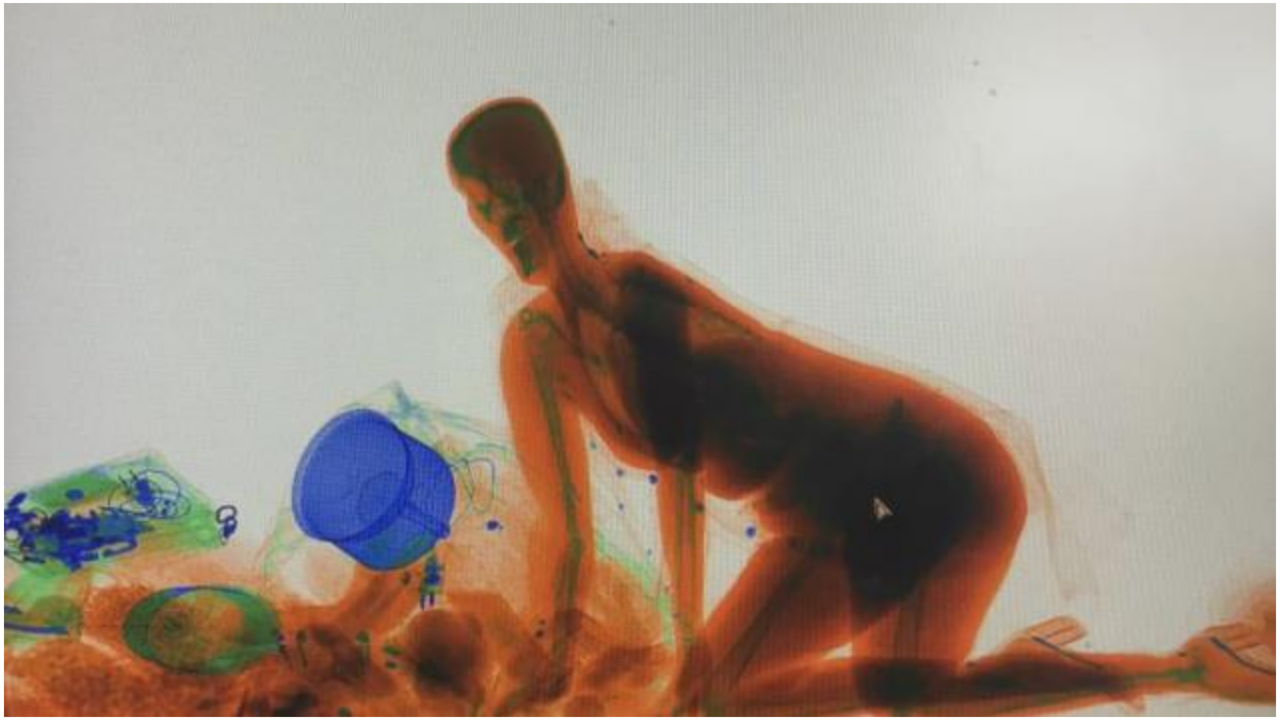
ELSEVIER

Principles of Radiation Protection

ICRP103:

- **Justification** **(benefits must outweigh the risks)**
- **Optimisation (keep doses As Low As ~~Reasonably Achievable~~ Diagnostically Acceptable)**
- **Dose Limits** **(1 mSv per year for members of the public)**
  (no dose limits for medical exposures)

Benefit versus Risk



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

Optimisation

Want to Optimise

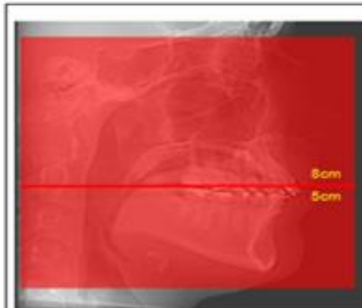
$$\frac{\text{Benefit to Patient*}}{\text{Risk to Patient}}$$

*** not to the dentist!**

What is the best way to Optimise the Dose?

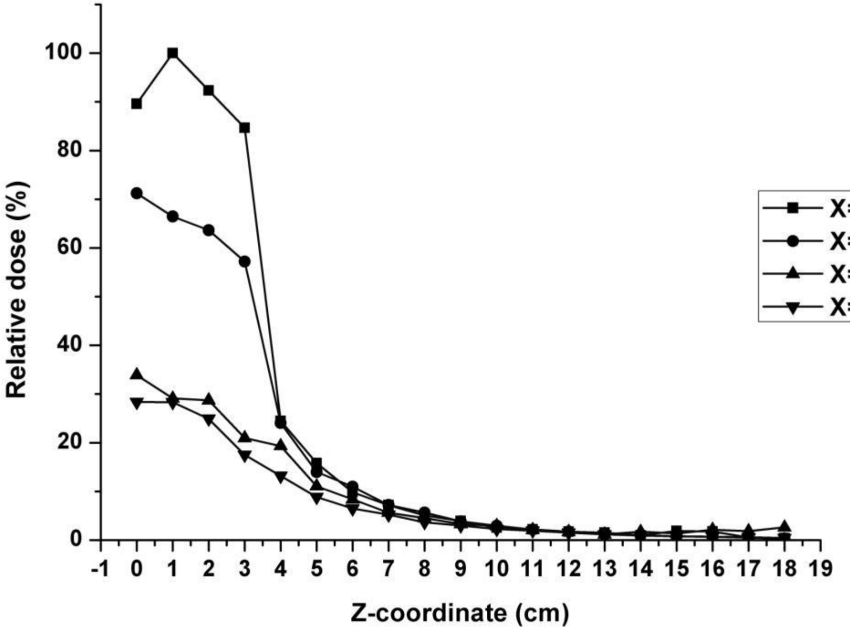
1. **Reduce the Height (vertical collimation)**

   Reduces the risk without loss of benefit in most cases.

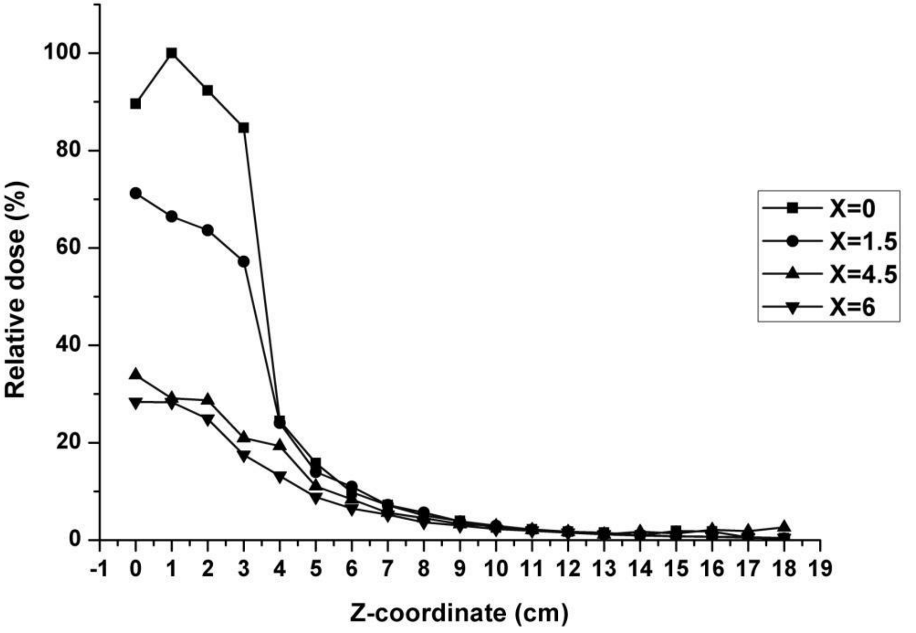
	Full face 13cm height x 16cm diameter 83 microSieverts
	Both arches 8cm height x 16cm diameter 56 microSieverts (interpolated)
	Mandible 6cm height x 16cm diameter 45 microSieverts

Absorbed Dose outside primary beam is effectively zero

SCANORA 3D



3D Accuitomo XYZ



More ways to Reduce the Dose

2. Reduce the mAs (tube current, scan duration)

- **Reducing the mA may increase the noise**

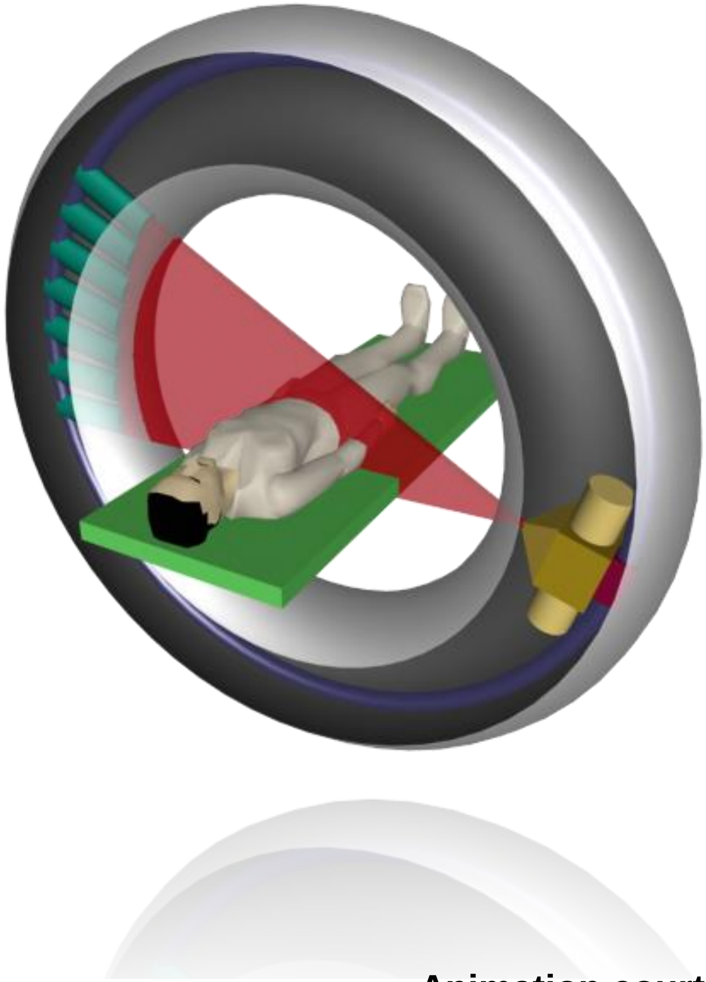
- **Reducing the scan duration may decrease the number of projections.**

how CT works…

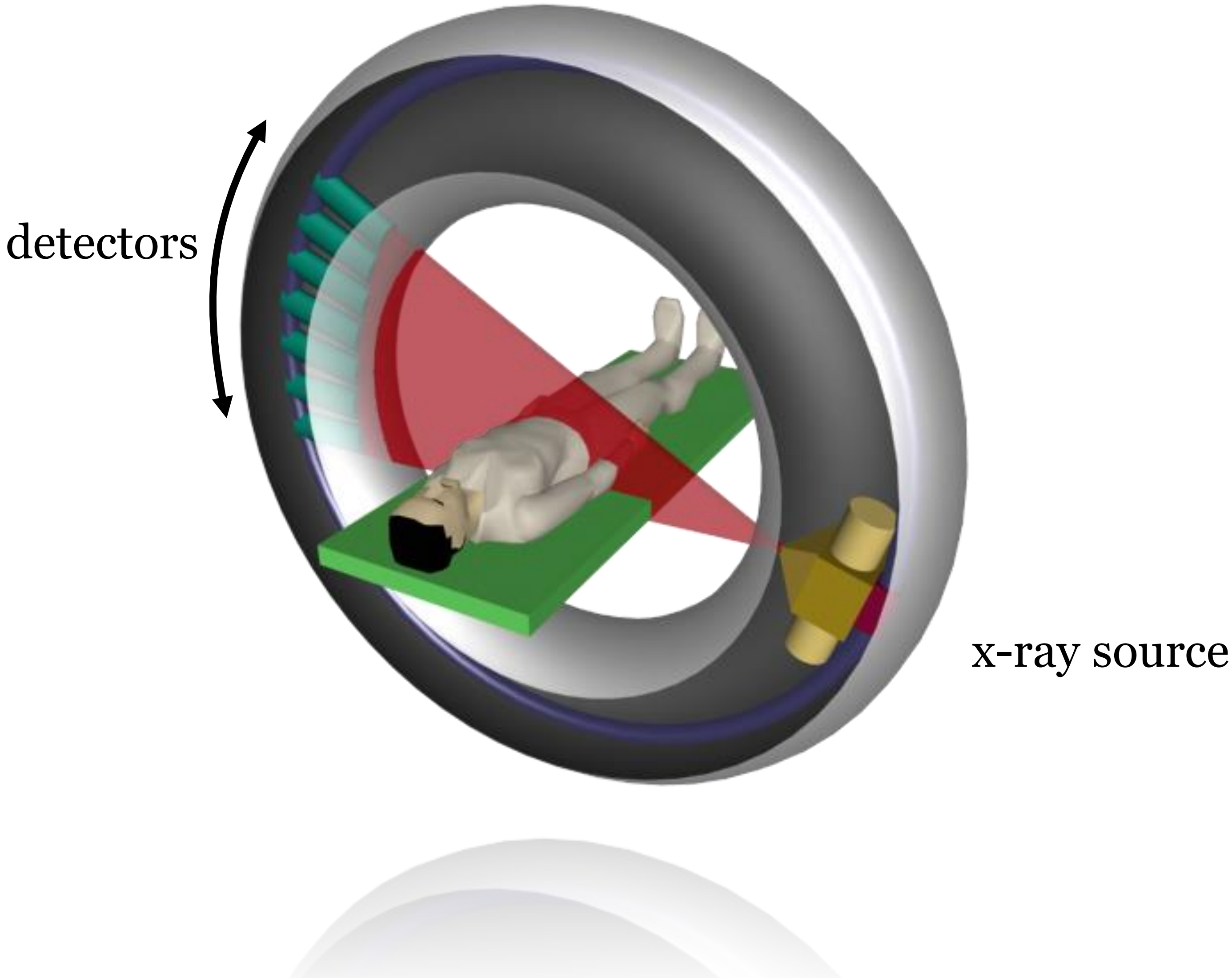
Godfrey Hounsfield

Allan Cormack

Nobel prize in Medicine, 1979



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


detectors
x-ray source

Reducing the Scan Duration

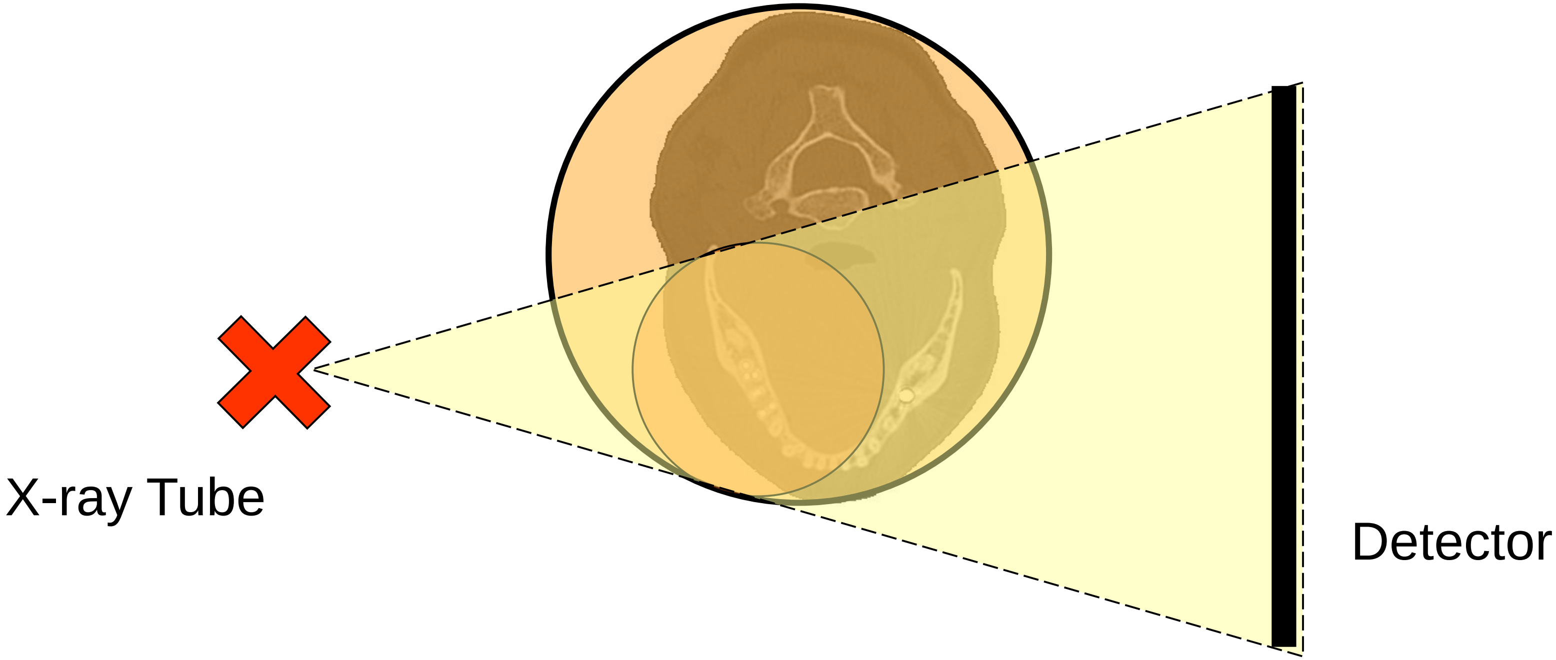
- Fewer projections

- Less detail (spatial resolution)

- Example: i-CAT Classic

  40 second scan has better detail than 20 second scan

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**

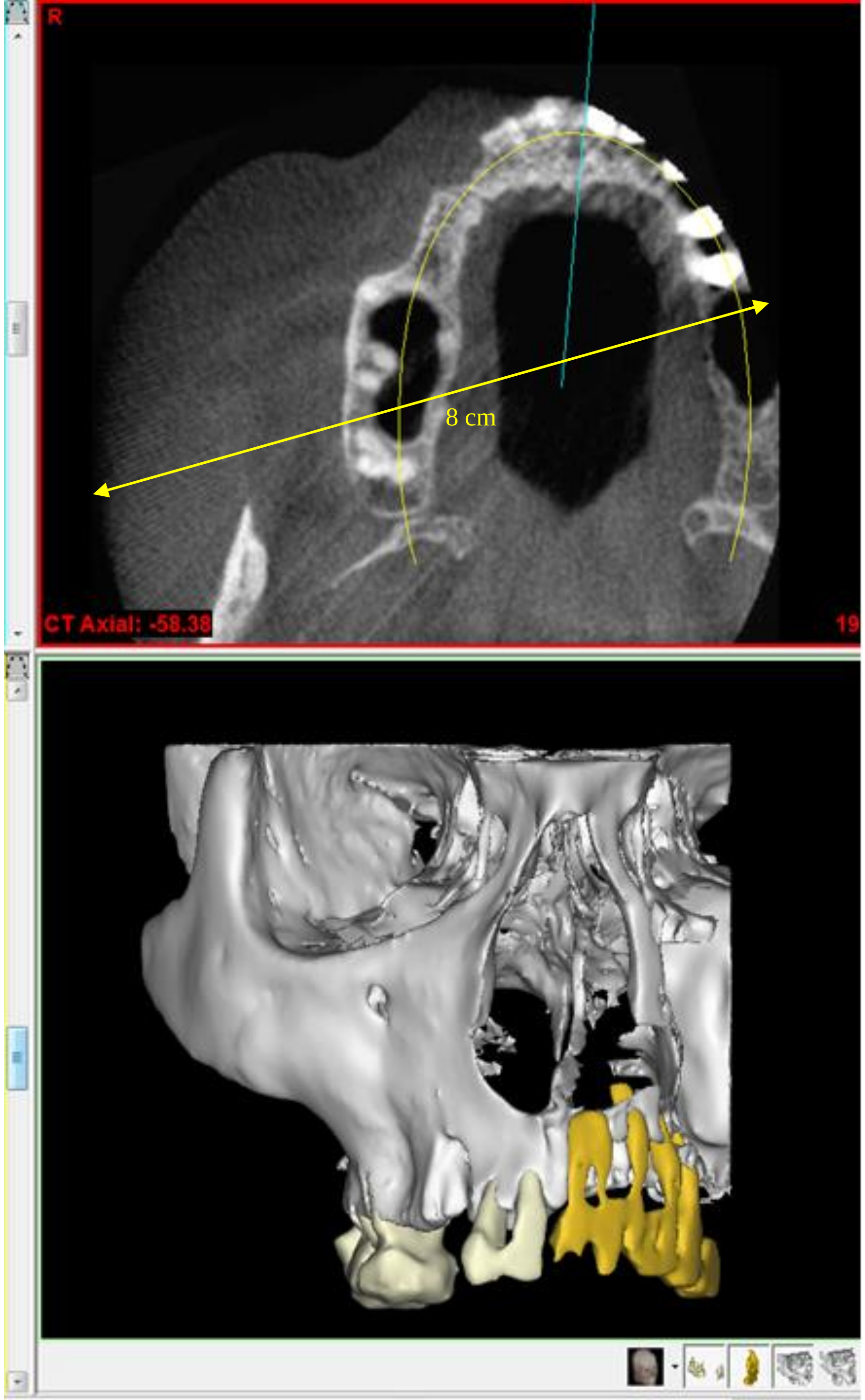
Which is the best way to reduce the dose?

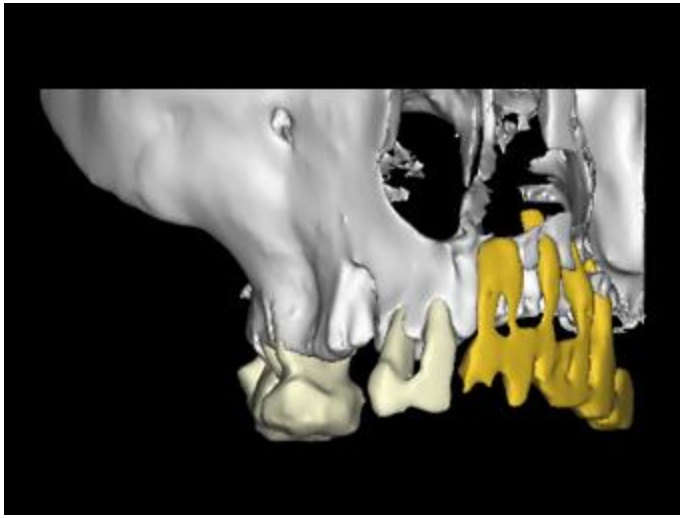
1. **Reduce the Height**
   - linear reduction in risk, no loss of benefit in most cases

2. **Reduce the mAs**
   - linear reduction in risk, some loss of benefit

3. **Reduce the Width**
   - less than linear reduction in risk, more loss of benefit

4. **Move patient to the side**
   - Very little reduction in risk, large loss of benefit


R
8 cm
CT Axial: -58.38
19



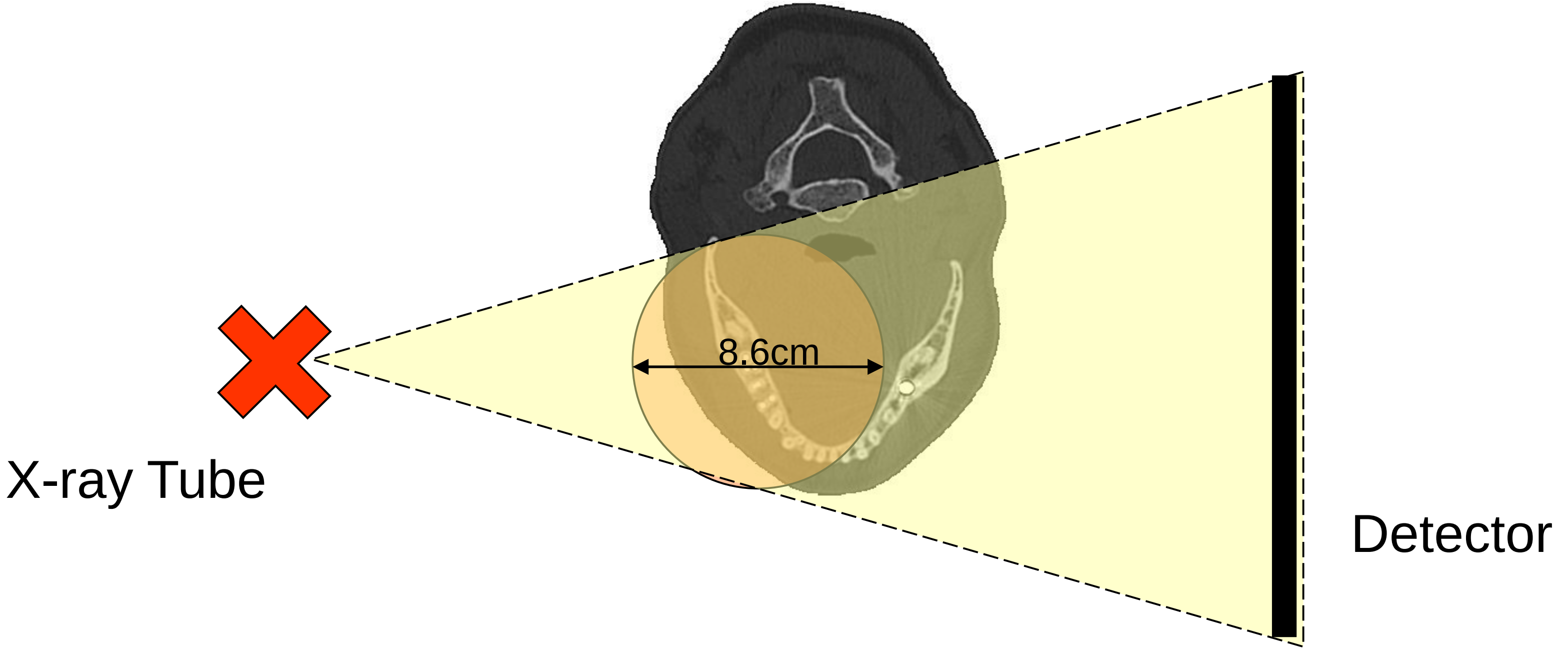
Fact #2:

If you halve the diameter of the scan (from 8cm to 4cm) then the dose will be roughly half as much (for the same kVp and mAs).

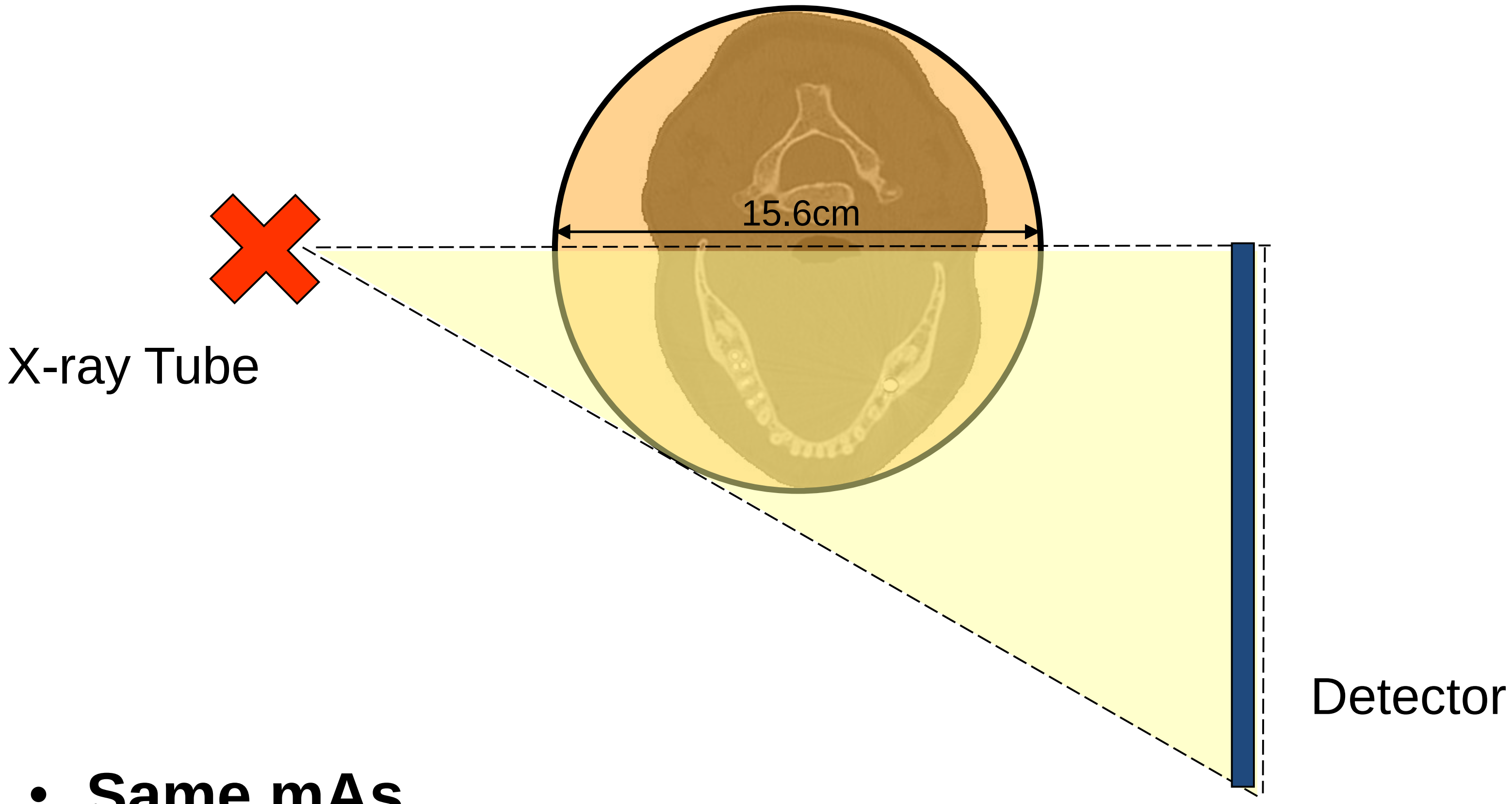
Fact #2a:

If you double the diameter of the scan (from 8cm to 16cm) then the dose will be roughly twice as much (for the same kVp and mAs).

Gendex CB-500: 8.6cm FOV



Gendex CB-500: 15.6cm FOV



- **Same mAs**
- **Same DAP**
- **Same Dose**

Gendex CB-500 – Cesium Iodide panel

Medium Field Of View (MFOV)			8.6cm			
Scan Duration (s)	Rotation (°)	Projections	Exposure (mAs)	Voxel Sizes (mm)	Typical DAP (mGy.cm) Both Jaws	Typical E.D. (μSv) Both Jaws
4.8	180	160	8.5	0.4, 0.3	155	20
8.9	360	300	15.4	0.4, 0.3	285	35
12.6	180	320	16.9	0.25, 0.2, 0.125	315	40
23	360	600	30.9	0.25, 0.2, 0.125	570	70
Extended Field Of View (EFOV)*			15.6cm			
Scan Duration (s)	Rotation (°)	Projections	Exposure (mAs)	Voxel Sizes (mm)	Typical DAP (mGy.cm) Both Jaws	Typical E.D. (μSv) Both Jaws
8.9	360*	300	15.4	0.4, 0.3	285	30
23	360*	600	30.9	0.25, 0.2	570	65

Effect of Offsetting the Detector:

- Data are collected over 360°
- Half the patient gets irradiated for the first 180° and the other half gets irradiated for the second 180°.
- Therefore a 360° EFOV scan is equivalent to two 180° MFOV scans.
- There will be some loss of resolution, but no increase in dose.

Just about all modern CBCT machines use a small detector multiple times to obtain a larger Field Of View.

- **On the Gendex CB-500 the mAs stays the same**
- **On most other scanners the mAs does not stay the same.**

Example:

- Gendex DP-700 uses 4cm detector twice to get 8cm Field Of View
- However, the mAs increases from 24.6 for the 4cm FOV
  to 51.0 for the 8cm FOV.
- The increase in dose is due to the increase in mAs, not the increase in Field Of View.

Fact #2 revisited:

It's the diameter of the beam that counts, not the diameter of the visible images.

Fact #3:

CBCT Scanners are much more dose efficient now than they were 10 years ago.

CBCT State of the Art (circa 2005)

fixed mA
2 scan times
20s or 40s

pulsed
x-ray tube

low dose
typical Mx 30μSv
typical Mn 45μSv

adjustable
collimator
4 to 13 cm height
9.5 or 16 cm width

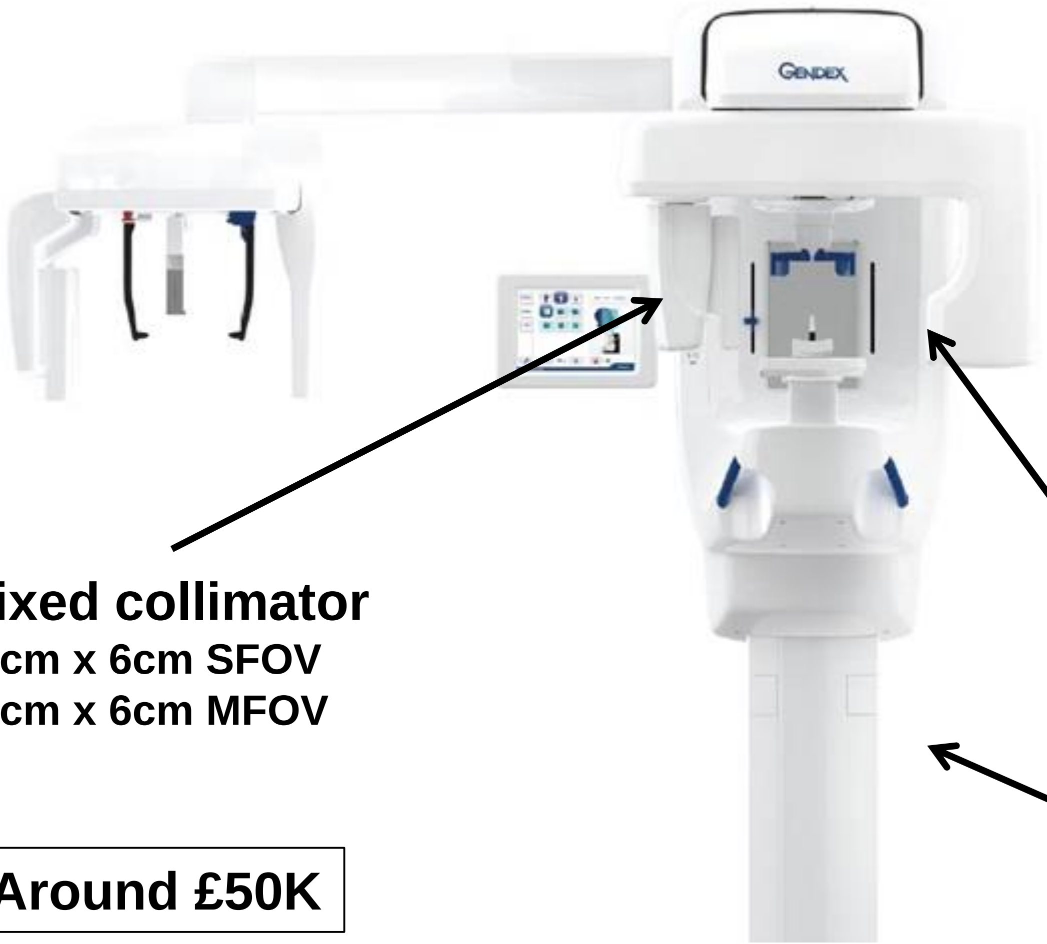
large
detector
18cm x 24cm

adjustable
chair

Around £150K

i-CAT™ is a trademark of Imaging Sciences International LLC of Hatfield, USA

CBCT State of the Art (circa 2015)



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 £50K

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

How do we know what the Effective Dose is?

Method 1: Measure it!

1. **Put TLD chips in a Rando phantom and measure Absorbed Doses to each organ**

2. **Apply correction factors to obtain Equivalent Doses for each organ**

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

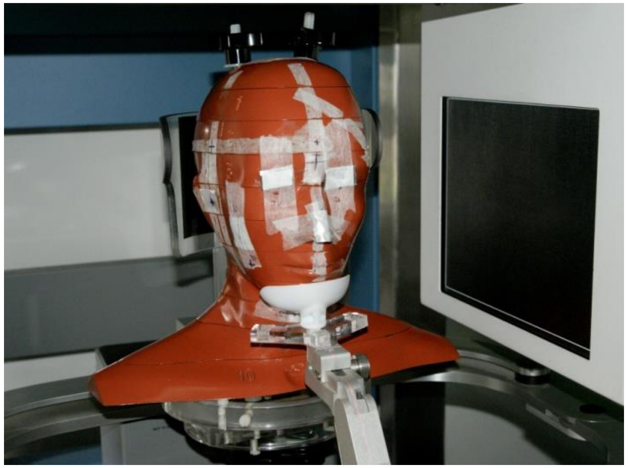
Effective Dose (E)

$$E = \sum_T H_T w_T$$

H_T = Organ Equivalent Dose
w_T = Tissue weighting factor

Unit = (Sv) Sievert
Effective Dose is proportional to risk of fatal cancer

	w_T value ICRP103
Brain	0.01
Salivary glands	0.01
Skin	0.01
Thyroid	0.04
Oesophagus	0.04
Lung	0.12
Red bone marrow	0.12
Breast	0.12
Bone surface	0.01
Liver	0.04
Stomach	0.12
Colon	0.12
Ovary	0.08
Bladder	0.04
Testes	0.08
Remainder	0.12

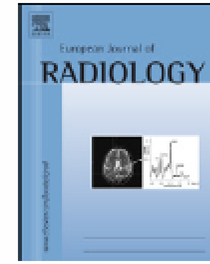


Method 2: Use published data.

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

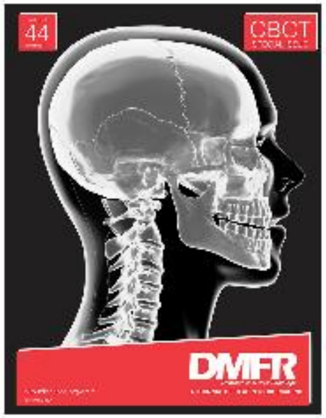


Effective dose range for dental cone beam computed tomography scanners

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

[a] *Oral Imaging Center, School of Dentistry, Oral Pathology and Maxillofacial Surgery, Faculty of Medicine, Catholic University of Leuven, Belgium*
[b] *Center for Periodontology and Implantology, Heverlee, Belgium*
[c] *North Western Medical Physics, The Christie NHS Foundation Trust, Manchester Academic Health Sciences Centre, UK*
[d] *School of Dentistry, University of Manchester, Manchester Academic Health Sciences Centre, UK*
[e] *School of Medicine, University of Manchester, Manchester Academic Health Sciences Centre, UK*
[f] *Department of Radiology, University Hospital Gasthuisberg, Leuven, Belgium*
[g] *Department of Experimental Radiotherapy, University Hospital Gasthuisberg, Katholieke Universiteit Leuven, Belgium*

Eur J Radiol 81,2,267-271 (February 2012)



DentoMaxilloFacial Radiology

CBCT Special Issue

VOLUME 44, ISSUE 1, 2015

Dentomaxillofacial Radiology (2015) 44, 20140197

birpublications.org/dmfr

CBCT SPECIAL ISSUE: REVIEW ARTICLE

Effective dose of dental CBCT—a meta analysis of published data and additional data for nine CBCT units

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

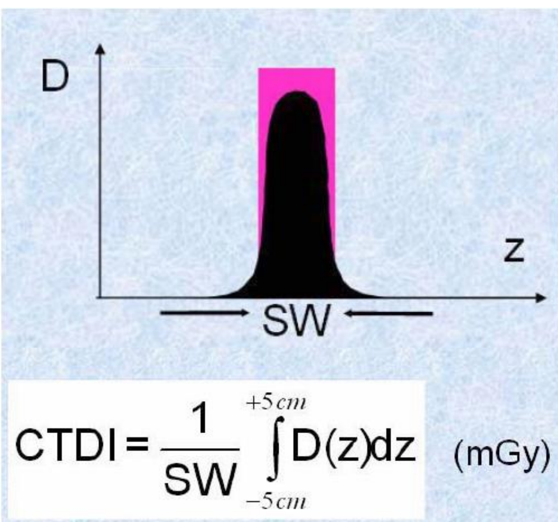
[1]North Carolina Oral Health Institute, Koury Oral Health Sciences, Chapel Hill, NC, USA; [2]Graduate Program in Oral and Maxillofacial Radiology, University of North Carolina, Chapel Hill, NC, USA; [3]Department of Orthodontics, University of Missouri, Columbia, MO, USA; [4]Private Practice of Orthodontics, Houston, TX, USA; [5]University of Michigan School of Dentistry, Ann Arbor, MI, USA; [6]University of North Carolina School of Dentistry, Chapel Hill, NC, USA

Method 3: Use the Dose Length Product (DLP)

$CTDI_{vol}$ is the dose per cm

DLP = $CTDI_{vol}$ x Irradiated Length

Effective Dose = DLP x F **(where F is a conversion factor)**



- **works well for medical CT**
- **most CBCT manufacturers don't display $CTDI_{vol}$ (exception: J.Morita, NewTom)**

Conversion Factor F

Tab. 3.1
Average values f_{mean} of conversion factor (in mSv/mGy·cm) to convert from dose free-in-air on the axis of rotation into effective dose for different regions of the body and patient groups (beam quality: 125 kV, 9 mm Al-equivalent); demarcation of the body regions was made according to (Hidajat96/2) (see also fig. 3.1 - 3.3).

Body region	Adults		Children (7 year-old)		Babies (8 week-old)	
	(female)	(male)	(female)	(male)	(female)	(male)
Head	0.0022	0.0020	0.0028	0.0028	0.0075	0.0074
Neck	0.0051	0.0047	0.0056	0.0055	0.018	0.017
Chest	0.0090	0.0068	0.018	0.015	0.032	0.027
Upper abdomen	0.010	0.0091	0.020	0.016	0.036	0.034
Pelvis (*)	0.011	0.0062	0.018	0.011	0.045	0.025
Entire abdomen (*)	0.010	0.0072	0.019	0.014	0.041	0.031

Table from "Radiation Exposure in Computed Tomography" edited by Hans Dieter Nagel
F can also by calculated from ImPACT CTDosimetry calculator www.impactscan.org

Roughly speaking, F = ~~0.002mSv~~ / mGy.cm for Maxilla and ~~0.003mSv~~ / mGy.cm for Mandible

2 µSv **3 µSv**

Accuracy: ±50%

Effective Dose for Medical CT Scanners

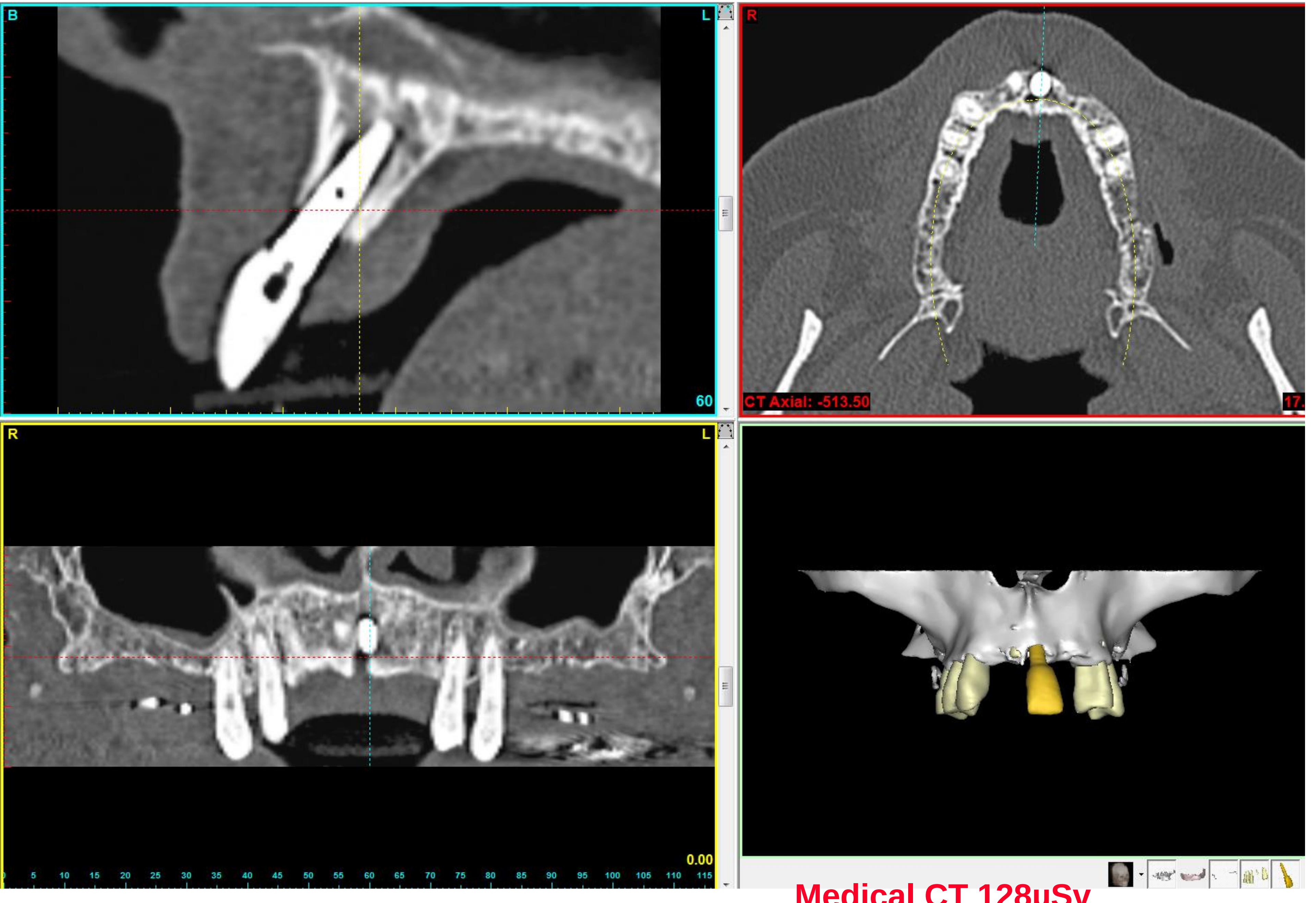
Patient ID : 15625528 Study ID : 6021
Sex : F Patient's Birth Date : 1952.07.20
Patient's Age : 58Y
Image Comment :

Study Date : 2011.06.30
Body Part :
Contrast Enhance : NONE
Contrast/Bolus Volume : Contrast density :
Requesting Service :
Referring Physician's Name :
Name of Physician Reading Study :
Operators Name :
Total mAs in Study : 652
Total Scan time in Study : 10.85
Total DLP mGycm : 64.00
Total slice : 5
Scanning Sequence : HELICAL_CT

Multiply DLP by 2 for Maxilla or 3 for Mandible to get the Effective Dose in microSieverts (µSv)

Accuracy: ±50%

Mx 128µSv ROUGHLY



Medical CT 128μSv

Method 4: 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

Table 5. Most commonly used exposure parameters in three specified regions and corresponding dose-are product (DAP) value and effective dose according to ICRP 60 (1991)

Region	*Volume size (mm x mm)*	*Tube voltage (kV)*	*Tube current (mA)*	*DAP value (mGy cm²)*	*Effective dose (μSv)*
Upper jaw					
Cuspid	30 x 40	80	5.0–6.0	263–316	21–25
	40 x 40	75	4.0–5.0	260–325	21–26
	60 x 60	75	4.5–5.5	645–788	52–63
Lower jaw					
Second premolar–first molar	30 x 40	75–80	3.0–6.0	140–316	11–25
	40 x 40	75	4.0–6.0	260–390	21–31
	60 x 60	75	5.0–6.0	716–859	57–69
Lower jaw					
Third molar	30 x 40	75–80	3.0–6.5	140–342	11–27
	40 x 40	75–80	4.0–5.0	260–366	21–29
	60 x 60	75–80	4.5–6.0	645–967	52–77

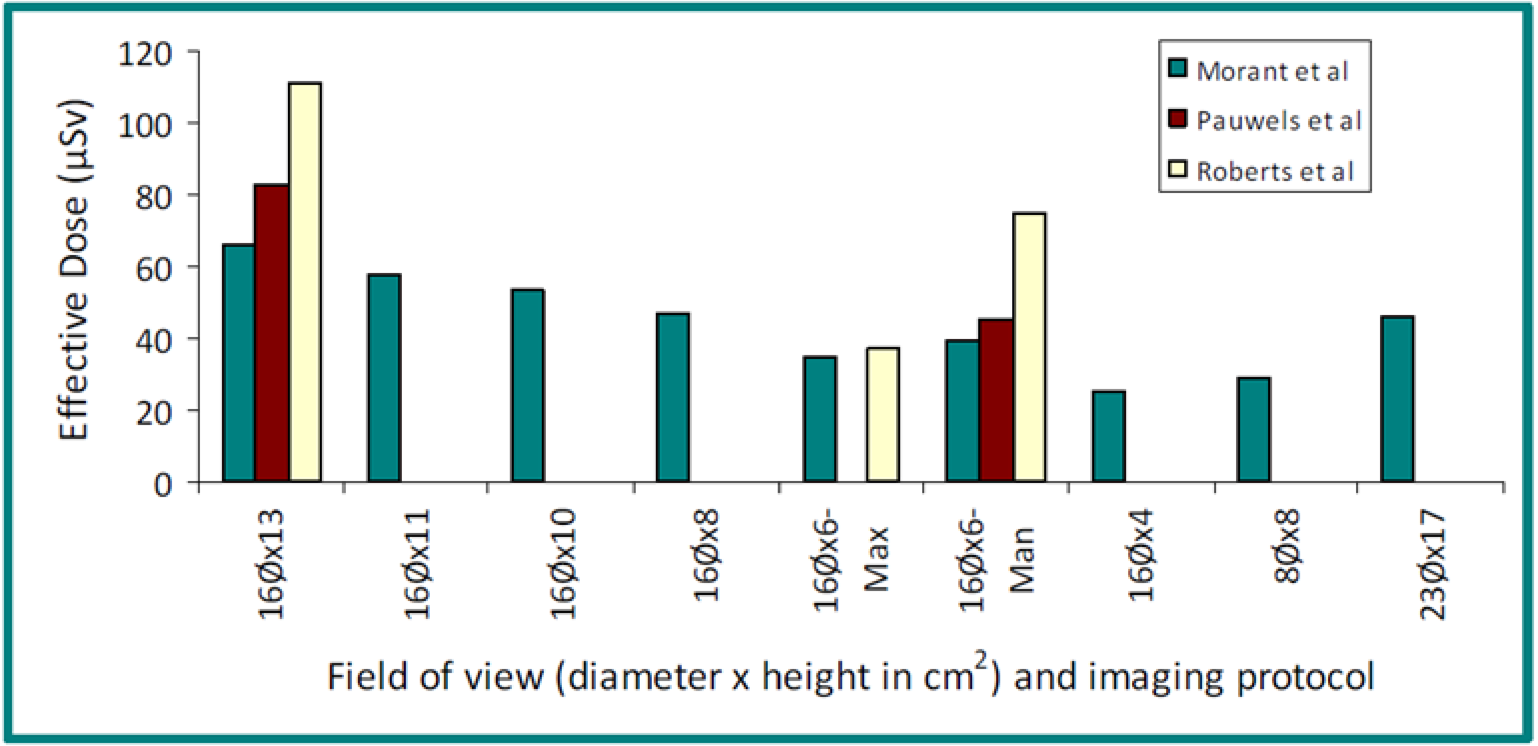
Effective Dose (μSv) = 0.1 x DAP (mGy.cm2) for **Maxilla**
Effective Dose (μSv) = 0.15 x DAP (mGy.cm2) for **Mandible**
Effective Dose (μSv) = 0.125 x DAP (mGy.cm2) for **Mn & Mx**

VERY ROUGH – USE WITH CAUTION !

Results of Monte Carlo calculations

Morant J, Salvadó M, Hernández-Girón I, Casanovas R, Ortega R, Calzado A. Dosimetry of a cone beam CT device for oral and maxillofacial radiology using Monte Carlo techniques and ICRP adult reference computational phantoms. Dentomaxillofac Radiol. 2012 Aug 29. [Epub ahead of print]

i-CAT 17-19

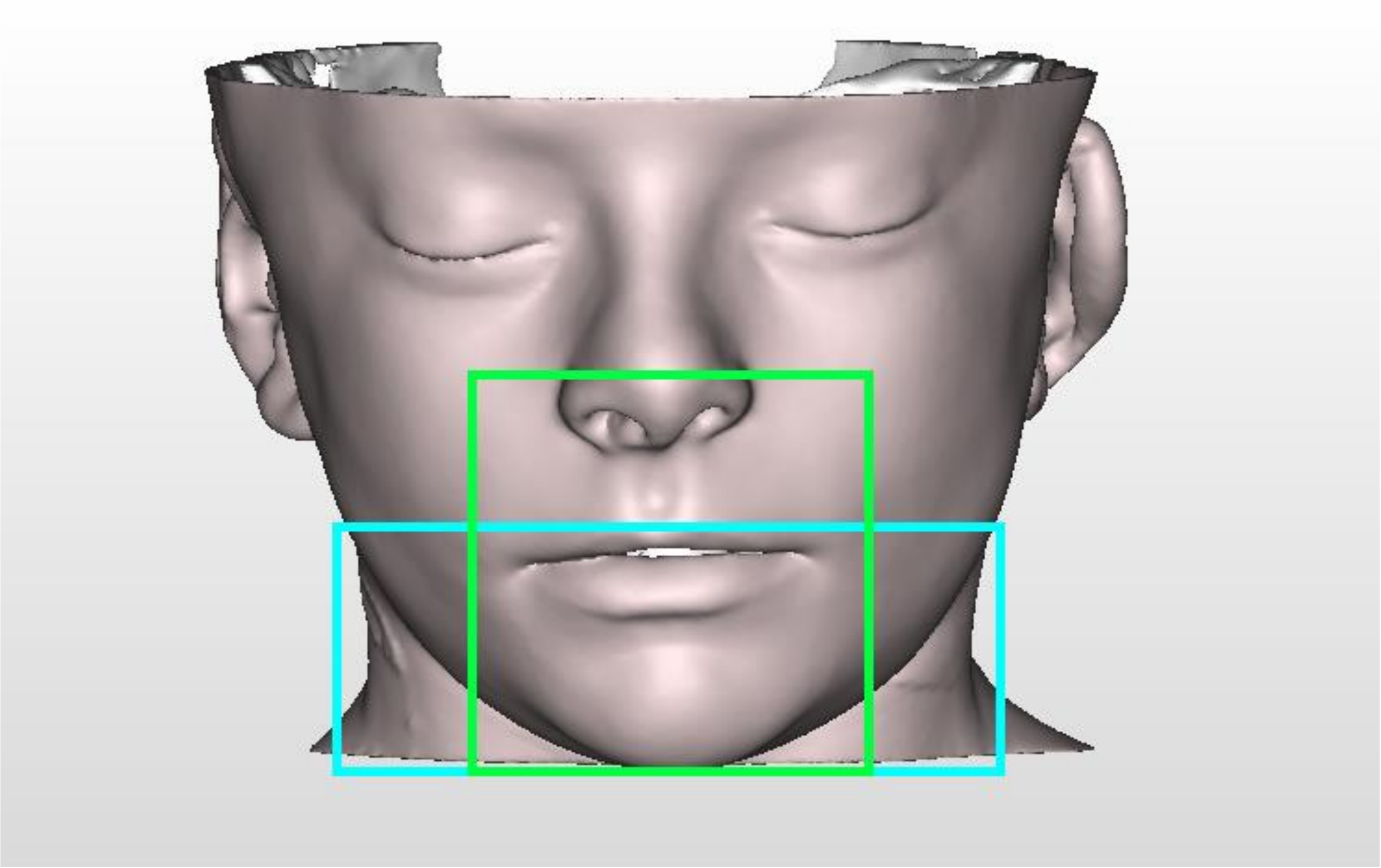


- Effective dose-DAP relationship:
  - Effective dose (µSv) = 0.130 x DAP ($mGycm^2$), r^2=0.994

slide from presentation by
Dr Chrysoula Theodorakou, "Dental Cone Beam Computed Tomography", BIR, London, 6 November 2012

The Christie NHS
NHS Foundation Trust

Use the DAP with caution!



- **Same DAP**
- **Different Dose**

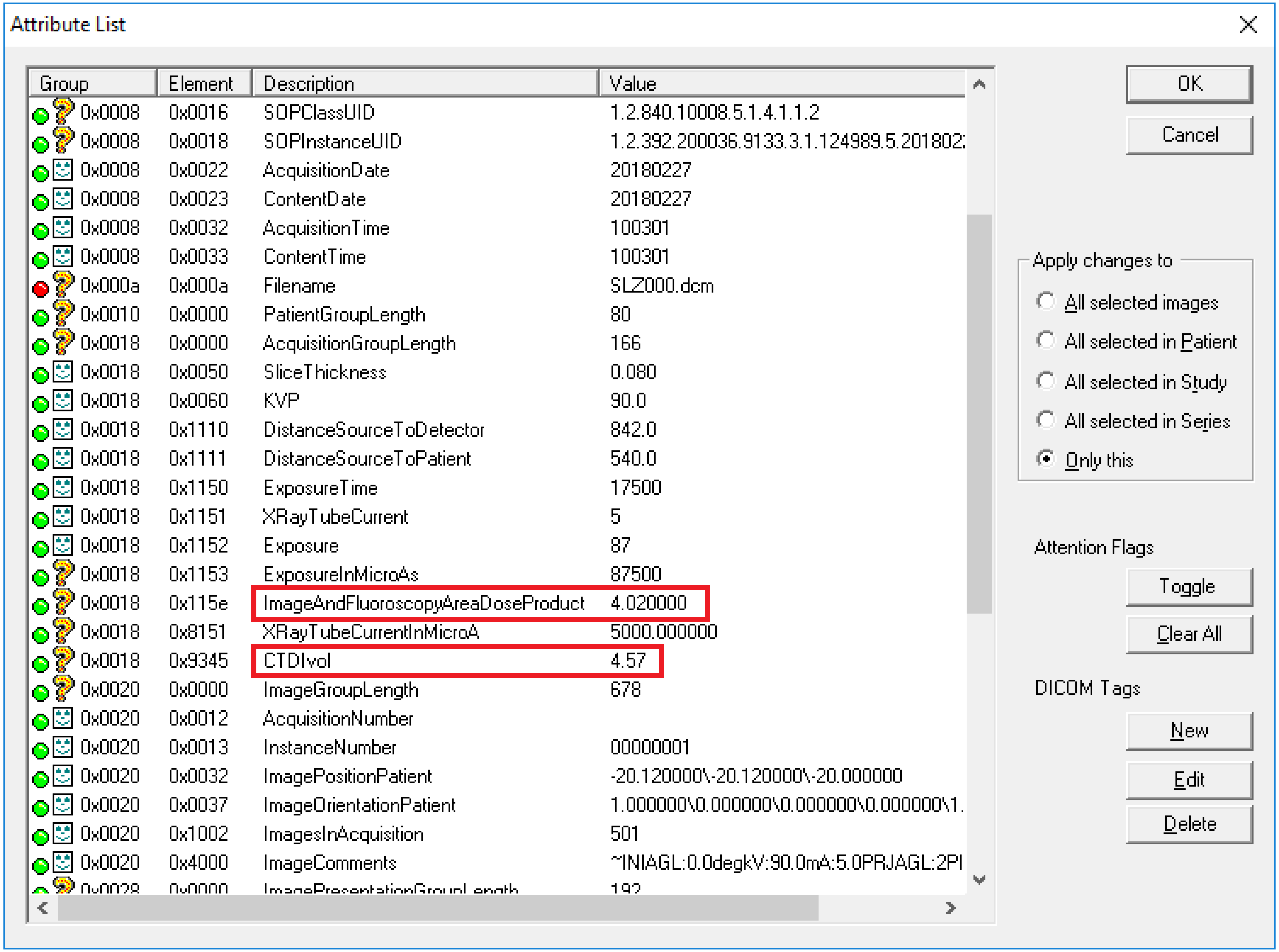
Effective dose range for dental cone beam computed tomography scanners

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

Table 5
Absorbed organ dose and effective dose for small FOV (localised) protocols.

	3D Accuitomo 170	Kodak 9000 3D	Kodak 9000 3D	Pax-Uni3D
FOV positioning	Lower jaw, molar region	Upper jaw, front region	Lower jaw, molar region	Upper jaw, front regio
Red bone marrow	37	21	78	47
Thyroid	195	30	251	209
Skin	32	25	24	55
Bone surface	37	27	35	49
Salivary glands	2120	523	709	1073
Brain	37	18	290	28
Remainder	70	74	86	146
Effective dose	43	19	40	44

Accuitomo 4cm x 4cm @ 90kVp and 87.5mAs



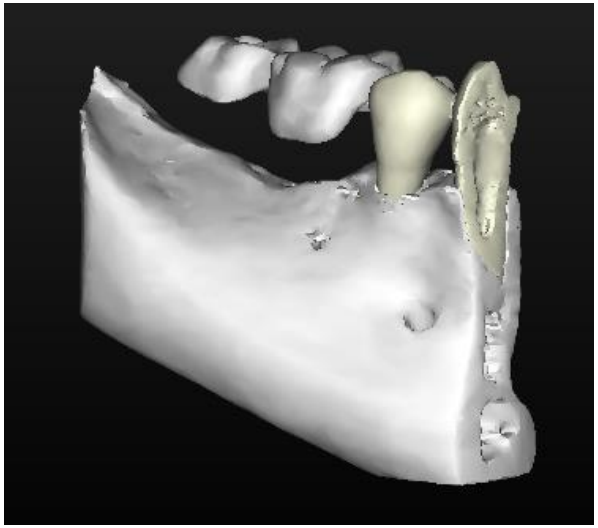
Group	Element	Description	Value
0x0008	0x0016	SOPClassUID	1.2.840.10008.5.1.4.1.1.2
0x0008	0x0018	SOPInstanceUID	1.2.392.200036.9133.3.1.124989.5.201802
0x0008	0x0022	AcquisitionDate	20180227
0x0008	0x0023	ContentDate	20180227
0x0008	0x0032	AcquisitionTime	100301
0x0008	0x0033	ContentTime	100301
0x000a	0x000a	Filename	SLZ000.dcm
0x0010	0x0000	PatientGroupLength	80
0x0018	0x0000	AcquisitionGroupLength	166
0x0018	0x0050	SliceThickness	0.080
0x0018	0x0060	KVP	90.0
0x0018	0x1110	DistanceSourceToDetector	842.0
0x0018	0x1111	DistanceSourceToPatient	540.0
0x0018	0x1150	ExposureTime	17500
0x0018	0x1151	XRayTubeCurrent	5
0x0018	0x1152	Exposure	87
0x0018	0x1153	ExposureInMicroAs	87500
0x0018	0x115e	ImageAndFluoroscopyAreaDoseProduct	4.020000
0x0018	0x8151	XRayTubeCurrentInMicroA	5000.000000
0x0018	0x9345	CTDIvol	4.57
0x0020	0x0000	ImageGroupLength	678
0x0020	0x0012	AcquisitionNumber	
0x0020	0x0013	InstanceNumber	00000001
0x0020	0x0032	ImagePositionPatient	-20.120000\-20.120000\-20.000000
0x0020	0x0037	ImageOrientationPatient	1.000000\0.000000\0.000000\0.000000\1.
0x0020	0x1002	ImagesInAcquisition	501
0x0020	0x4000	ImageComments	~INIAGL:0.0degkV:90.0mA:5.0PRJAGL:2PI
0x0028	0x0000	ImagePresentationGroupLength	192

DAP = 4.02 x 100 = 402mGy.cm2

Effective Dose ≈ 402 x 0.15 = 60μSv

DLP = 4.57 x 4 = 18.28mGy.cm

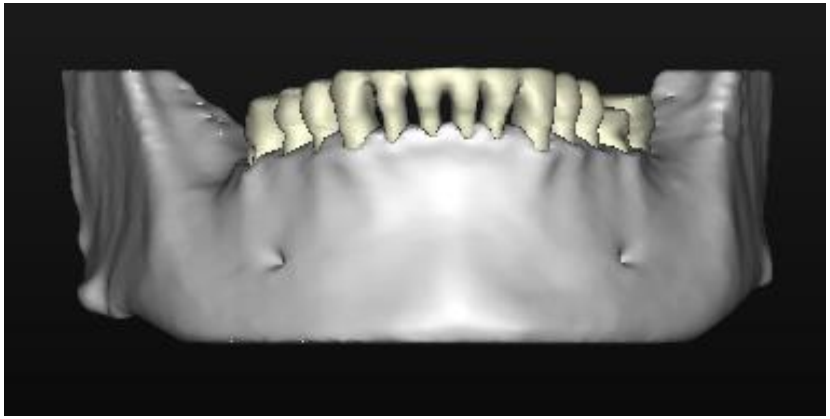
Effective Dose ≈ 18.28 x 3 = 55μSv



Accuitomo 4cm x 4cm:

43µSv from SEDENTEXCT
55µSv from DLP
60µSv from DAP

50µSv ± 20%



i-CAT 16cm x 4cm:

38µSv from Ludlow's meta-analysis

How accurate do we need to be?

- **Only interested in dose because it enables us to estimate the risk.**
- **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.**

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.

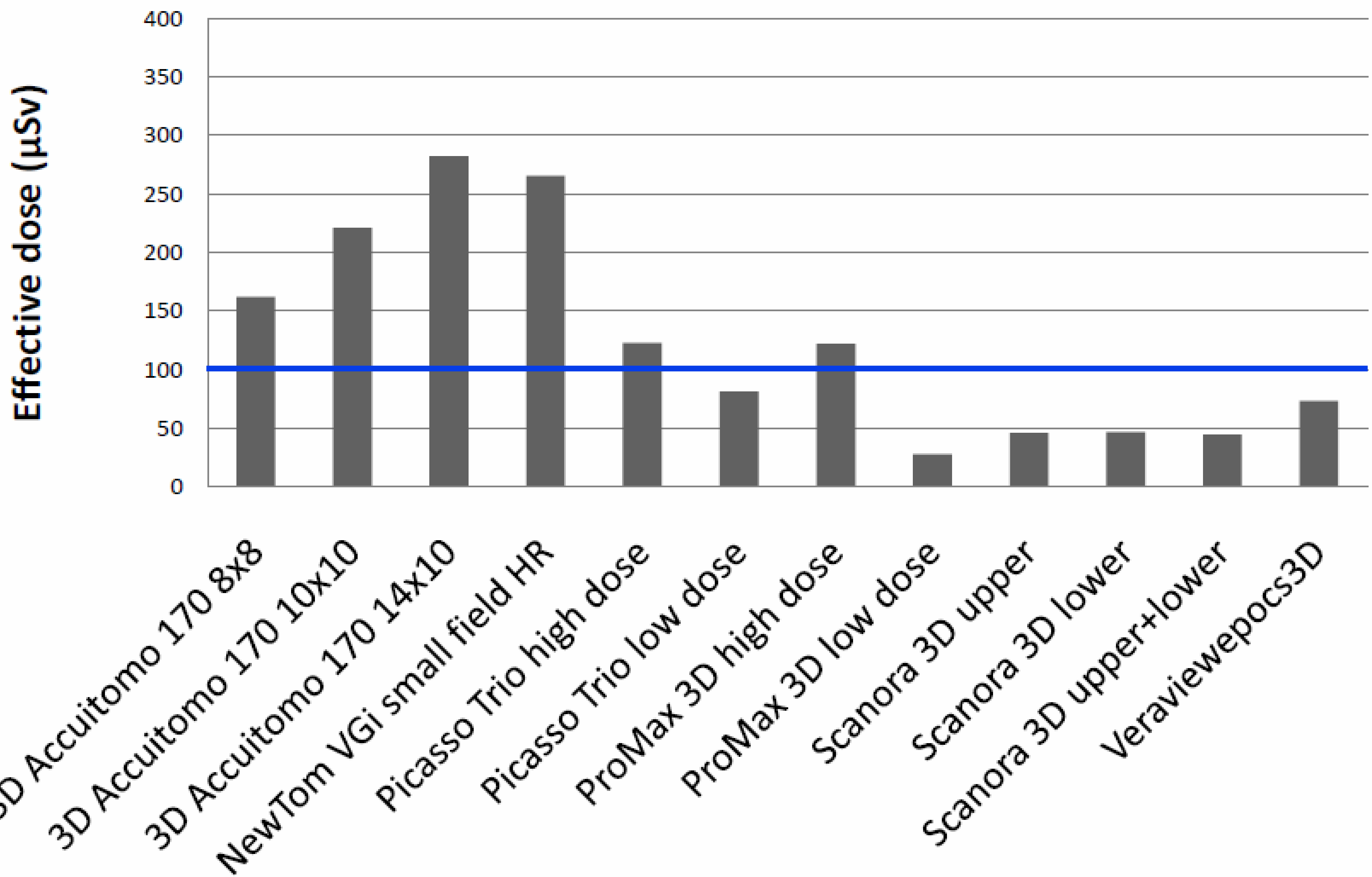
Table 2—*Descriptions of risk in relation to the risk of an individual dying (D) in any one year or developing an adverse response (A)*

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

What is the Risk from a CBCT scan?

- **Assume adult patient, dento-alveolar scan, both jaws**
- **What is a typical dose?**

Effective dose for medium field CBCTs



Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

What is the Risk from a CBCT scan?

- **Assume adult patient, dento-alveolar scan, both jaws**
- **Effective Dose might be 100 microSieverts**
- **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 100 microSv

Health & Safety people would call this a "Minimal Risk"

*** If your patient is a child the risk is 3x more**

Risk varies with Age

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

5.7% per Sievert at age 30

RADIATION PROTECTION N° 172 A report prepared by the SEDENTEXCT project 2011

www.sedentexct.eu

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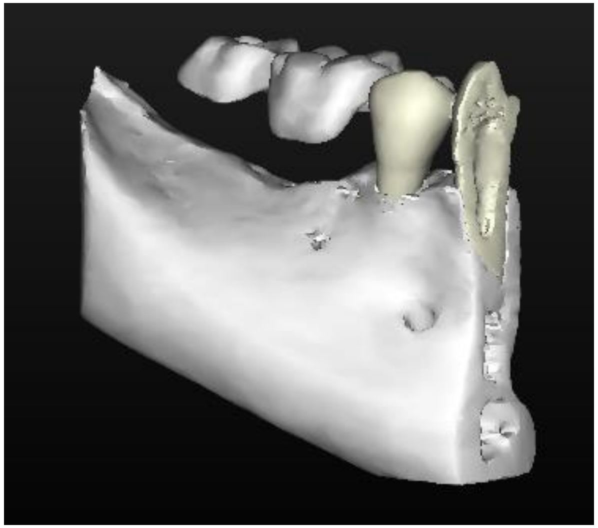
		(A) Vaccination associated polio[10]	1:1 000 000
Negligible	≤1:1 000 000	(D) Hit by lightning[9]	1:10 000 000
		(D) Release of radiation by nuclear power station[9]	1:10 000 000

Fact #3 revisited:

Doses are not getting lower (but scanners are getting cheaper).

Fact #4:



Even if the Effective Dose is a bit high, we are only irradiating a very small region of the body, so that's OK.

How do we know that exposure to radiation results in harm?

Deterministic Effects are reproducible

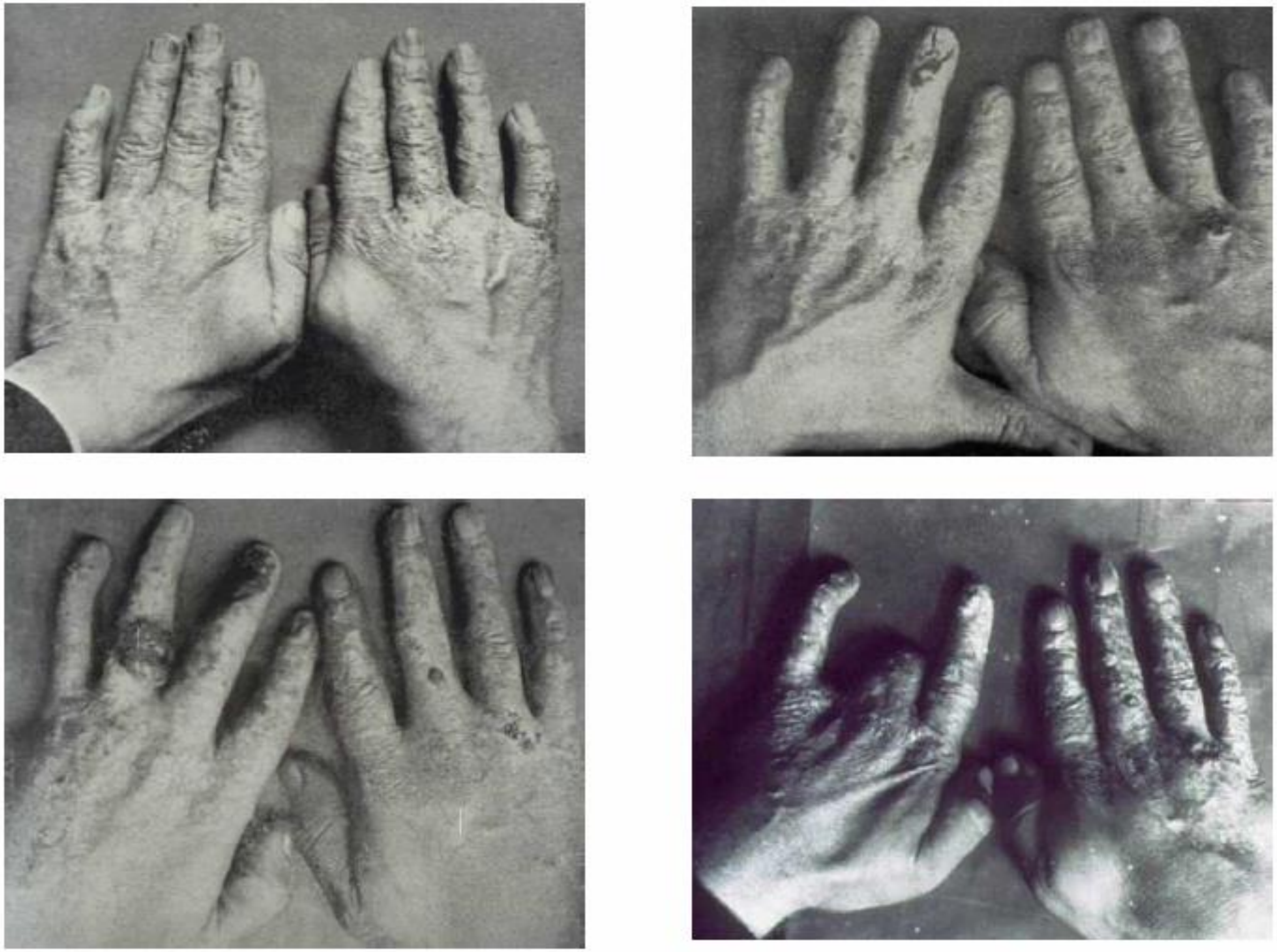
- **severity of the effect increases with the dose**
- **not observed below a threshold dose of about 500mSv**

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**

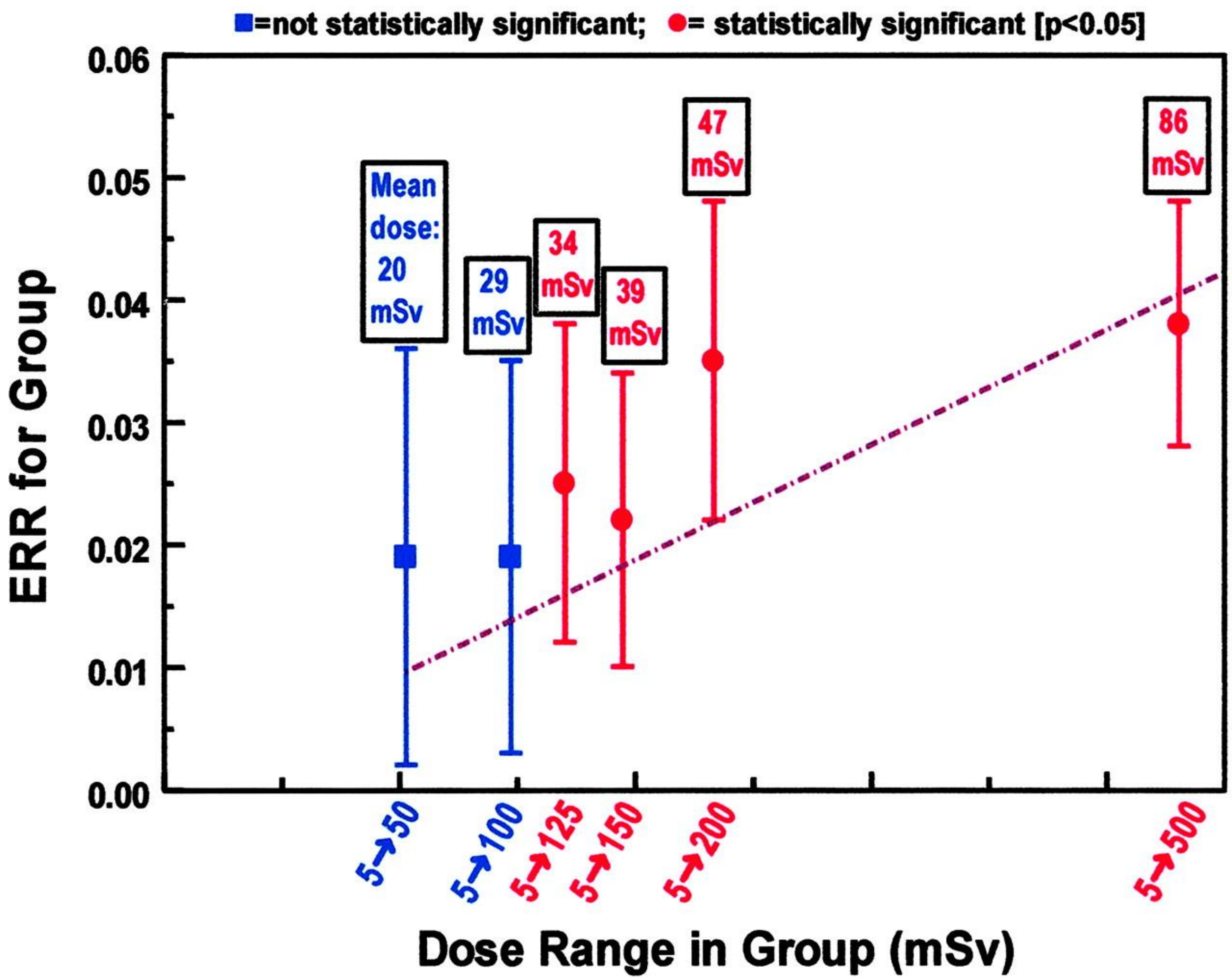
Hereditary Effects are random but the incidence is very low

Dr Mihran Kassabian (1870–1910)



Deterministic Effect

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

PNAS

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**.

The concept of Effective Dose

We know the risks from high doses of radiation

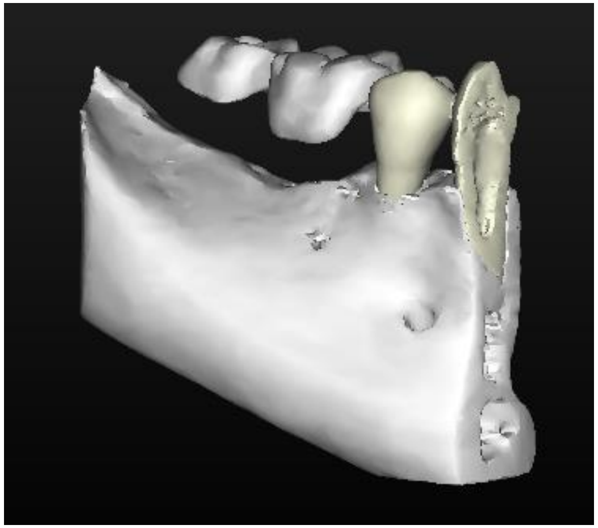
- **e.g. Atom Bomb survivors**

- **Atom Bomb survivors received whole body doses**
- **Dental patients receive doses to a very small region**
- **How can we relate the risks?**

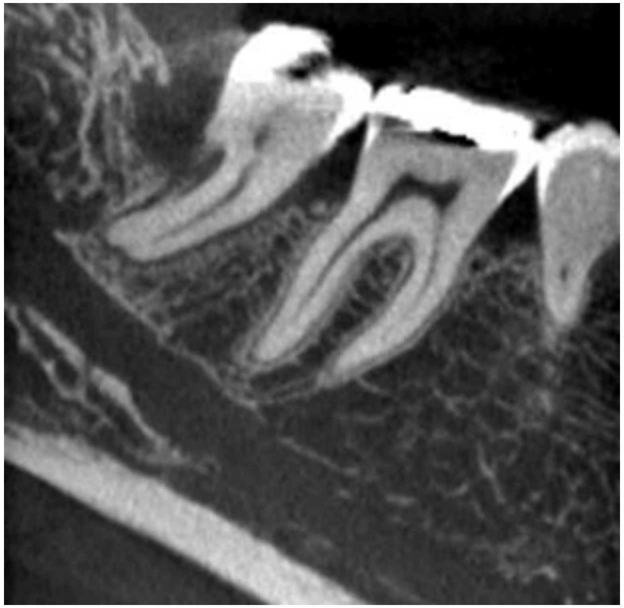
Effective Dose **is a way of describing the dose to a limited region in terms of the whole body dose that would result in the same risk to the patient**

Effective Dose takes the size and the nature of the region into account.

Fact #4 revisited:



The Effective Dose already takes the size of the region (and the organs involved) into account.



0.08mm voxels

Fact #5:

The smaller the voxel size, the higher the dose (this is a basic law of nature).

Image Quality in CBCT scans

- Noise

- *electronic noise (dark current)*
- *photon noise (not enough x-rays)*

- Artefact

- *patient movement*
- *metal objects within the patient*
- *rings (machine calibration, poor operator technique)*

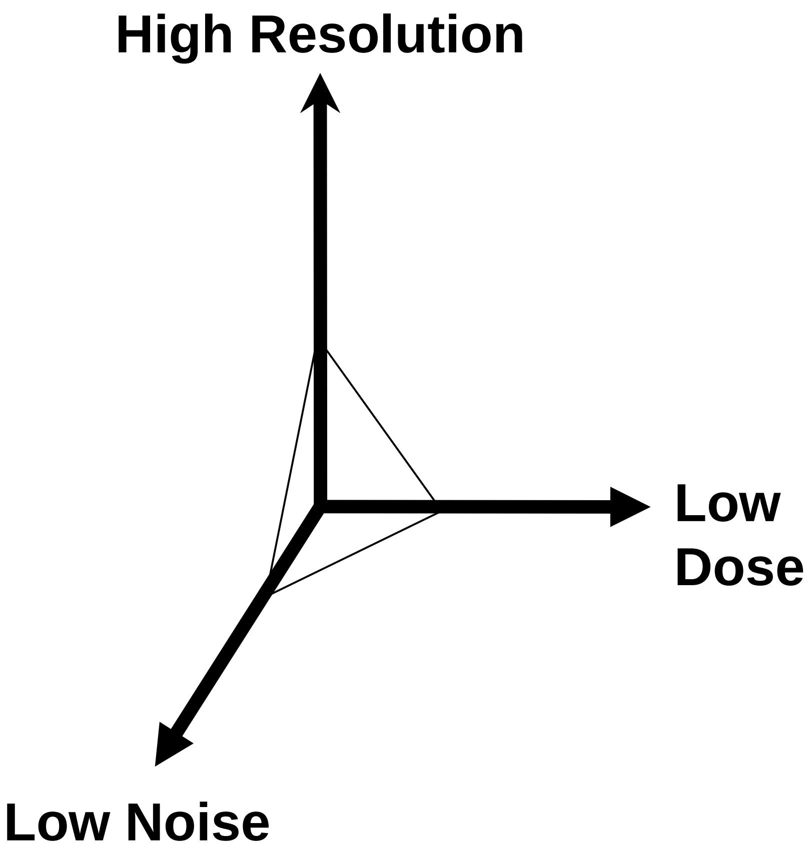
- Spatial Resolution (resolution at high contrast)

- *depends on machine design*
  (focal spot size, detector elements, sampling, mechanical stability)
- *voxel size can only limit the resolution – cannot increase it!*

- Contrast Resolution (resolution at low contrast)

- *depends on machine design (kVp, filtration, reconstruction algorithms)*

The impossible dream



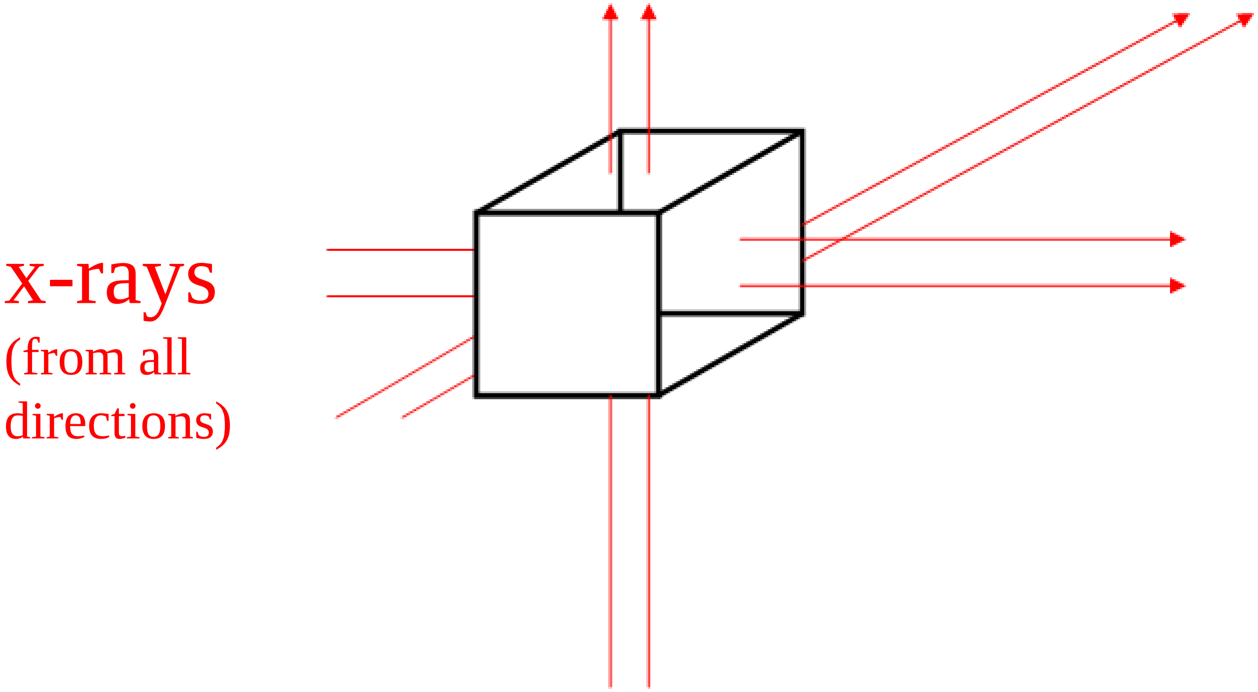
A good scanner will offer a range of voxel sizes, mAs and field sizes to suit the imaging task at hand.

Noise in CT / CBCT images

Noise = unstructured contribution to the image which has no counterpart in the object.

- **Electronic noise (dark current)**
  - **Calibrating the scanner will reduce this**
- **Photon noise (not enough x-rays)**
  - **Signal-to-Noise Ratio is proportional to $\sqrt{n}$**
  - **Where n is the number of x-ray photons**

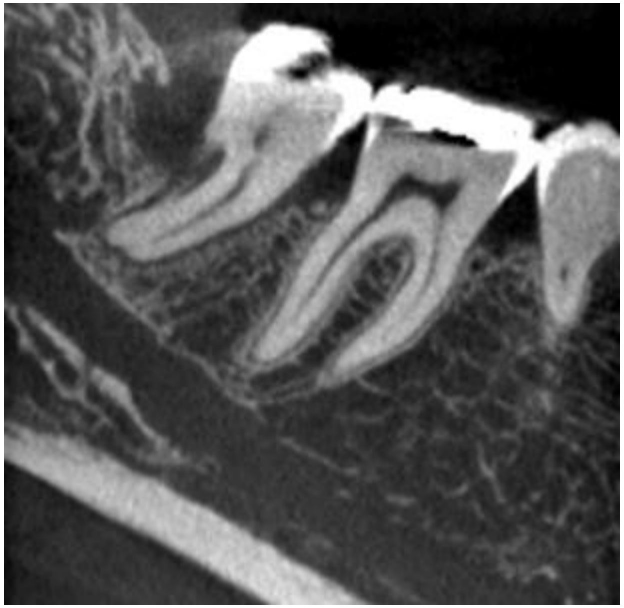
Noise depends on voxel size



If you halve (1/2) each side of a cube e.g. from 0.4mm to 0.2mm
Number of x-ray photons passing through it goes down by 8 (i.e. 1/8)
Noise goes up by $\sqrt{8}$ = 2.83
mAs (dose) may have to be increased to compensate

Dose does not depend directly on Voxel Size

- **The noise depends on the voxel size**
- **On some machines (i-CAT Classic, Accuitomo F170) the operator may choose to increase the dose to compensate for a smaller voxel size**
- **On other machines (i-CAT 17-19 and CB-500) the machine automatically increases the dose for a smaller voxel size.**

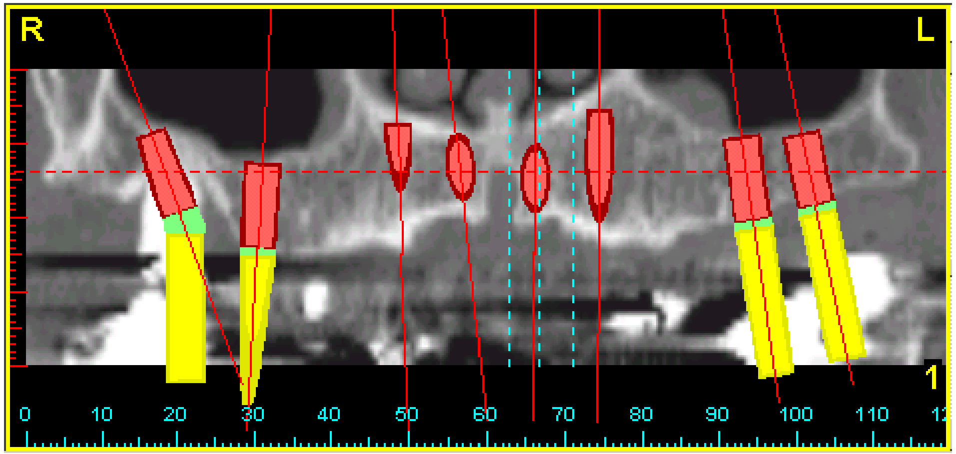


0.08mm voxels
50µSv

Fact #5 revisited:

The smaller the voxel size, the higher the noise.
Increasing the dose is a choice made by the operator (or the manufacturer).

Fact #6:

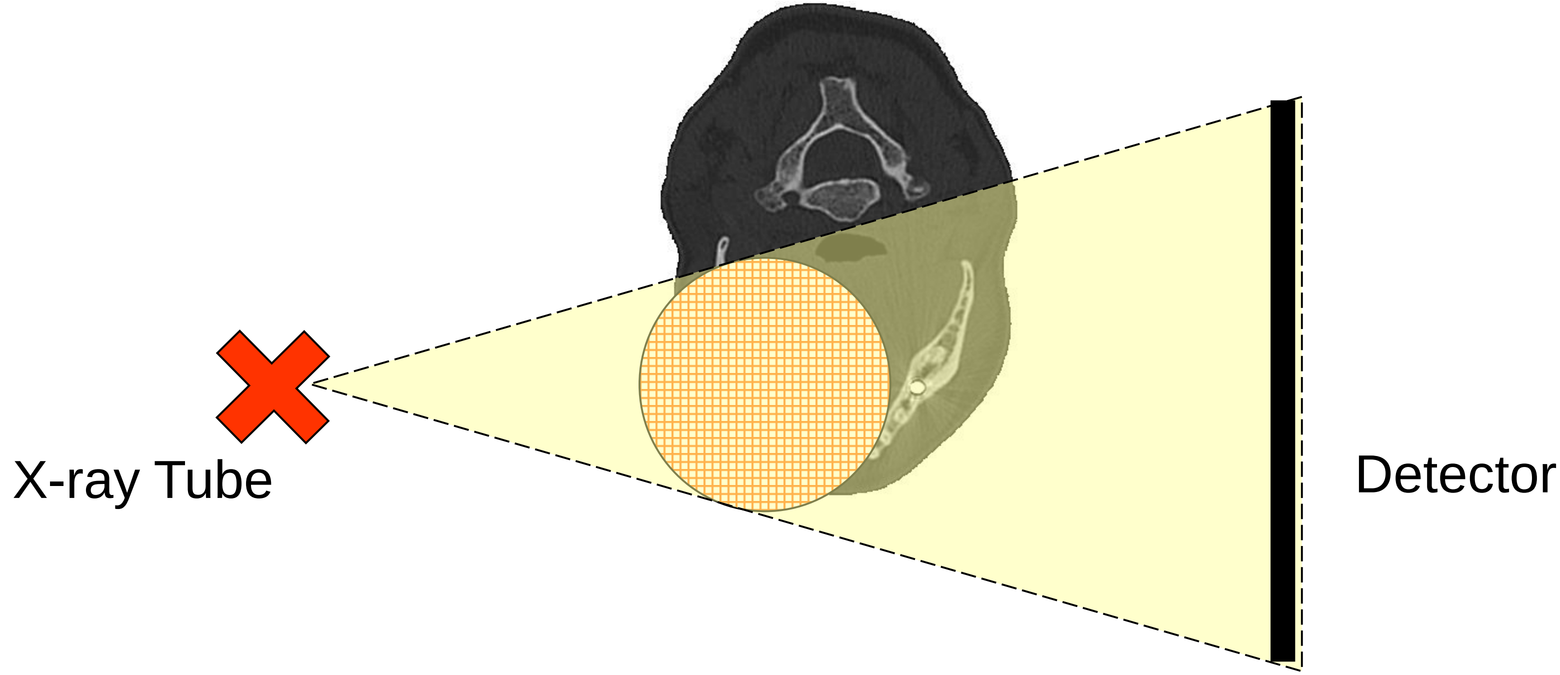


The pixel values in a CBCT scan are an accurate representation of the tissue densities.

Three reasons why CBCT pixel values don't lie on the Hounsfield scale:

- **The Hounsfield Scale is defined at 120kVp, but most CBCT scanners run at 80-90kVp**
- **The x-ray spectrum contains more low energy photons because of scattered radiation**
- **The voxel densities cannot be calculated accurately!**

Fundamental Limitation of Small Field Of View



- **CBCT measures the density within the Field Of View only**
- **Material outside the Field Of View has an unpredictable effect**
- **Software corrections means pixels may change with updates**

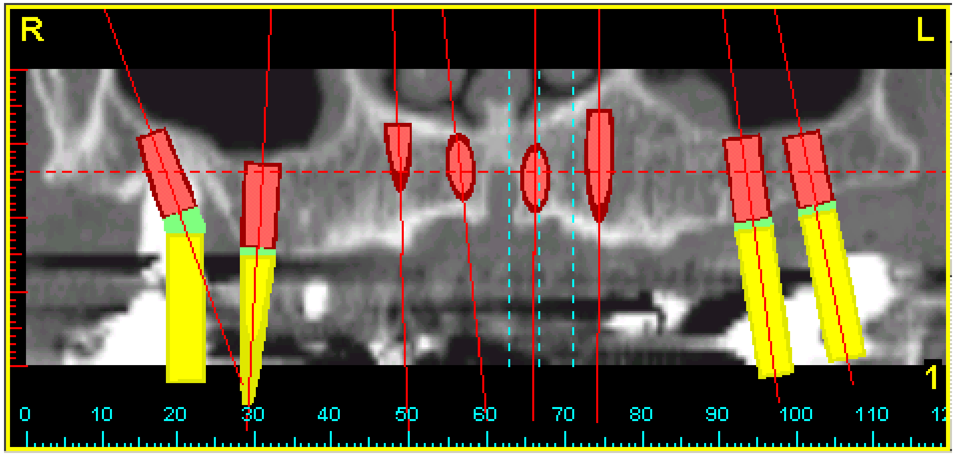
4cm x 4cm

6cm x 4cm

8cm x 5cm

10cm x 6cm

Fact #6 revisited:



The smaller the Field Of View, the less reliable the pixel values are.

Fact #7:

Medical CT scanners deliver a much higher dose than dental CBCT scanners.

The Best CBCT Scanner on the Market

Toshiba Aquilion ONE medical CT Scanner

320 detector rows

operates in cone beam mode

0.5s scan time

volume capture
24cm x 16cm max

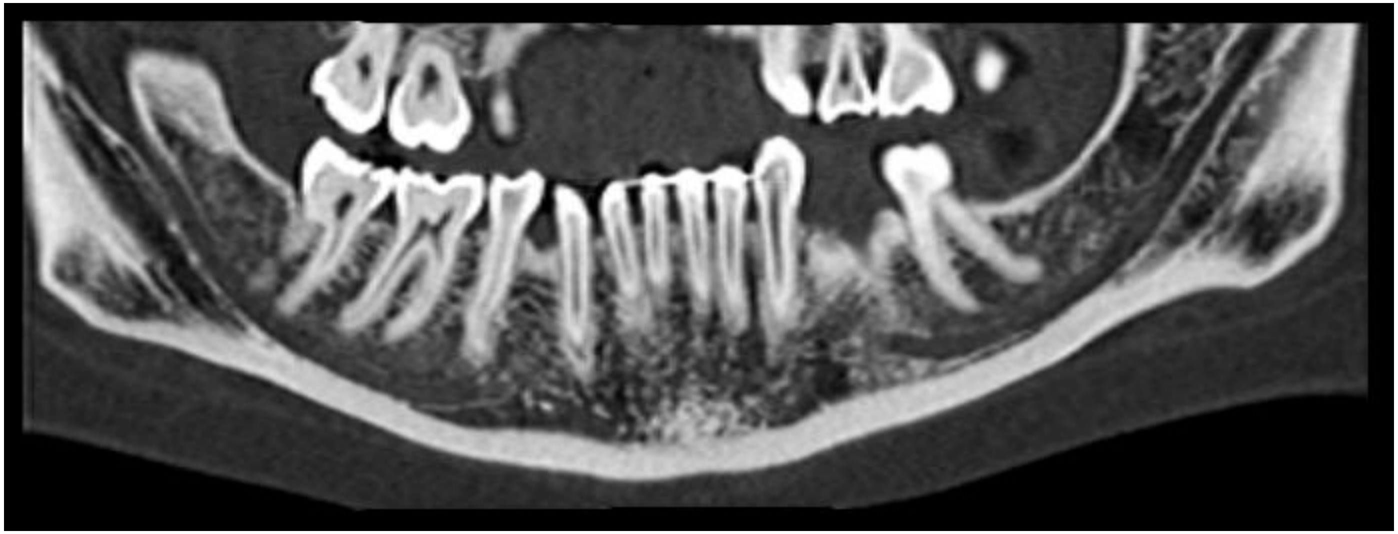
Effective Doses
typical Mx 100μSv
typical Mn 150μSv

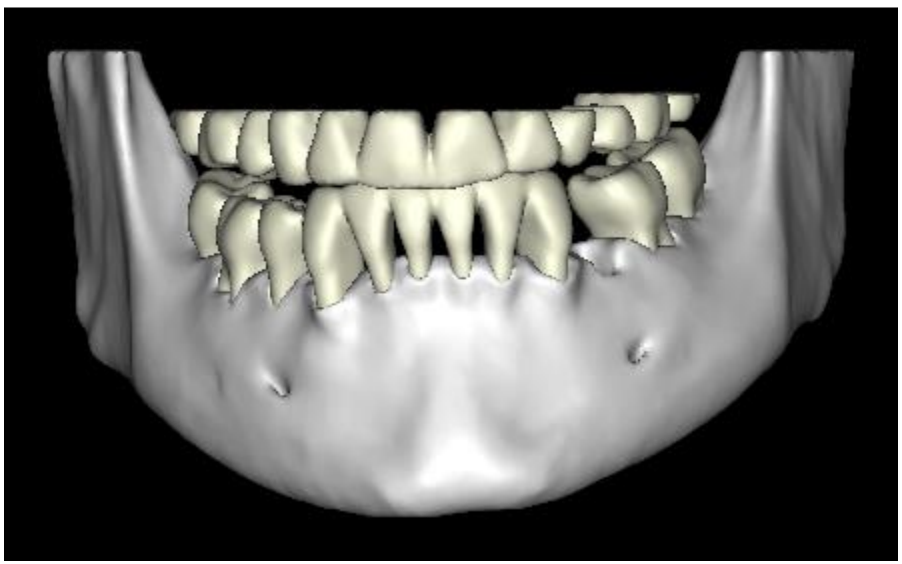
Around £1M

Aquilion™ is a trademark of Toshiba Medical Systems Corporation

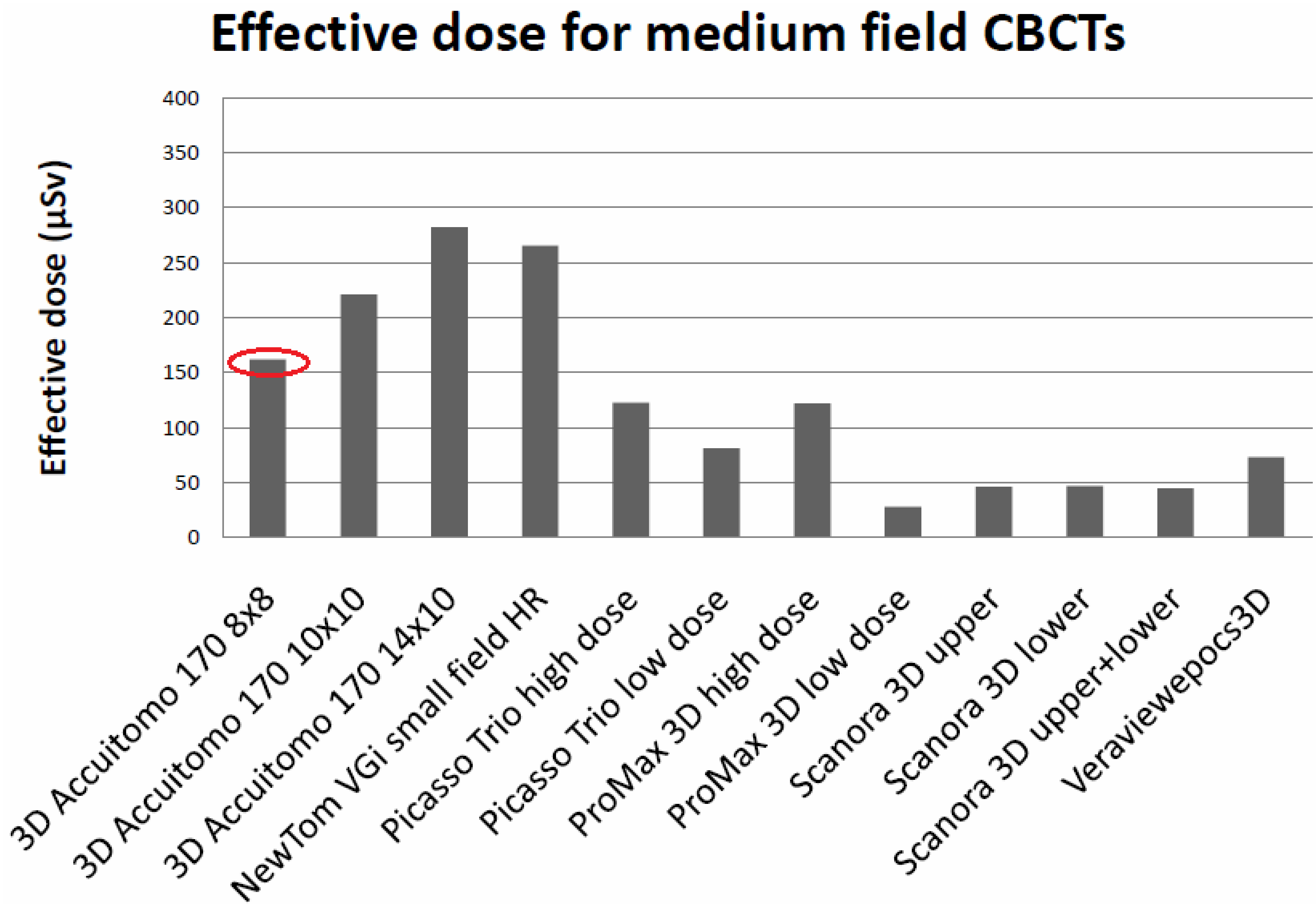
Dental Protocols on medical CT Scanners

- **Operator has more control over kVp, mAs, pitch than on a dental CBCT scanner.**
- **The dentoalveolar region has high natural contrast, so we can get away with a low radiation dose.**
- **Figures quoted in the literature (e.g. 2100μSv) are for brain scans, not for dental CT scans**
- **Training is required to help operators choose a low dose protocol for dental CT scans.**





Toshiba Aquilion ONE
12cm x 6cm
0.25mm voxels
DLP 54mGy.cm
Effective Dose 150µSv approx.



Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

	Toshiba Aquilion ONE	Siemens Definition AS	GE LIghtSpeed VCT	Siemens Sensation 64	Philips Brilliance 64	Toshiba Aquilion 64	Siemens Emotion 6
Min E.D.	70	100	150	150	160	111	145
Avg E.D.	**124**	**276**	**370**	**310**	**346**	**416**	**343**
Max E.D.	200	550	750	475	630	880	650
n=	**28**	**46**	**351**	**36**	**70**	**129**	**35**

Table 2B. Effective Doses (μSv) estimated from DLP*

***conversion factors from Shrimpton PC et al. Effective dose and dose-length product in CT.**
***Radiology* 2009; 250; 604-605.**

Review

E.A.O. guidelines for the use of diagnostic imaging in implant dentistry 2011. A consensus workshop organized by the European Association for Osseointegration at the Medical University of Warsaw

David Harris[1,*], Keith Horner[2], Kerstin Gröndahl[3], Reinhilde Jacobs[4], Ebba Helmrot[3], Goran I. Benic[5], Michael M. Bornstein[6], Andrew Dawood[7] and Marc Quirynen[8]

Article first published online: 20 MAR 2012

DOI: 10.1111/j.1600-0501.2012.02441.x

Issue

Clinical Oral Implants Research

Volume 23, Issue 11, pages 1243–1253, November 2012

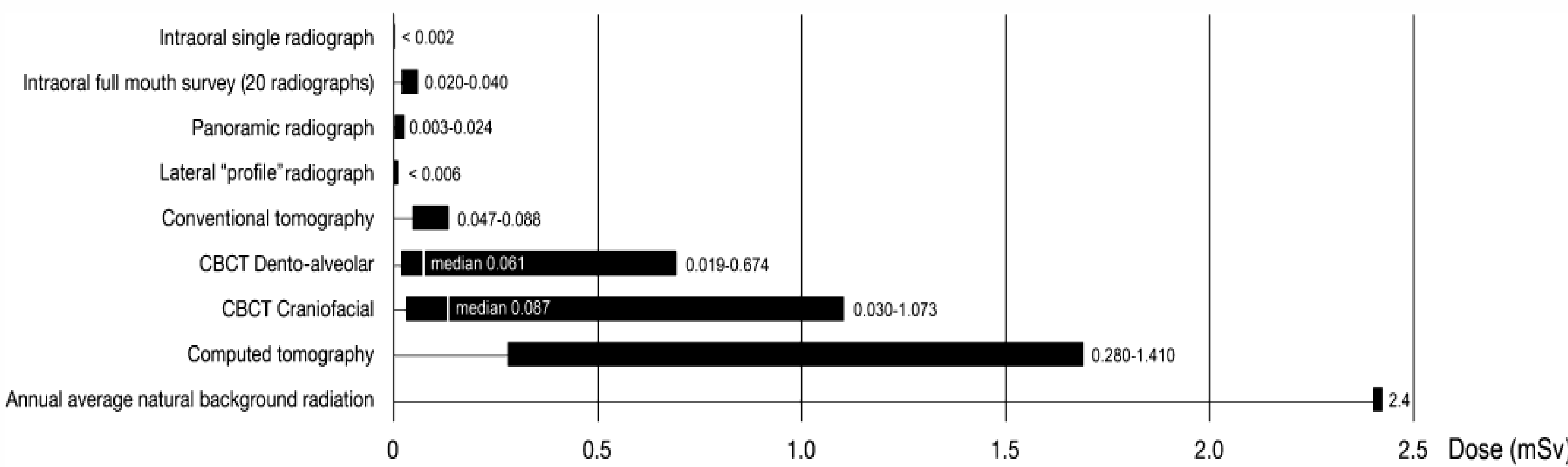


Fig. 1. Ranges of effective dose for the imaging modalities used in implant dentistry.

Fact #7 revisited:

The dose depends on the protocol, for both medical CT and dental CBCT.