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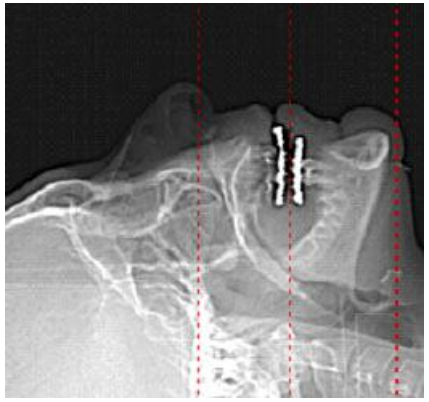
# *How to estimate the dose from a dental CT or CBCT scan*

**Anthony Reynolds**

**IDT Ireland**

**(we sell and maintain CBCT scanners)**

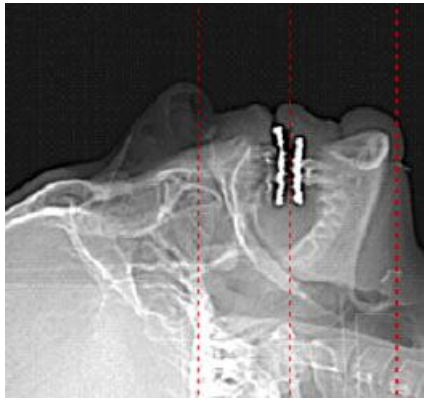
# *Dental (CB)CT Scans*



- **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**

# *Rationale for Work*

**Clinicians want to know the ~~dose~~ risk (today)**

**It is better to have an answer that is roughly right than very precisely wrong**

**It is not good to have no answer at all.**

# *Outline of Talk*

**Main Topic:**

- **How can we calculate doses quickly with sufficient accuracy for the task at hand?**

**Underlying Topics:**

- **Why do we care about radiation dose?**
- **How accurate do we need to be?**
- **What can we do if we only have limited information?**

# 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

**ICRP 103:**

**“Justification”**

“The process of determining whether … a planned activity involving radiation is, overall, beneficial, i.e. whether the benefits to individuals and to society from introducing or continuing the activity outweigh the harm (including radiation detriment) resulting from the activity …”

**Practitioners have a duty to ensure that the benefits of an exposure outweigh the risks.**

**ICRP 103:**

**“the combined detriment due to excess cancer and heritable effects remains unchanged at around 5% per Sv”**

***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 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!***

# *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

# *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.**

# 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 do we mean by "the right answer"?*

**a) Use ImPACT Spreadsheet to calculate Effective Doses**

**b) Use Monte Carlo methods to calculate Effective Doses**

**c) Use TLD measurements in a Rando phantom to calculate Effective Doses.**

Effective Dose (E)

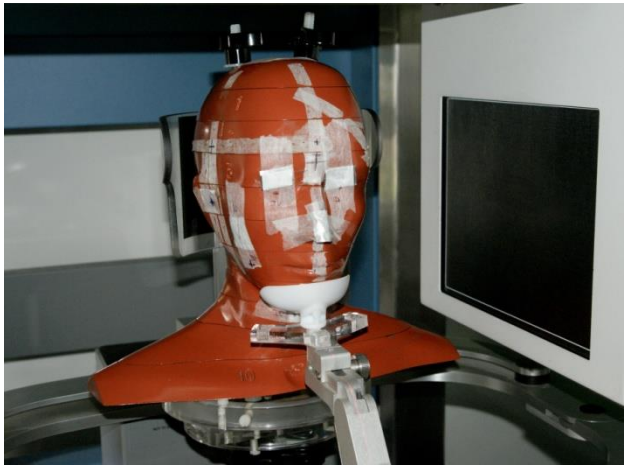
$$E = \sum_T H_T w_T$$

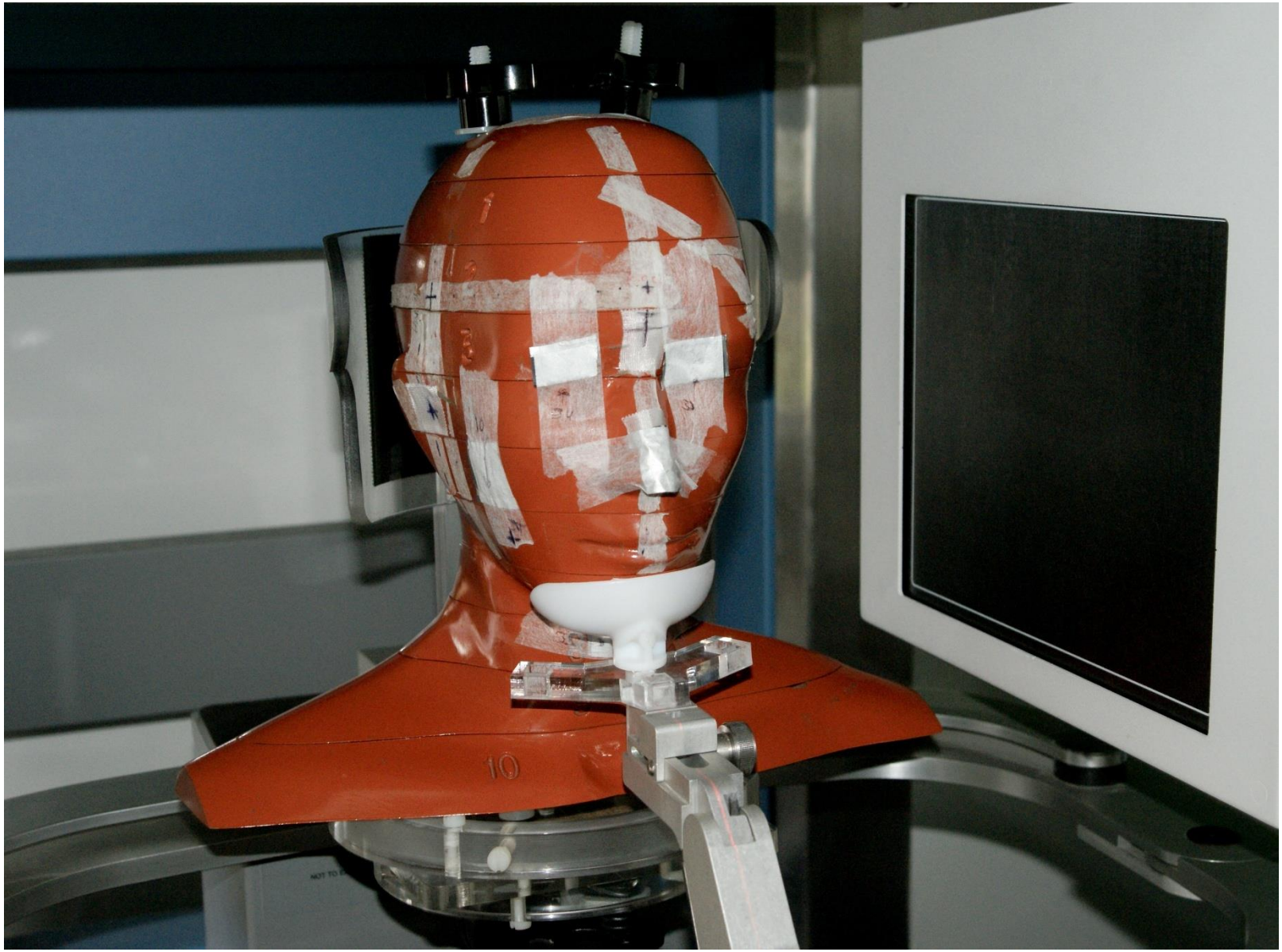
$H_T$ = Organ Equivalent Dose
$w_T$ = Tissue weighting factor

**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 |




10

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# 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]

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[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
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[f] Department of Radiology, University Hospital Gasthuisberg, Leuven, Belgium
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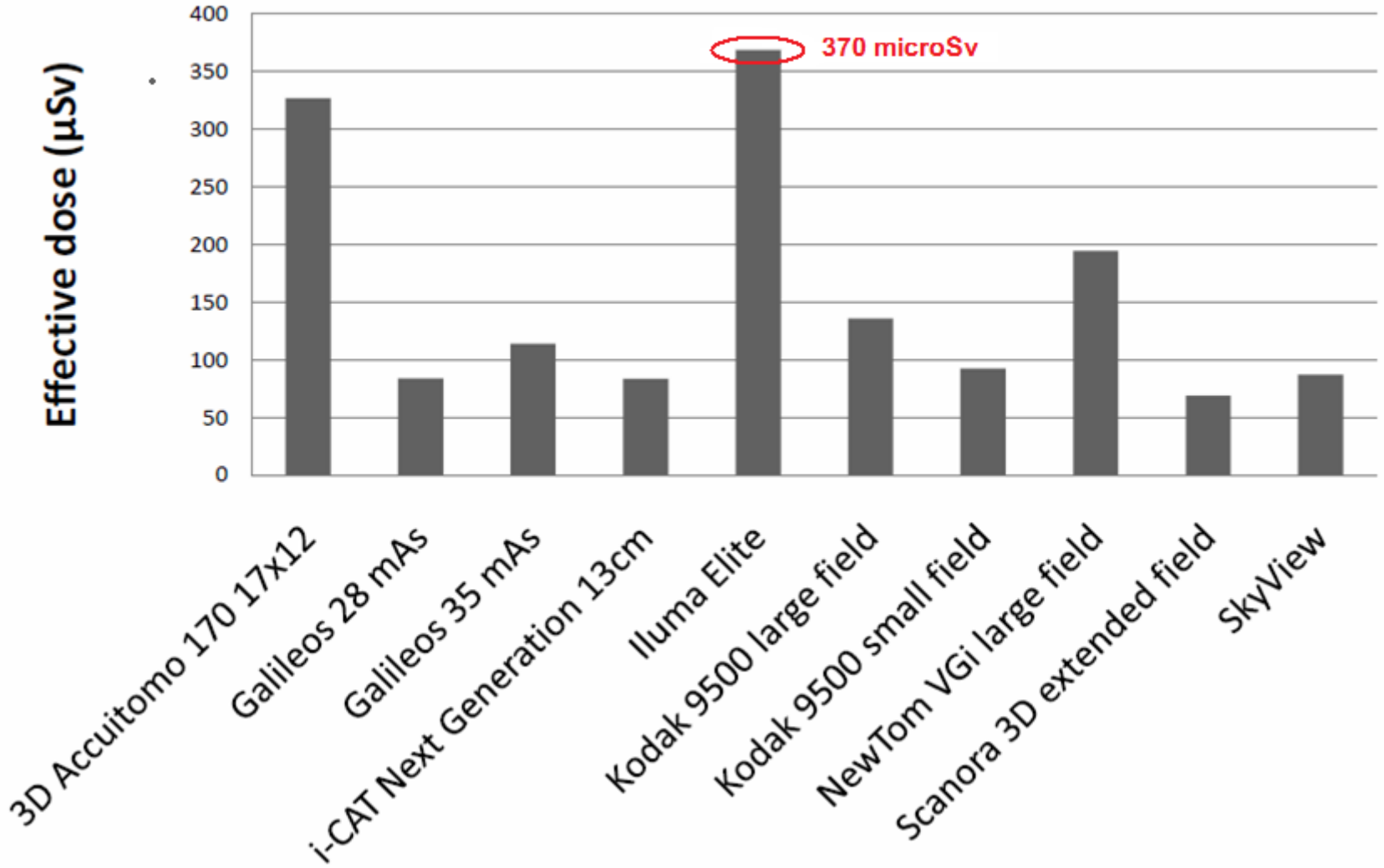
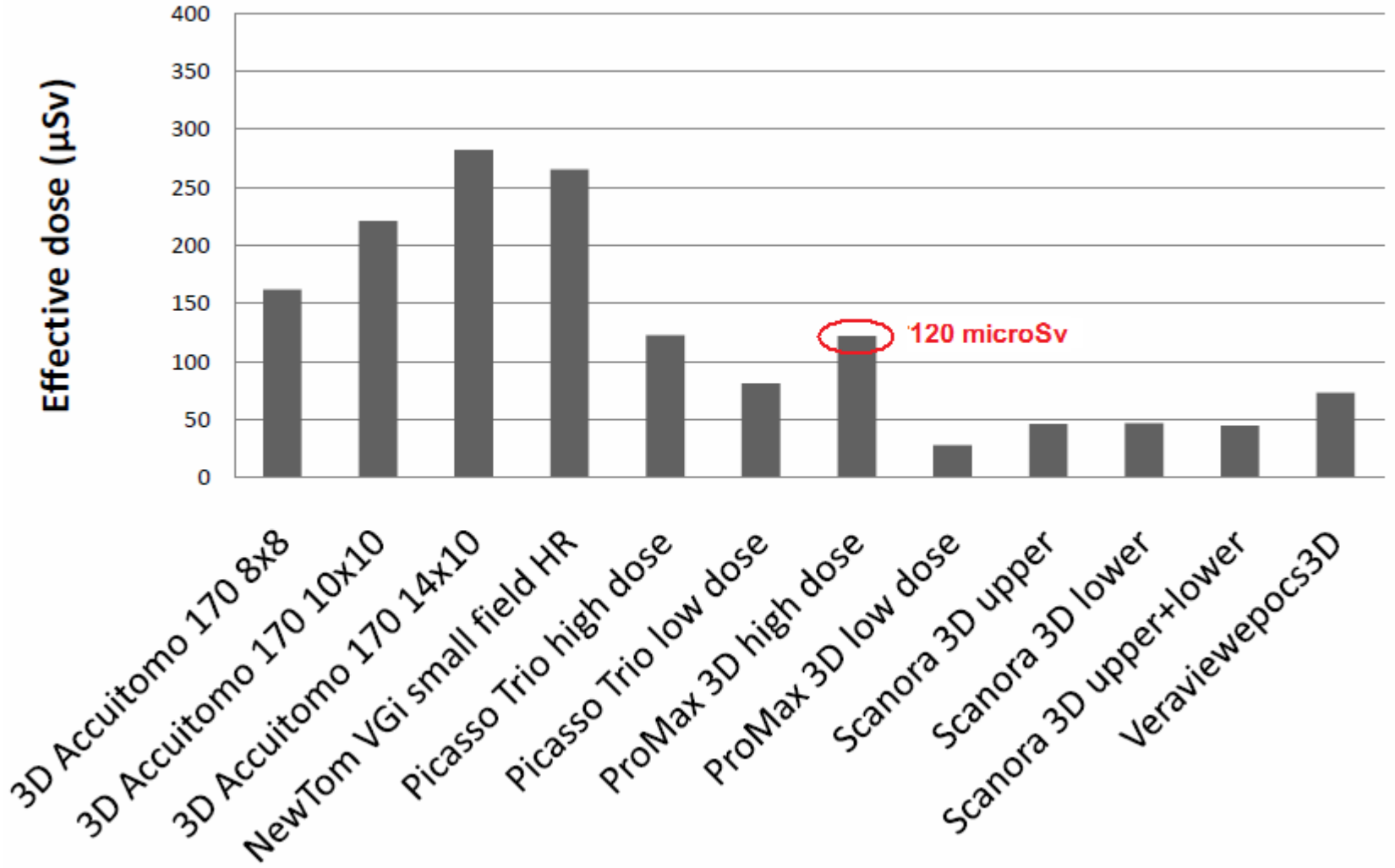
**Eur J Radiol 81,2,267-271 (February 2012)**

# Effective dose for large field CBCTs



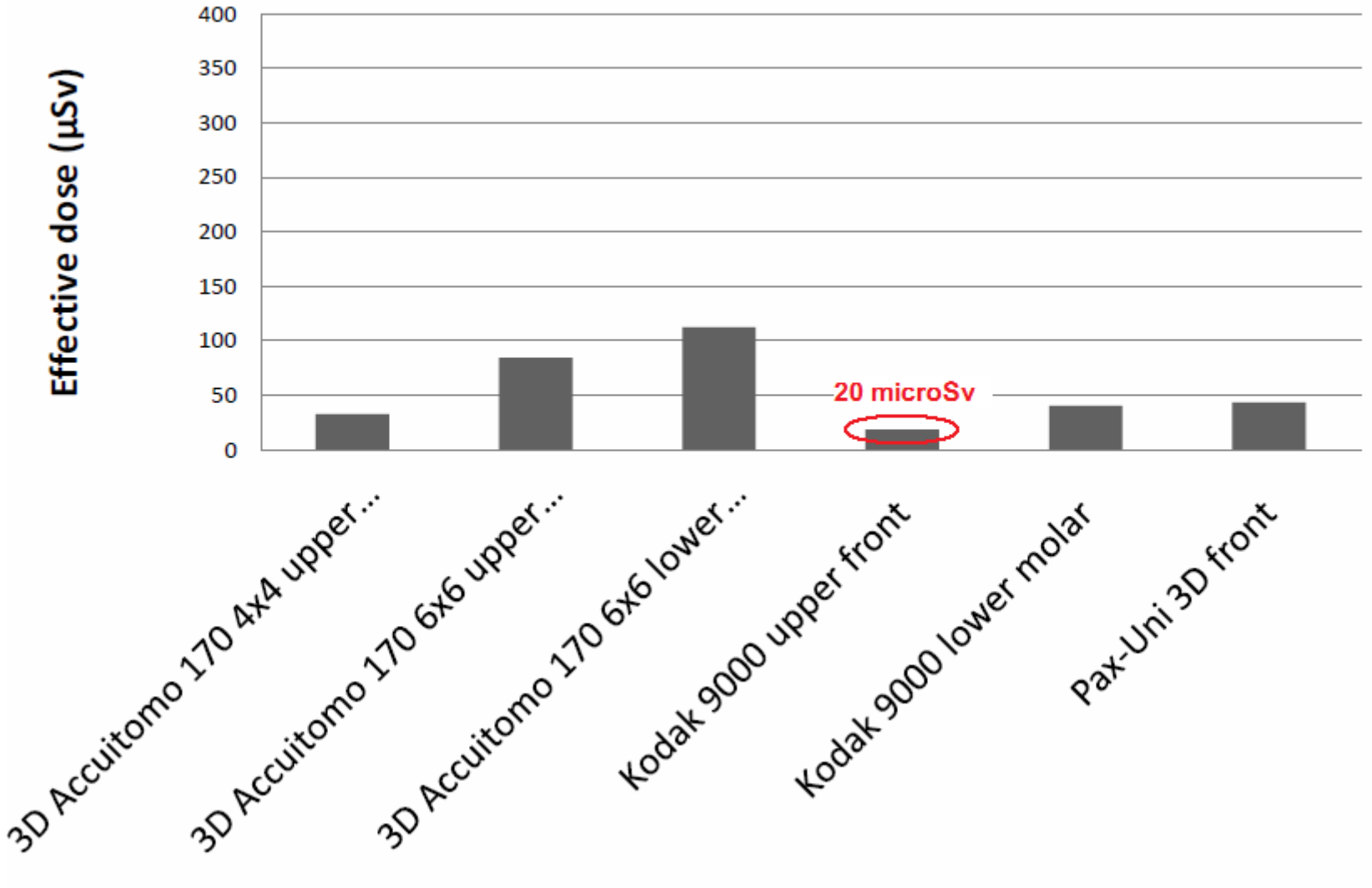

Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

# Effective dose for medium field CBCTs




Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

# Effective dose for small field CBCTs




Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

# *Estimating the Effective Dose from CT and CBCT scans*

**We can't measure the Effective Dose for every patient**

**The SEDENTEXCT report doesn't cover every situation**

**so**

**Use the DLP (if known)**

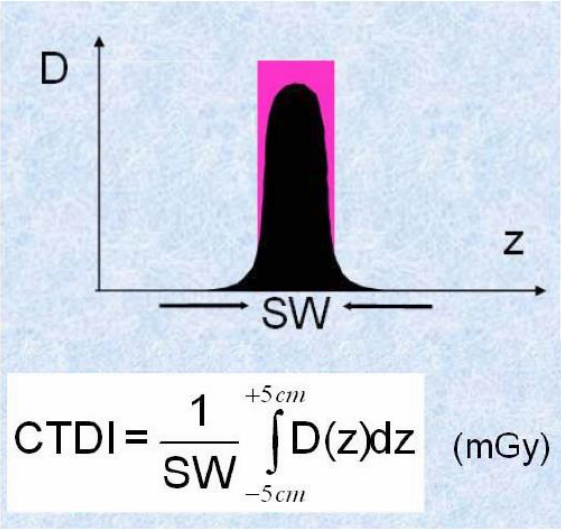
**or**

**Use the DAP (?accuracy)**

# *Dose Length Product (DLP)*

**DLP = $CTDI_{vol}$ x Irradiated Length**

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




- **tables for F have been published**
- **works well for medical CT (± 40%)**

# 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 |

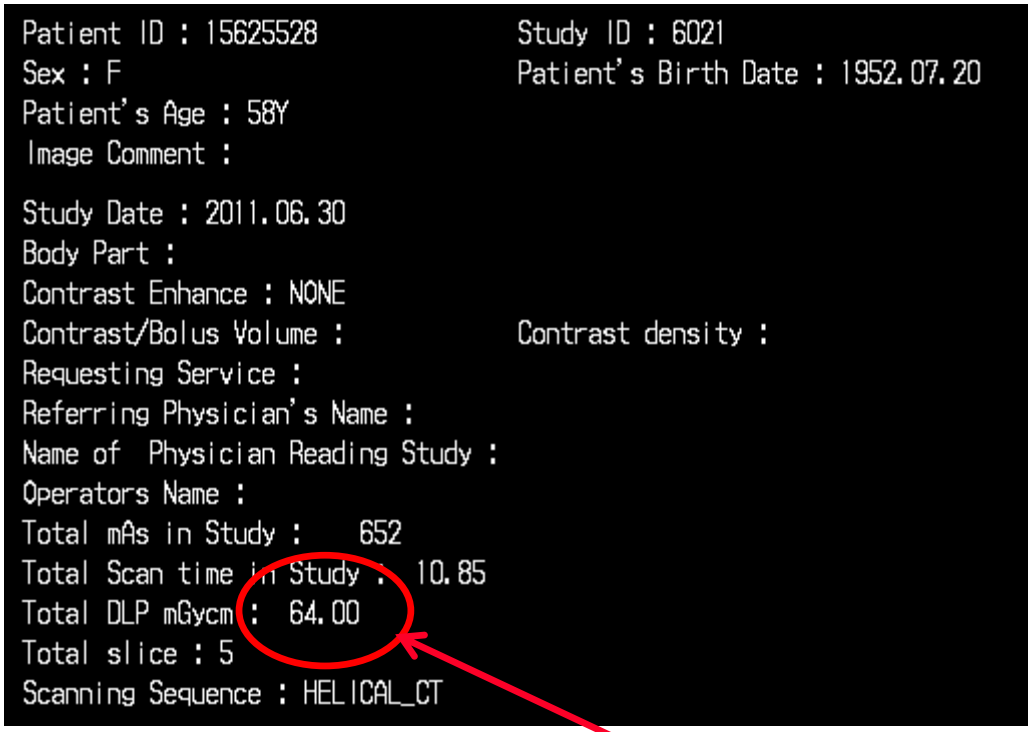
**Table from "Radiation Exposure in Computed Tomography" edited by Hans Dieter Nagel**
**F can also by calculated from ImPACT CTDosimetry calculator** www.impactscan.org

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

**2 µSv** **3 µSv**

**Accuracy: ±40%**

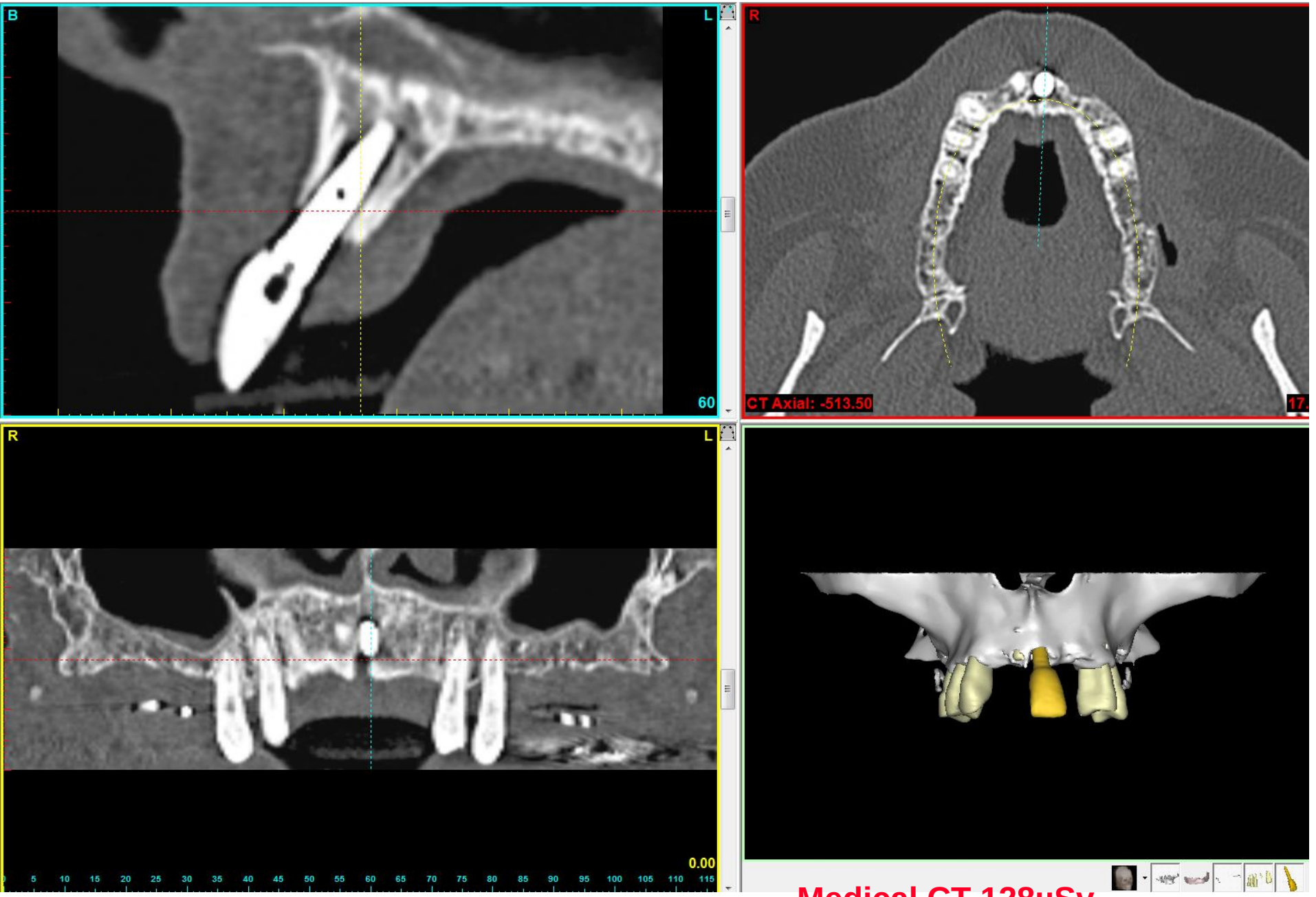
# *Effective Dose for Medical CT Scanners*




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

**Accuracy: ±40%**

**Mx 128µSv** ROUGHLY

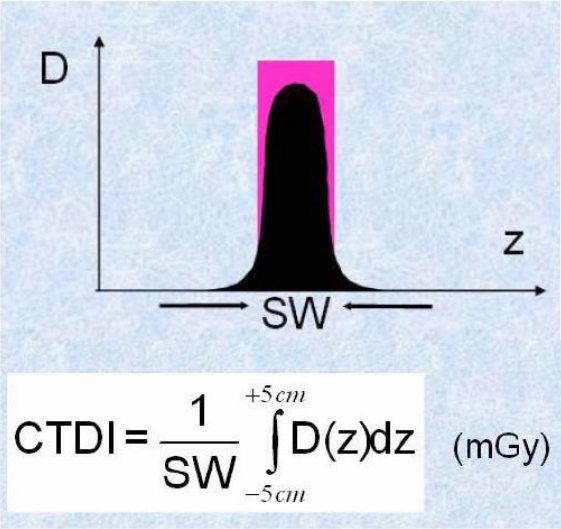



Medical CT 128μSv

# *Dose Length Product (DLP)*

**DLP = $CTDI_{vol}$ x Irradiated Length**

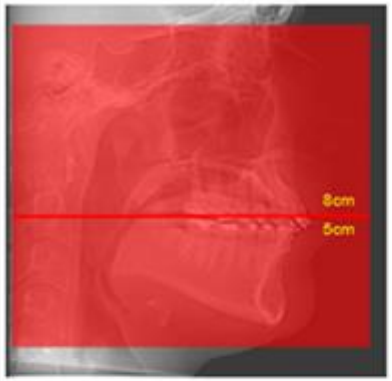
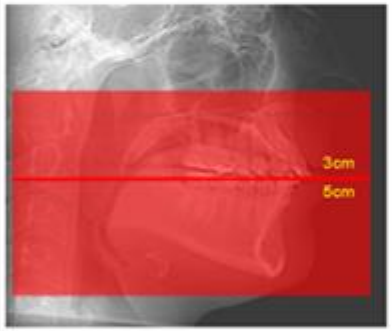
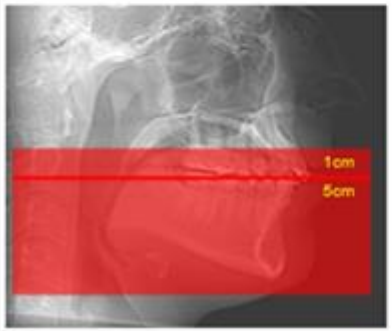
**Effective Dose = DLP x F (where F is a conversion factor)**




- **most CBCT manufacturers don't display $CTDI_{vol}$ (exception: J.Morita, NewTom)**
- **$CTDI_{vol}$ = <u>Effective Dose</u>**
  **F x Irradiated Length**
- **Can use $CTDI_{vol}$ to interpolate published data**

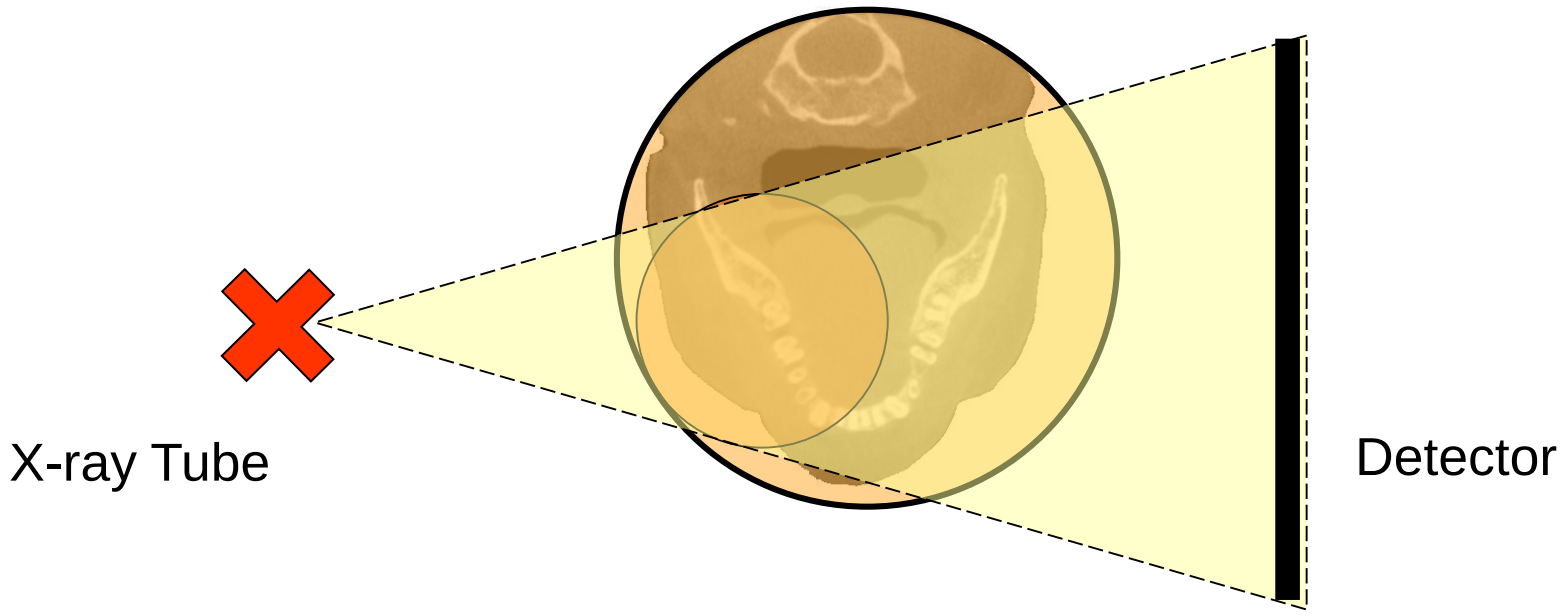
# *CBCT Scanners:*

# *Effect of Reducing Beam Height*

| | |
|---|---|
|  | **Full face**<br>**13cm height x 16cm diameter**<br>**83 microSieverts** |
|  | **Both arches**<br>**8cm height x 16cm diameter**<br>**56 microSieverts** |
|  | **Mandible**<br>**6cm height x 16cm diameter**<br>**45 microSieverts** |

**Effective Dose is (roughly) proportional to the DLP**

# *Effect of Reducing Beam Width*




- **Local Dose outside the imaged region is not zero**
- **Not clear that the Effective Dose is proportional to the DAP**

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

PLEASE AVOID SCANNING THE SPINE

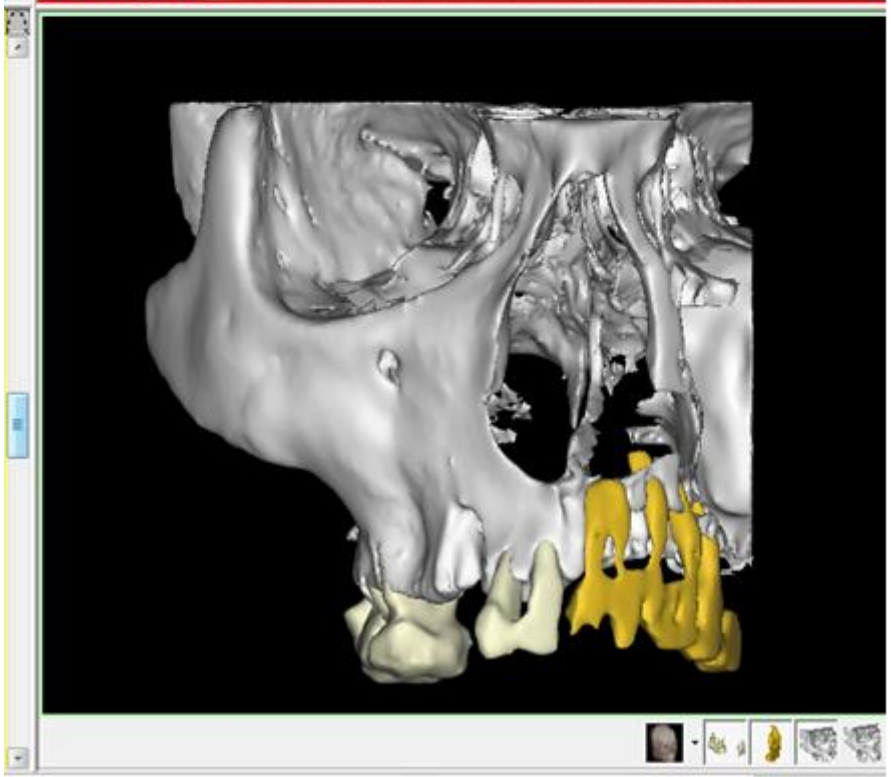
*"Sorry mate – no can do!"*

# *What Dentists Believe:*

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

2. **If the Field Of View is small then the dose must be low**
   **Effective Dose on a 4cm x 6cm can be up to 150µSv**

3. **If I can't see it in the images I don't have to report on it**
   **TRUE**

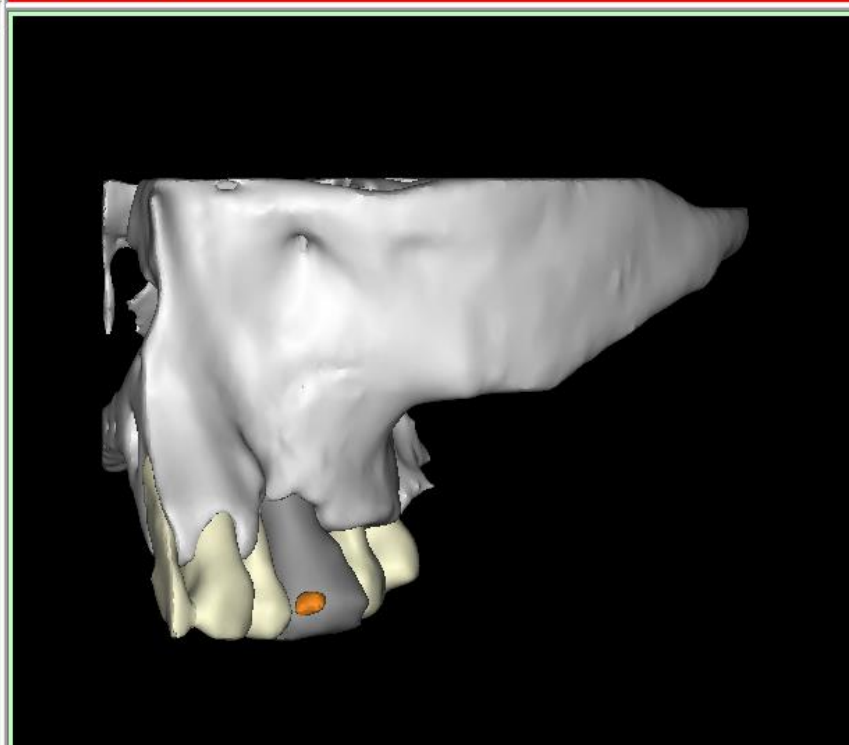



***Moving the patient to the side (without reducing the Field Of View) does not reduce the dose***


B
L
31


R
CT Axial: -27.38


R
L



# 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


Gothenburg 2010

***Can we use DAP to estimate Effective Dose?***

**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 cm$^2$)* | *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 !**

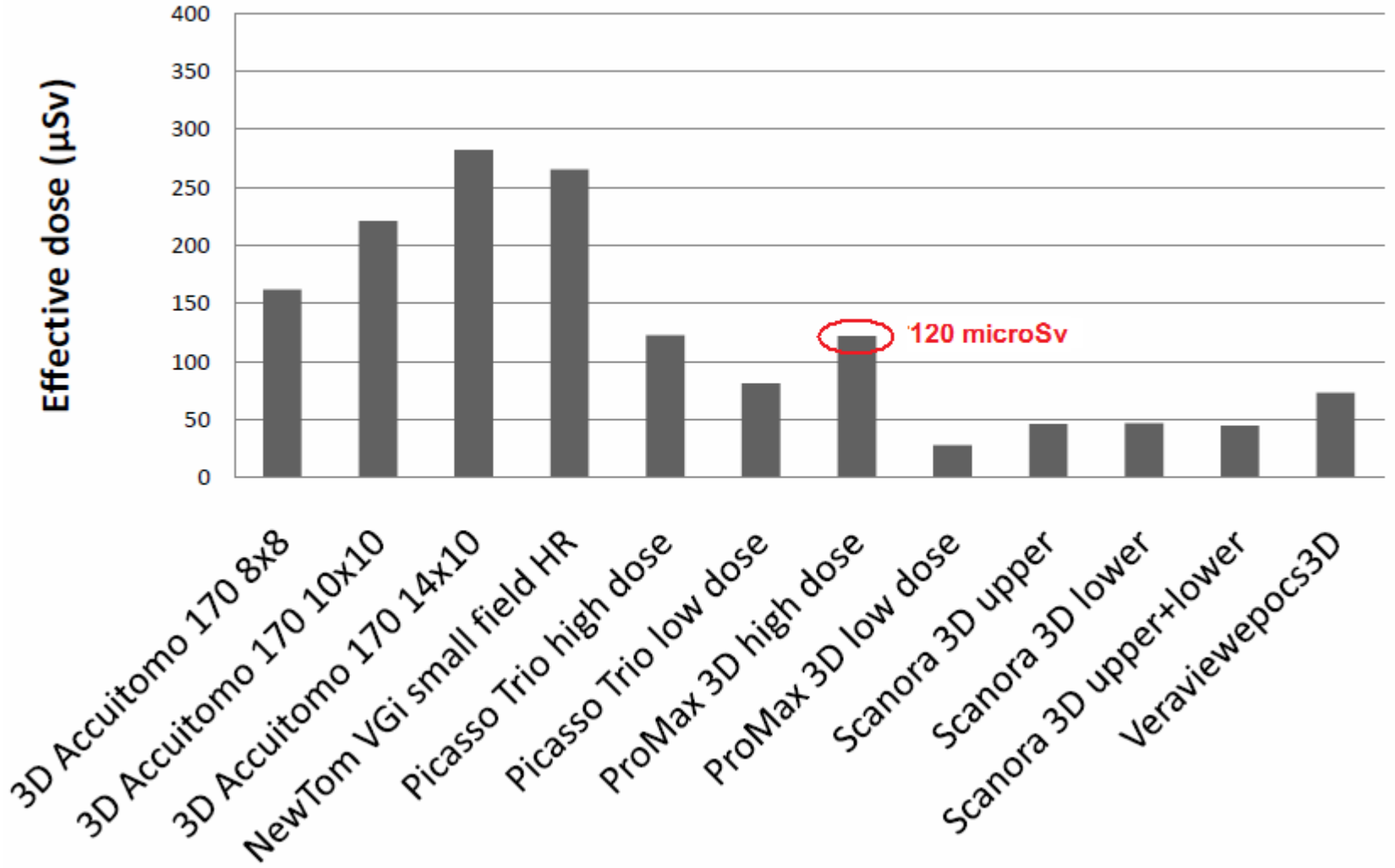
# *Effective Dose Calculator*

## *Examples:*

**Kodak/Carestream 9000 3D**

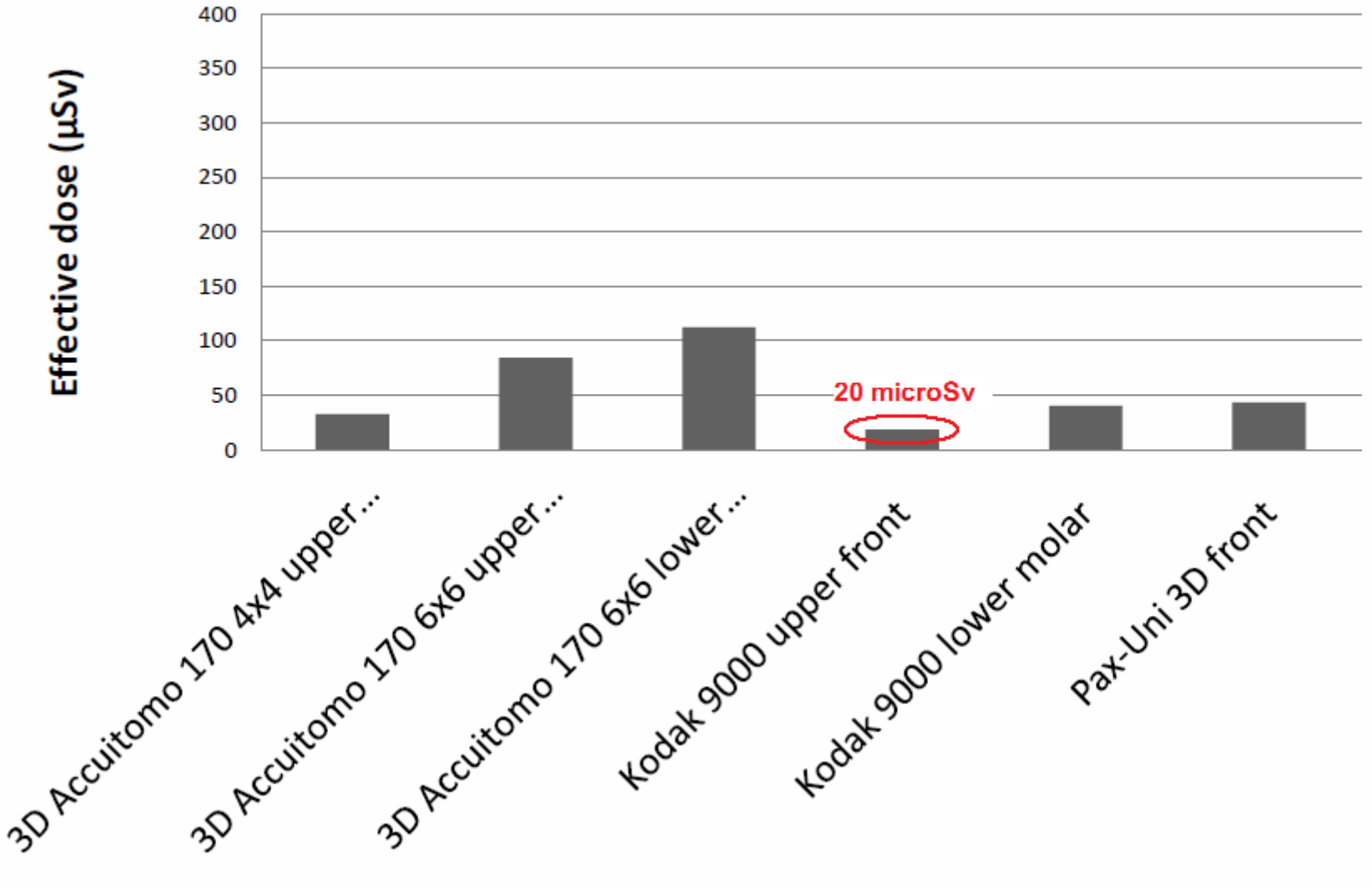
**Planmeca ProMax 3D**

# Effective dose for medium field CBCTs




Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

# Effective dose for small field CBCTs




Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

# *DICOM headers for similar scans:*

**CareStream 9000 3D**

- **kV: 70**
- **mA: 10**
- **ExpTime: 10.8s**
- **Diameter: 51.7mm**
- **Height: 35.8mm**
- **Voxel: 0.08mm**
- **DAP: 217.7mGy.cm$^2$**
- **Dose: 20 µSV**

**Planmeca ProMax 3D:**

- **kV: 84**
- **mA: 14**
- **ExpTime: 12.2s**
- **Diameter: 80.0mm**
- **Height: 80.0mm**
- **Voxel: 0.32mm**
- **DAP: 1170mGy.cm$^2$**
- **Dose: 120 µSv**

Patient:

**IDTNum** 17

Select Scanner | 47 CareStream 9000 3D | details

DateOfBirth:

ScanDate:

ScanTime:

Radiographer:

**Region:** **Maxilla** | **470 Dental**

| | Suggested | Actual |
|---|---|---|
| Voltage (kVp): | 70 | 70 |
| Exposure (mAs): | 108 | 108 |
| CTDIvol (mGy): | 3.40 | 3.40 |
| Slices: | 471 | 471 |
| Spacing (mm): | 0.076 | 0.076 |
| IrradiatedLength (mm): | 35.796 | 35.796 |
| DLP (mGy.cm): | 12.2 | 12.2 |
| Dose (microSv): | 21 | 21 |
| RawRisk (1 in N): | 826495 | 826495 |
| Age (years): | | 35 |
| AgeFactor: | .775 | 0.78 |
| Risk (1 in N): | 1066445 | 1000000 |

Patient:

**IDTNum** 18

Select Scanner | 53 Planmeca Promax 3D | details

DateOfBirth:

ScanDate:

ScanTime:

Radiographer:

**Region:** **Maxilla & Mandible** | **530 Standard 8cm**

| | Suggested | Actual |
|---|---|---|
| Voltage (kVp): | 84 | 84 |
| Exposure (mAs): | 169 | 169 |
| CTDIvol (mGy): | 6.56 | 6.56 |
| Slices: | 250 | 250 |
| Spacing (mm): | 0.32 | 0.32 |
| IrradiatedLength (mm): | 80 | 80 |
| DLP (mGy.cm): | 52.5 | 52.5 |
| Dose (microSv): | 125 | 125 |
| RawRisk (1 in N): | 140125 | 140125 |
| Age (years): | | 25 |
| AgeFactor: | 1.35 | 1.35 |
| Risk (1 in N): | 103796 | 100000 |

# *Conclusions*

- **A knowledge-driven approach based on published data allows us to estimate Effective Dose and Risk for a number of makes and models of CT / CBCT scanners and a variety of scanning protocols**

- **Even if we don’t have all of the information.**

# *Thank You!*

- **Any Questions?**