Image Diagnostic Technology Ltd

53 Windermere Road, London W5 4TJ
Tel: +44 20 8819 9158 www.idtscans.com email: info@idtscans.com

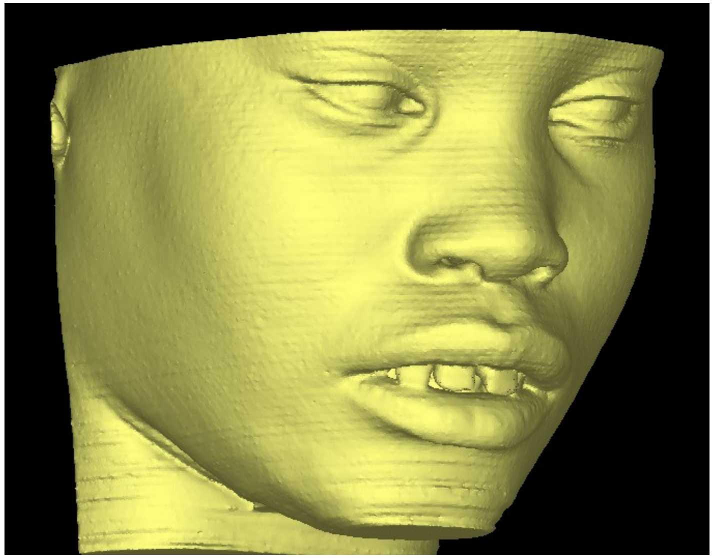
Cone Beam Computed Tomography (CBCT)

Anthony Reynolds BA MSc PhD
Registered Clinical Scientist CS03469
Medical Physics Expert ICPM 877781

Image Diagnostic Technology Ltd.

Who or what is IDT?

Image Diagnostic Technology Ltd aka "IDT Scans"

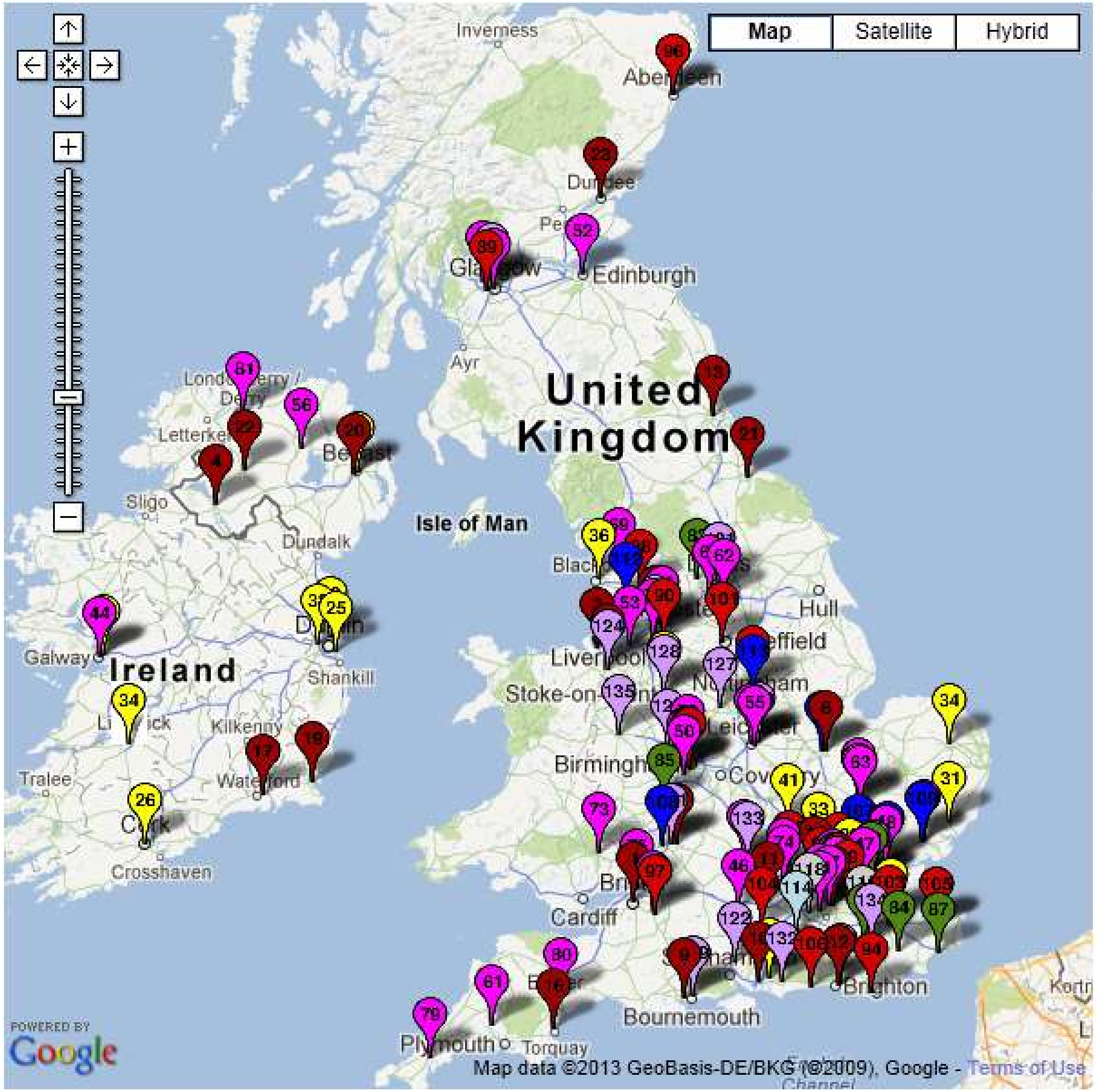


Specialises in:

- arranging dental CT/CBCT scans
- preparing datasets for implant planning
- implant simulation & treatment planning
- radiology reports
- 3D models
- surgical drill guides

37,500 scans processed since 1991

www.idtscans.com



Map
Satellite
Hybrid
Inverness
Edinburgh
Ayr
United Kingdom
Isle of Man
Sligo
Dundalk
Galway
Ireland
Shankill
Kilkenny
Tralee
Crosshaven
Hull
Birmingham
Cardiff
Bournemouth
Brighton
Torquay
POWERED BY Google
Map data ©2013 GeoBasis-DE/BKG (©2009), Google - Terms of Use

Scan Site Search

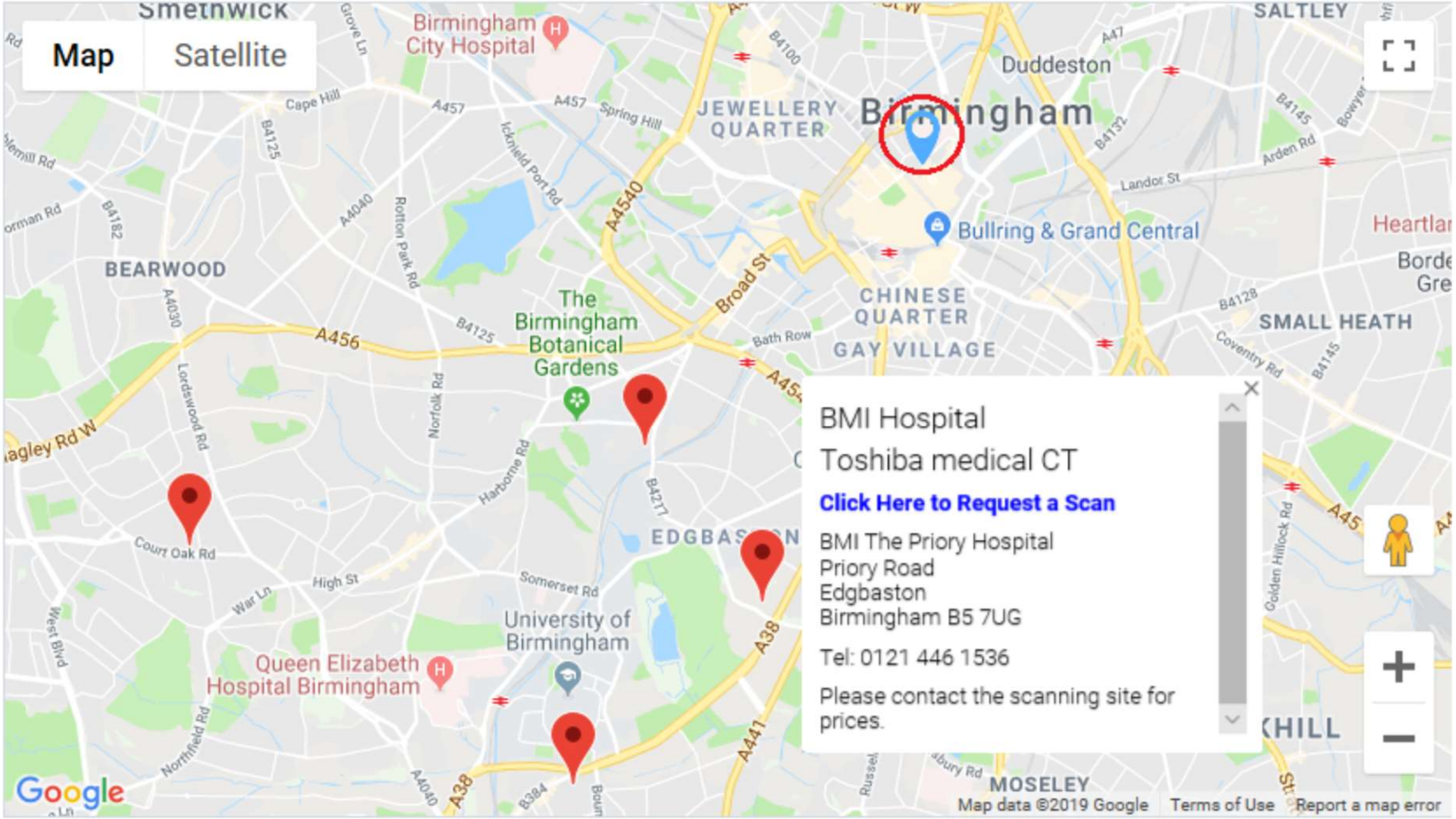
Location | Keyword | A-Z List

United Kingdom ◉ Ireland ○

B4 6BN | 10 miles | Search

Found 6 sites. Please click the icons for more information.

Name	Distance
Cavendish Imaging Birmingham	1.6 miles
BMI The Priory Hospital	1.9 miles
CT Dent Birmingham	2.9 miles
The Birmingham Periodontal and Implant Centre	3.4 miles
Scott Arms Dental Practice	4.5 miles
Central England Specialist Referral Centre	6.8 miles



www.idtscans.com

Support

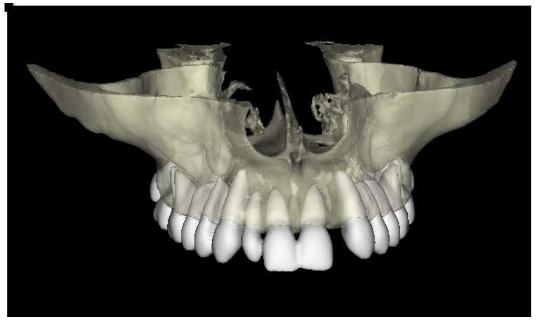
Please click on the links to access the Support pages:

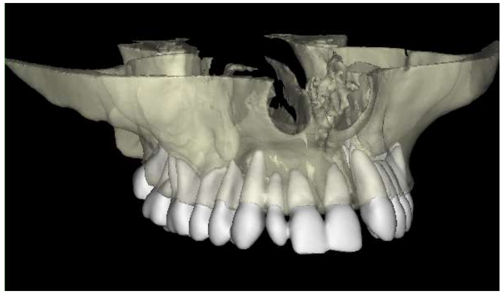
- Frequently Asked Questions
- For the Patient
- For the Dentist
- For the Imaging Centre
- Software
- Publications
- Lecture Slides
- DICOM Uploader
- SFTP Secure File Transfer Protocol
- Dental CT View
- Remote Help

Outline of Lectures

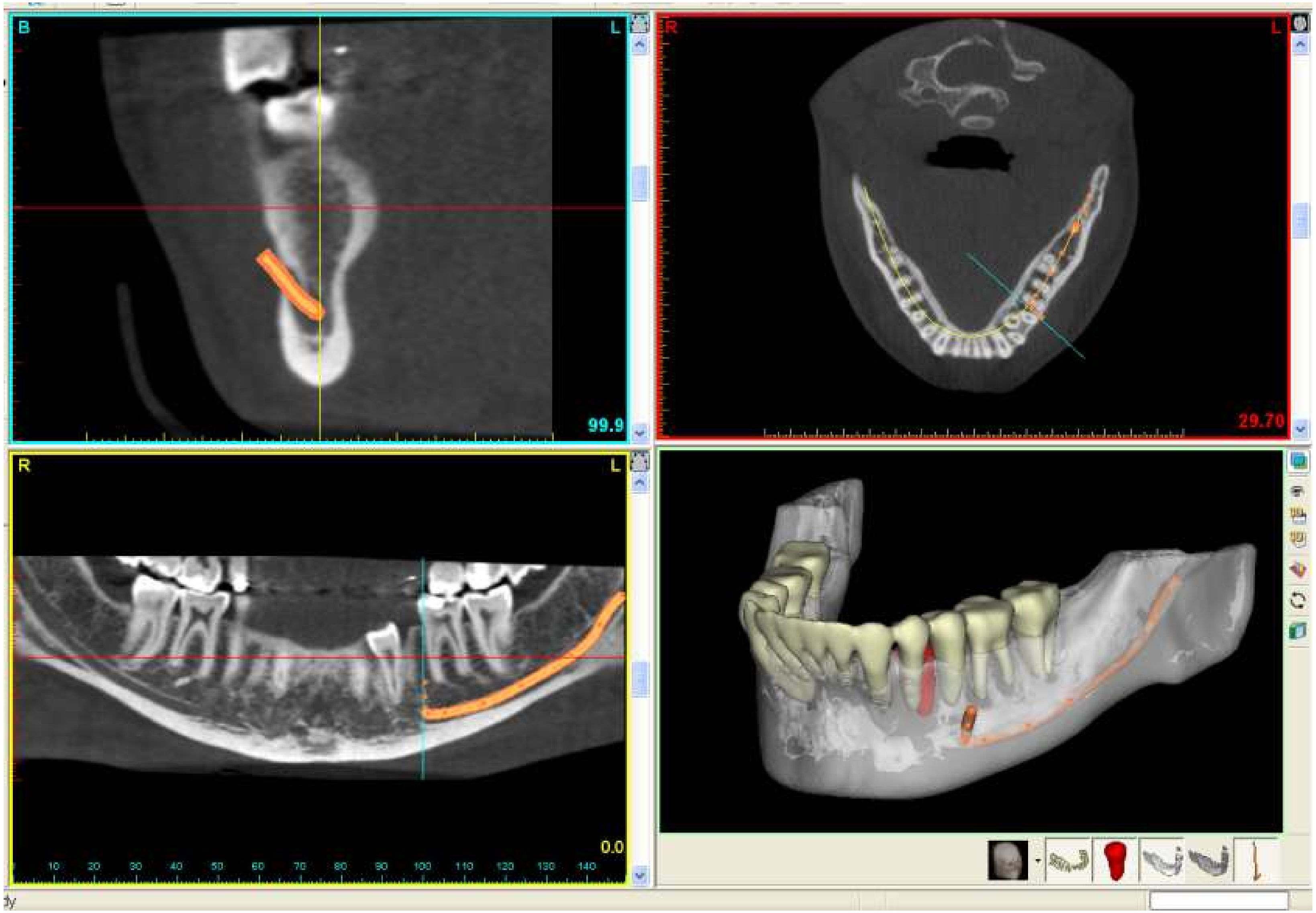
- ✔ **Introduction / Disclosures**
- **Principles of CBCT Imaging**
- **CBCT Image Acquisition and Processing**
- **Apparatus and Equipment**
- **Radiation Physics in relation to CBCT**
- **Radiation Protection in relation to CBCT**

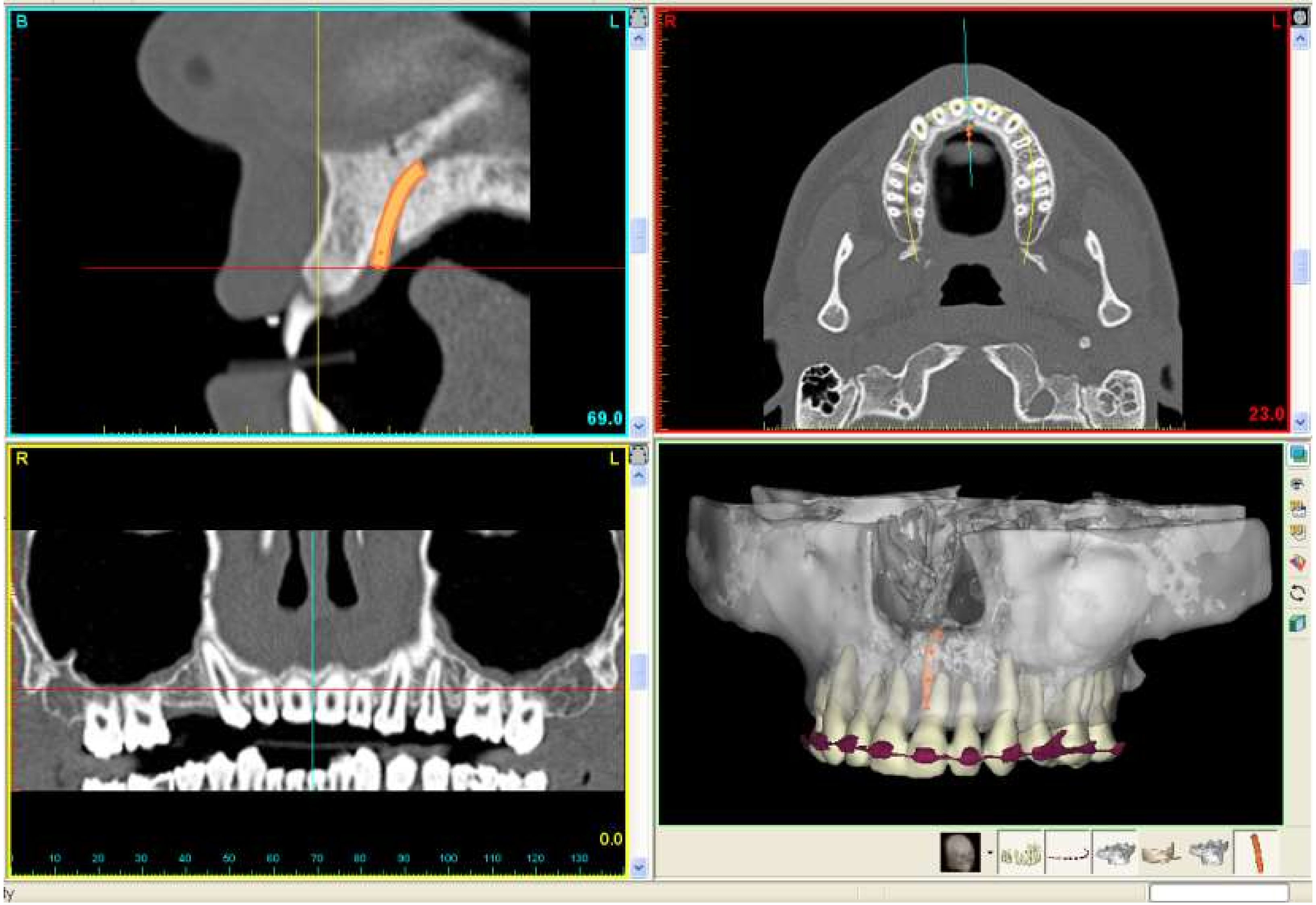
What can we do with CBCT scans?





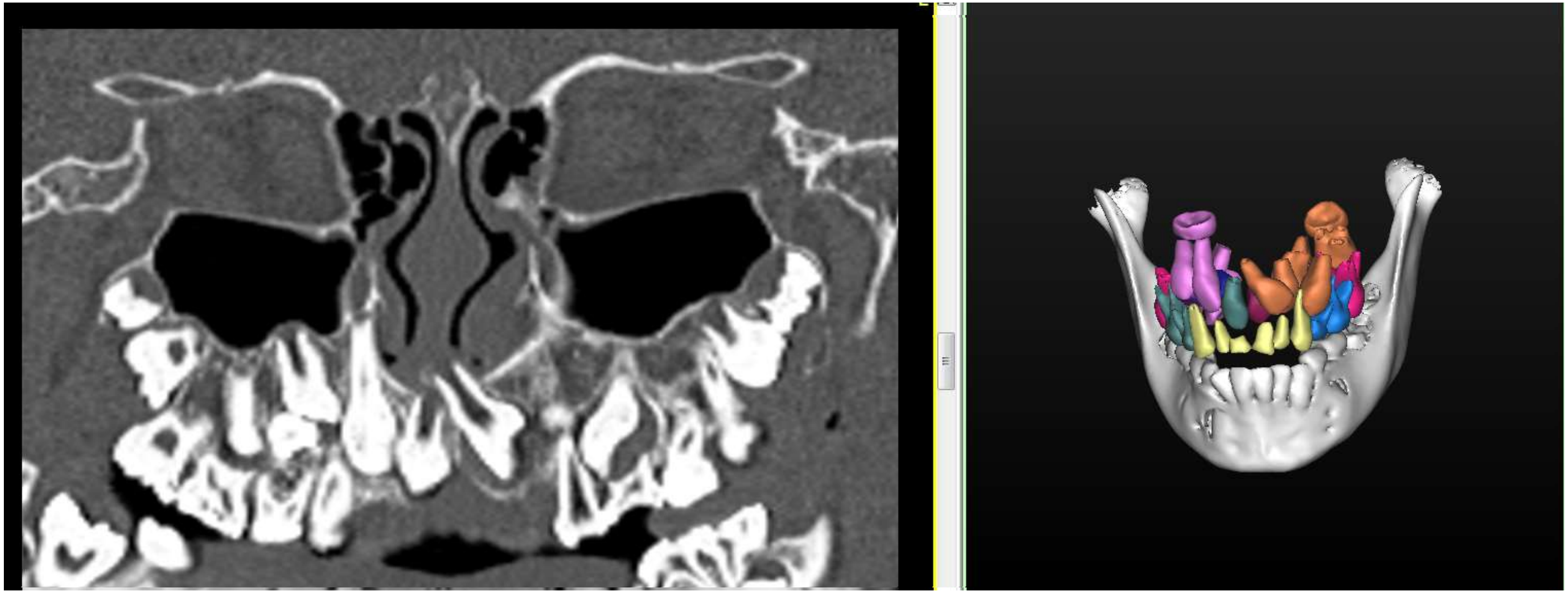
Segmentation


B
L
99.9
R
L
29.70
R
L
0.0
10
20
30
40
50
60
70
80
90
100
110
120
130
140

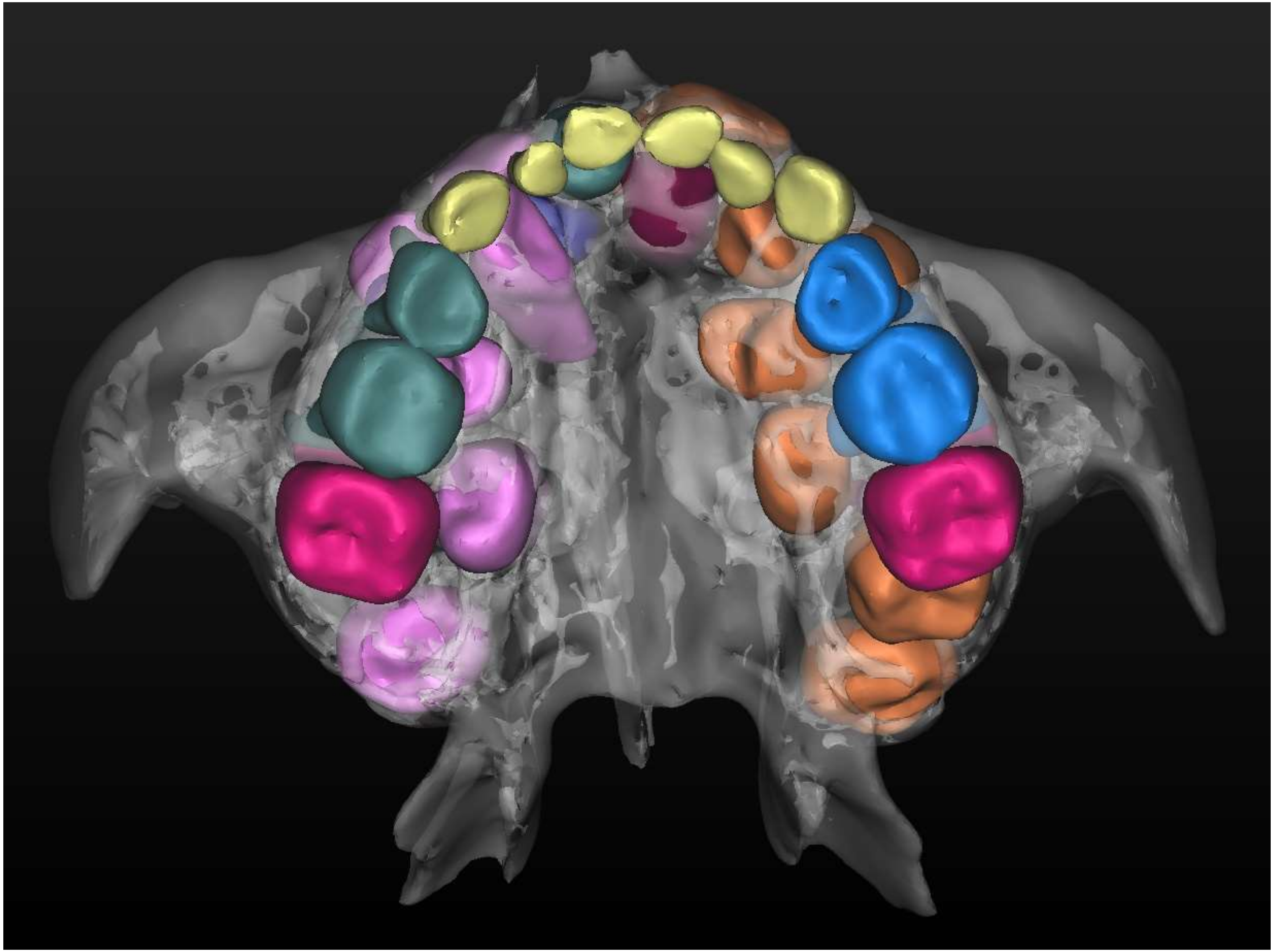


B
L
69.0
R
L
23.0
R
L
0.0
10
20
30
40
50
60
70
80
90
100
110
120
130

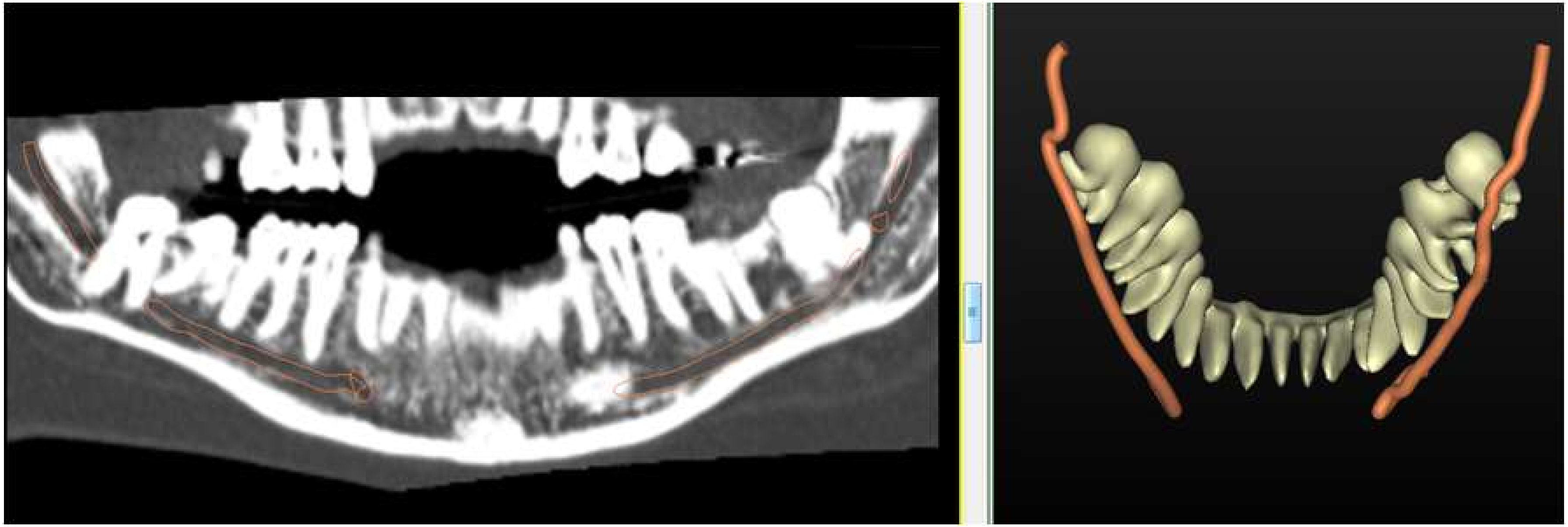
Hyperdontia



Courtesy of Nicolette Schroeder

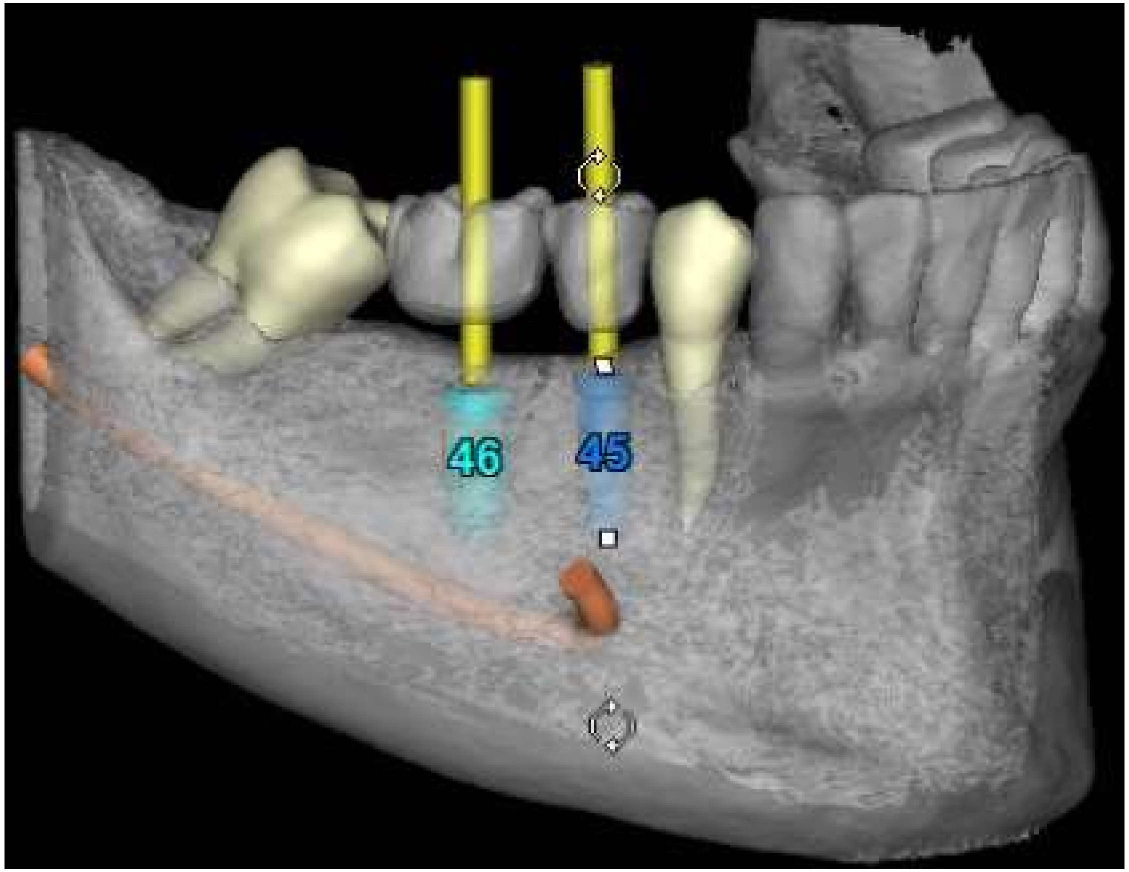


Third Molars



Courtesy of Barry Dace

Implant Simulation



Courtesy of Dr David Reaney

Surgical Drill Guide


2.3

Preliminary Restoration

Requirements for CBCT Imaging

Need to be able to:

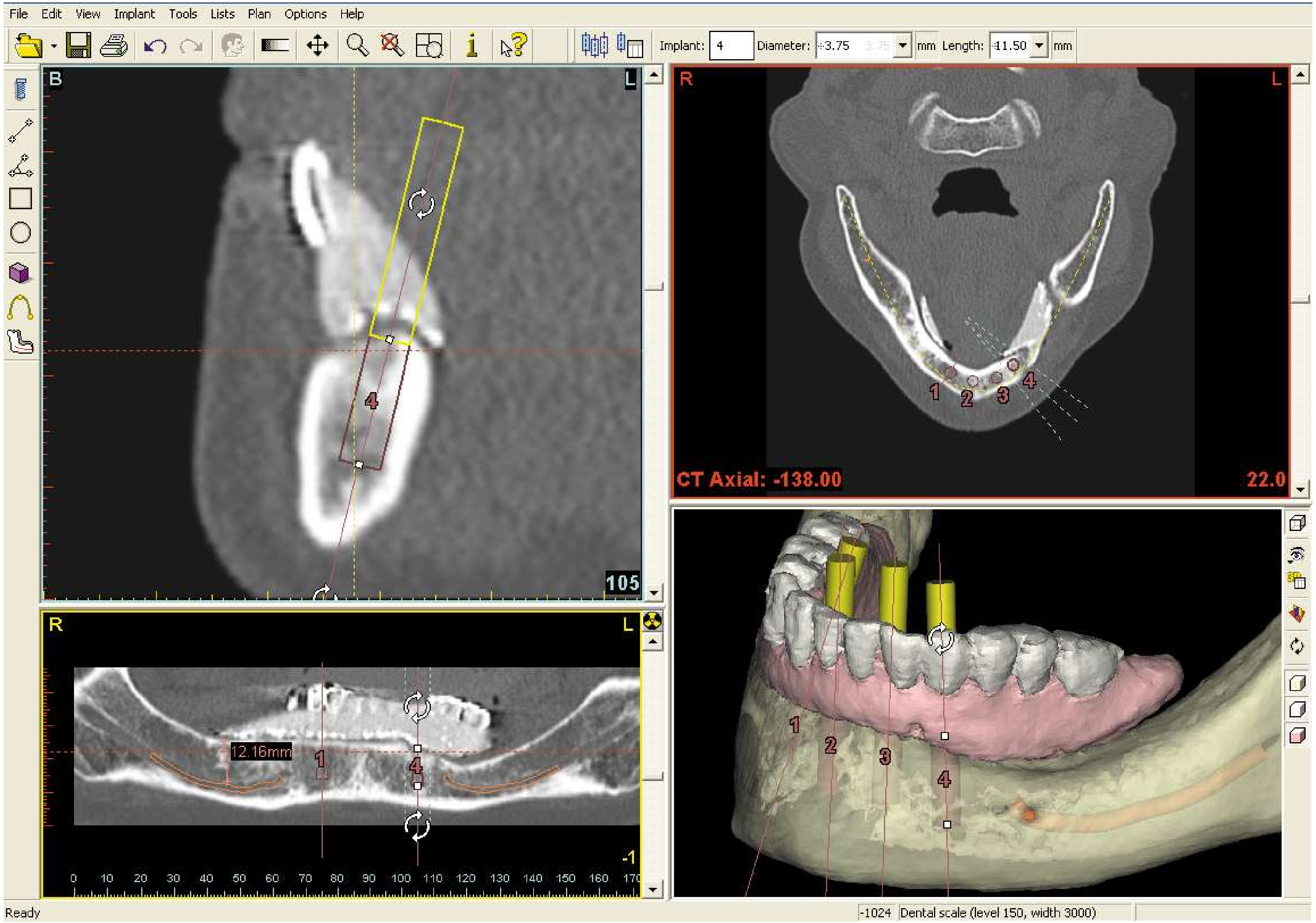
- **Review patient anatomy and pathology**
  - **diagnostic quality images**
- **Assess bone quantity and quality**
  - **quantitative assessment**
- **Decide where implants should go**
  - **accurate 3D measurements**
  - **avoid sensitive structures**
  - **must work mechanically and aesthetically**

Restoration-Driven Implant Planning

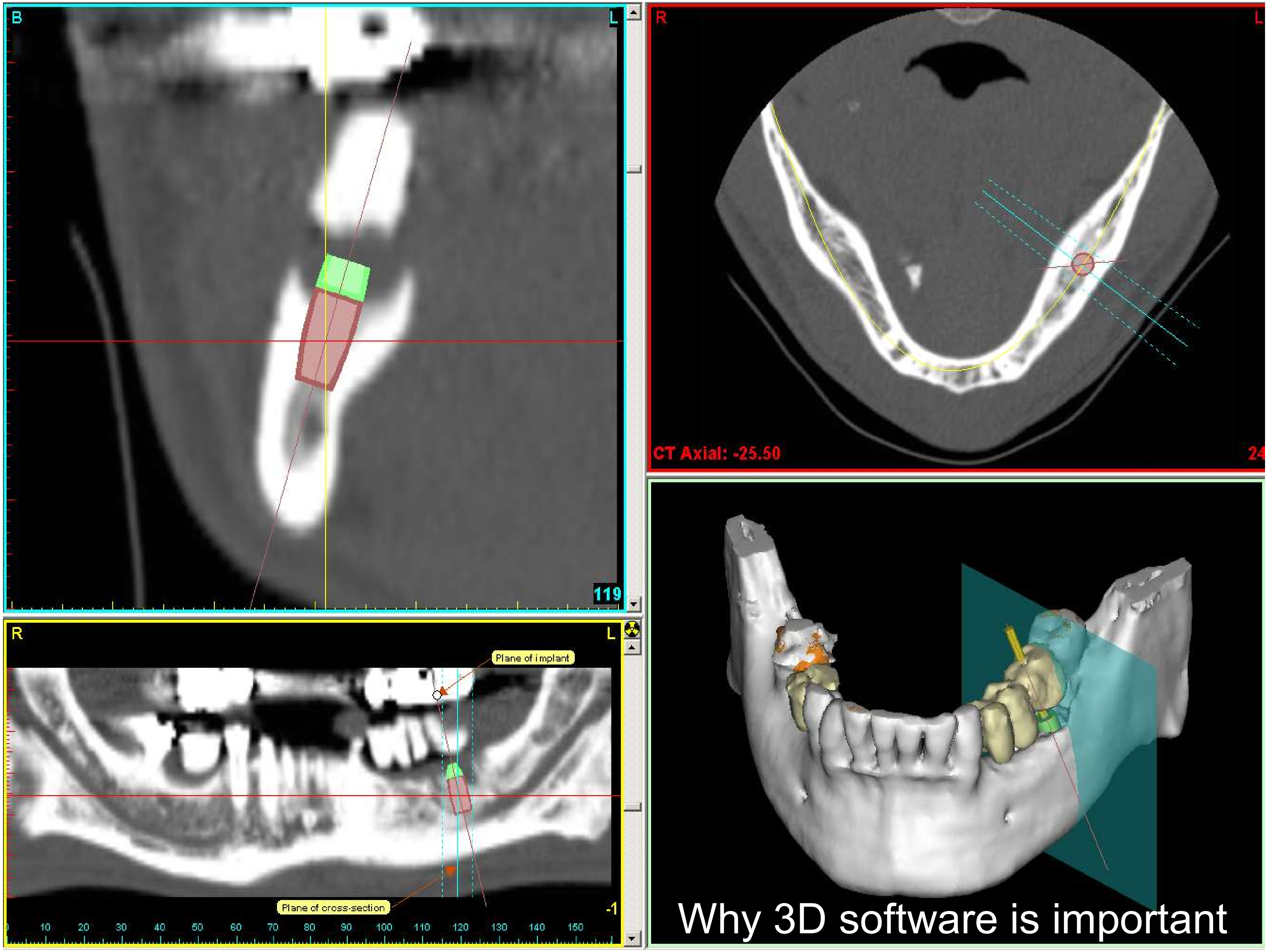
"Create a model of the desired result, then work backwards to determine how it can be achieved"

- ***CBCT Scans***
- ***3D Treatment Planning Software***
- ***Radio-Opaque Scanning Stents***
- ***Surgical Drill Guides***

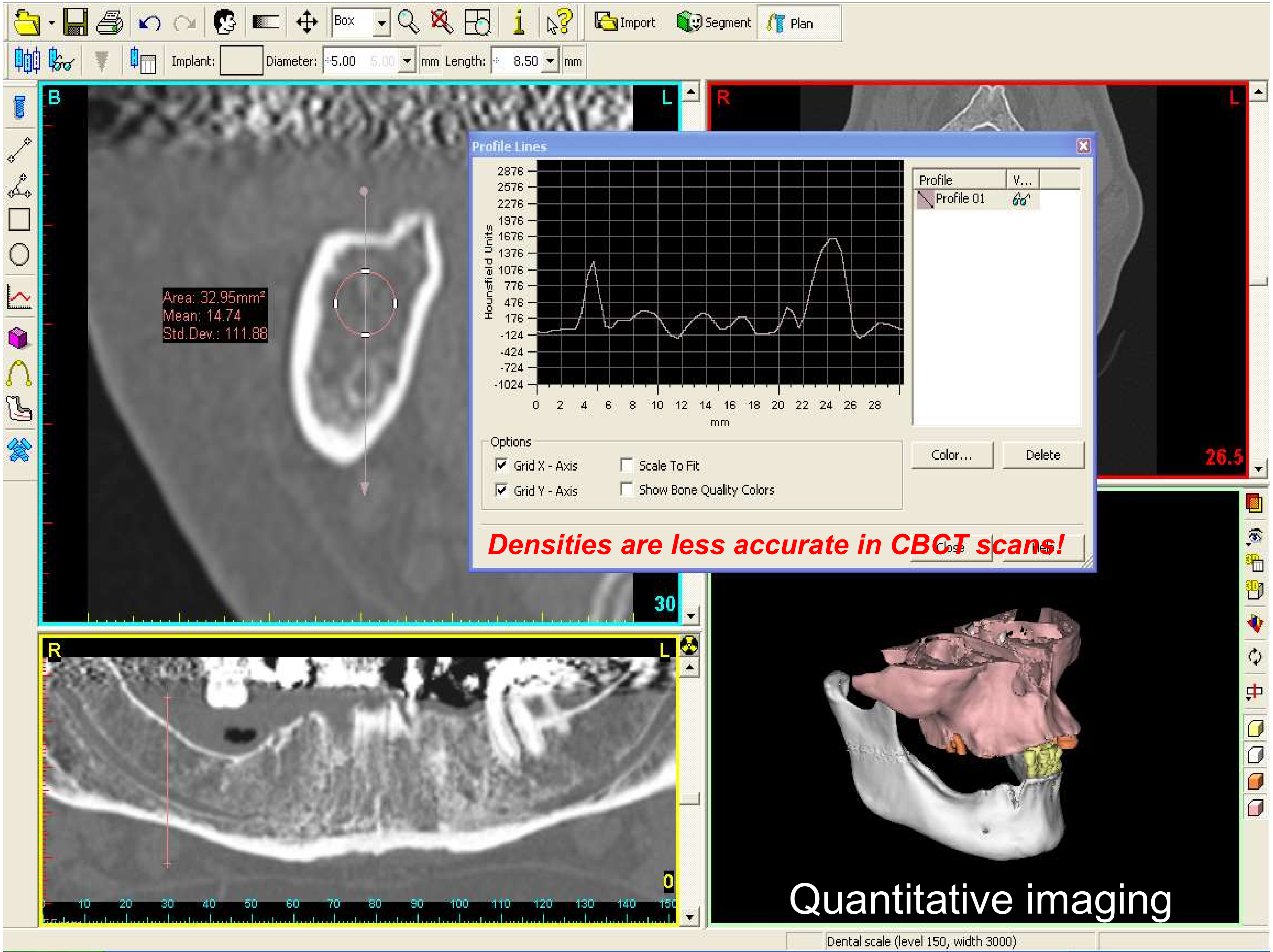
SimPlant® Computer Guided Implantology *interactive implant planning software*



Simplant™ is a trademark of Dentsply Sirona



Why 3D software is important


Import
Segment
Plan
Box
Implant:
Diameter: 5.00
mm Length: 8.50
mm
Area: 32.95mm²
Mean: 14.74
Std.Dev.: 111.88
Profile Lines
Hounsfield Units
2876
2576
2276
1976
1676
1376
1076
776
476
176
-124
-424
-724
-1024
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
mm
Profile
Profile 01
Options
Grid X - Axis
Grid Y - Axis
Scale To Fit
Show Bone Quality Colors
Color...
Delete
Densities are less accurate in CBCT scans!
26.5
30
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140
Quantitative imaging
Dental scale (level 150, width 3000)

Software for planning Dental Implants

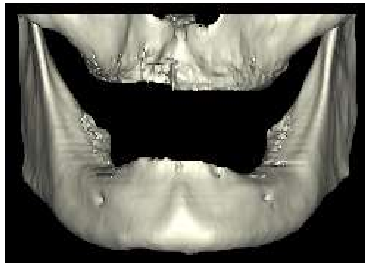
- Simplant (Dentsply Sirona)
- Blue Sky Plan (Blue Sky Bio) - free
- Osirix (with Dental3D plugin) - Macintosh only
- In Vivo Dental (Anatomage)
- Nobel Clinician (Nobel Biocare)
- coDiagnostiX (Dental Wings)
- Carestream CS3D - free
- etc etc

Restoration-Driven Implant Planning

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

- ✔ ***CBCT Scans***
- ✔ ***3D Treatment Planning Software***
- ***Radio-Opaque Scanning Stents***
- ***Surgical Drill Guides***

Advantages of using a Scanning Stent



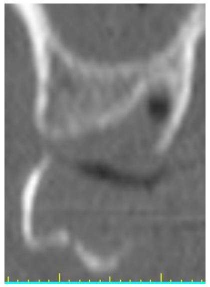
- **Gives inter-arch stability for the patient during the scan**
- **Opens the bite slightly (a few mm) using occlusal stops**
- **Shows position of the desired restorations**
- **Shows inter-arch relationship**
- **If you want a mucosa-supported surgical guide, edentulous patients MUST be scanned wearing a stent**

Making a Scanning Stent

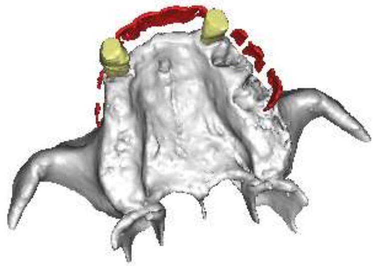
Plastic and clear acrylic does not show up on a CT scan.

To make it show up, you can:

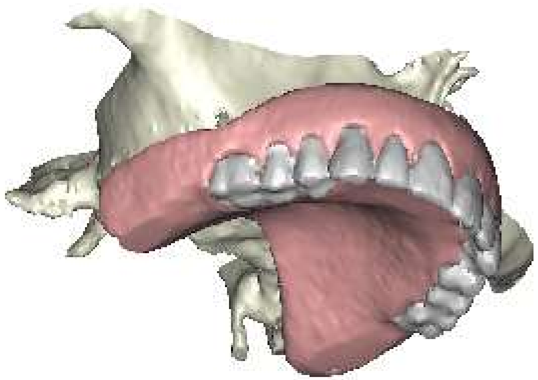
- **mix barium sulphate with the acrylic**
- **~~paint barium sulphate on the surface~~**
- **Make your own markers from a radio-opaque material**
  - **lab putty**
  - **gutta percha**
  - **glass ionomer**
- **use radio-opaque teeth**
- **use a dual-scan technique.**



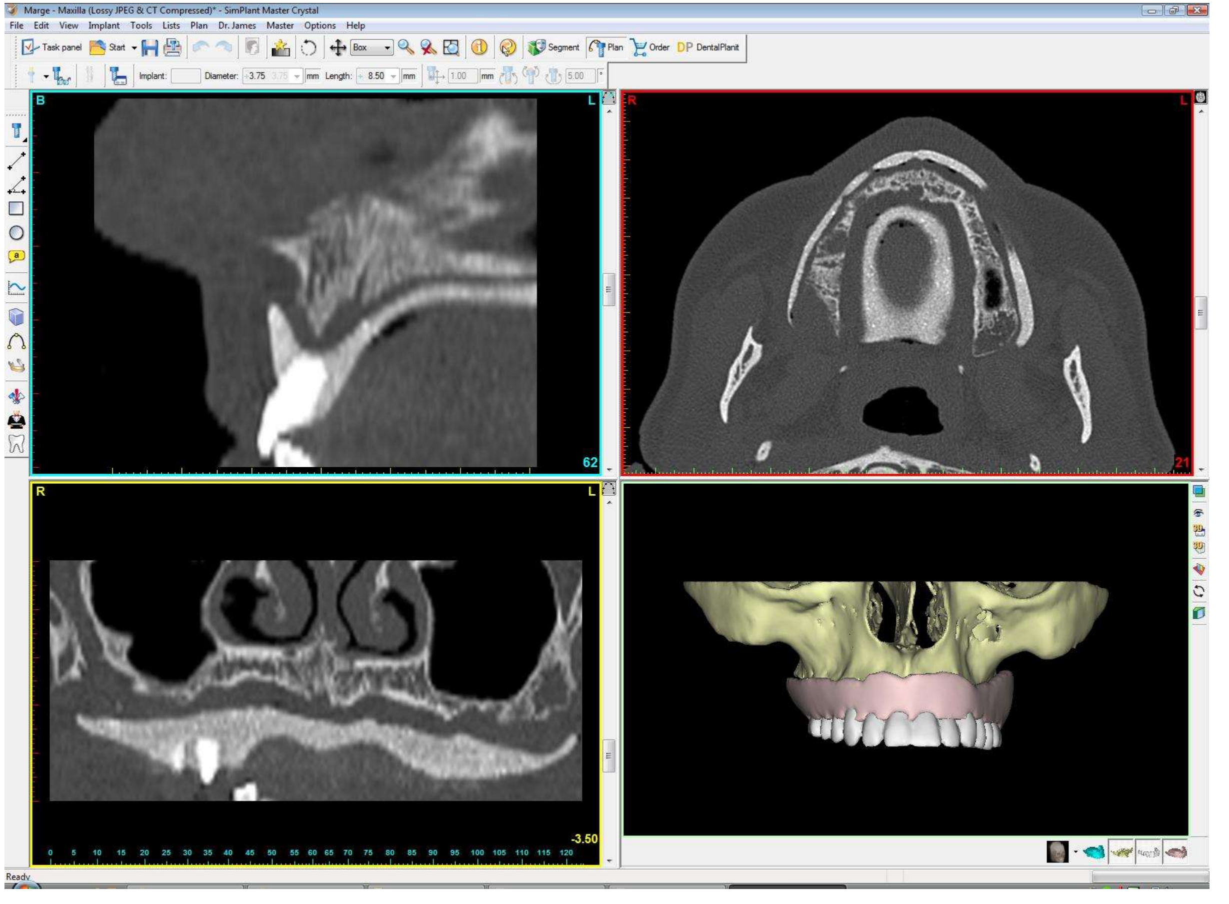
Not adequate to make a guide



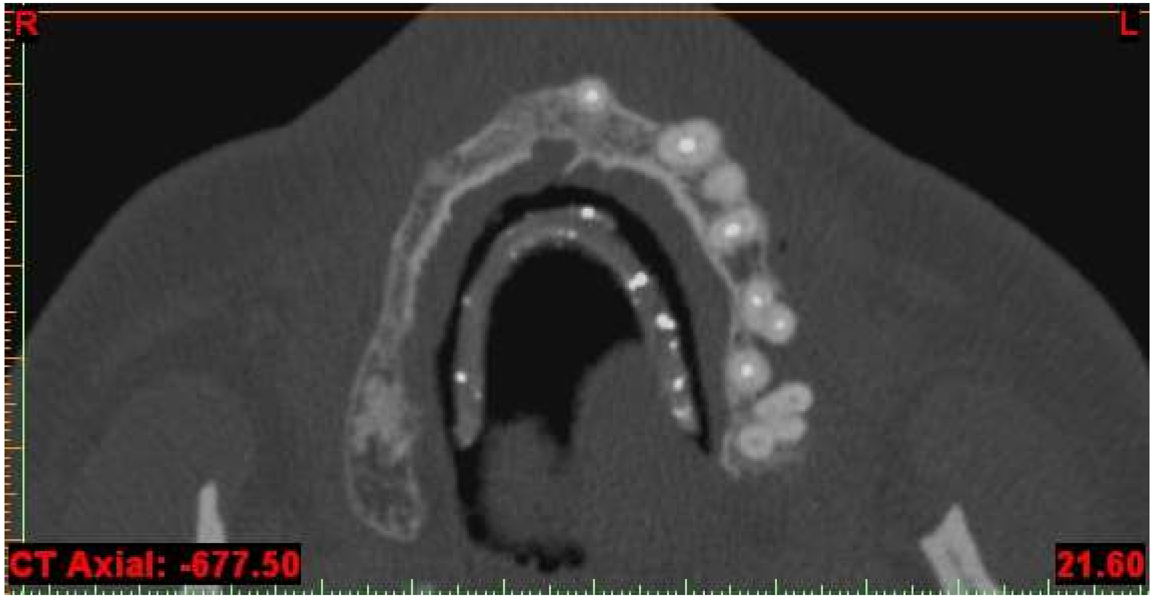
- We recommend using a barium sulphate-acrylic mix for both the radio-opaque teeth and the baseplate.
- Use 15% barium sulphate in the teeth and 10% barium sulphate in the baseplate. This allows the teeth to be picked out separately.
- Do not use too much Barium Sulphate as it will cause an artefact.
- An accurate fitting stent with radio-opaque baseplate is usually the best option for mucosa-supported surgical drill guides.

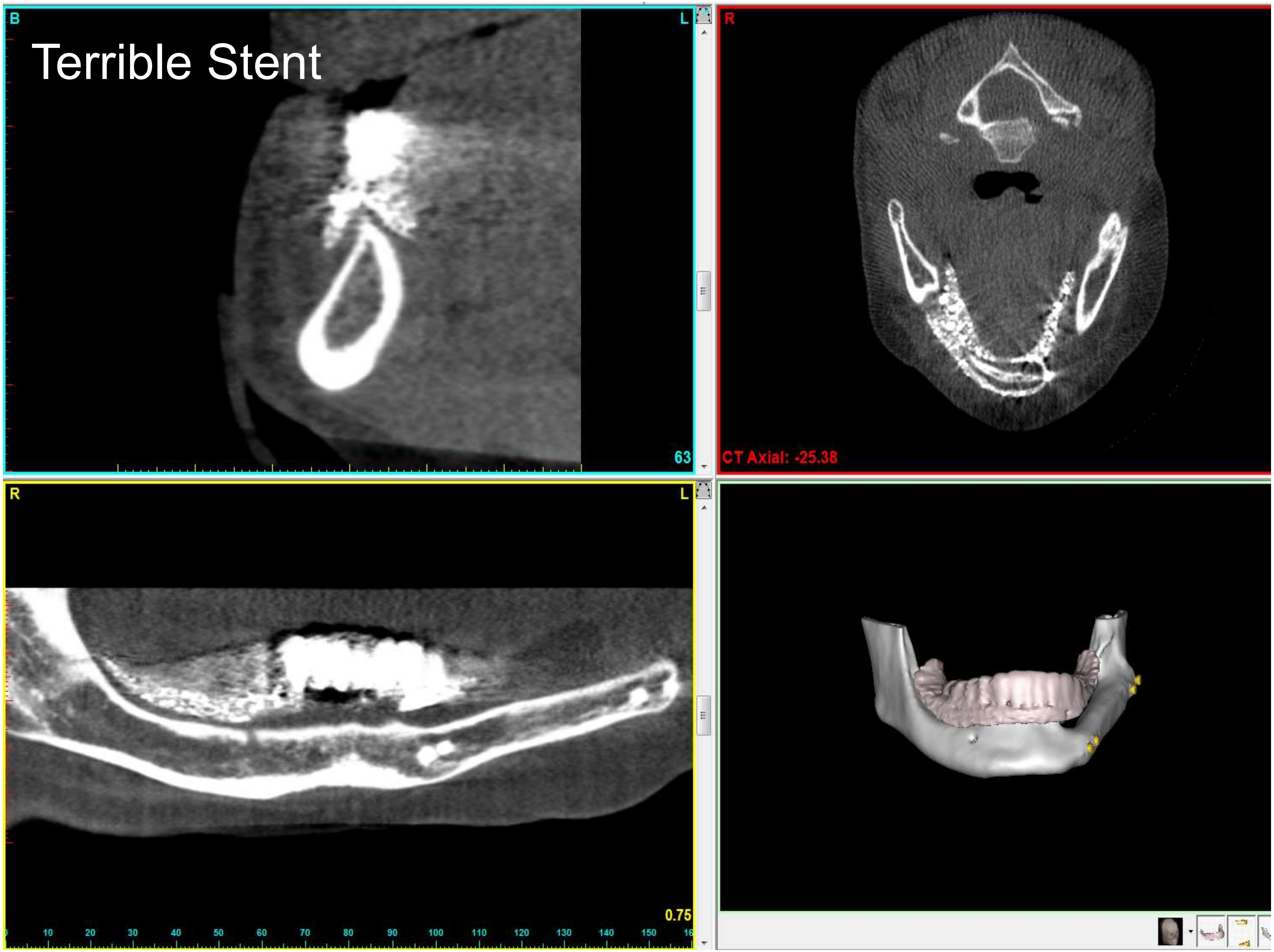


Good Stent


Marge - Maxilla (Lossy JPEG & CT Compressed)* - SimPlant Master Crystal
File Edit View Implant Tools Lists Plan Dr.James Master Options Help
Task panel
Start
Box
Segment
Plan
Order
DP DentalPlanit
Implant:
Diameter:
3.75
mm
Length:
8.50
mm
1.00
mm
5.00
62
21
-3.50
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Ready

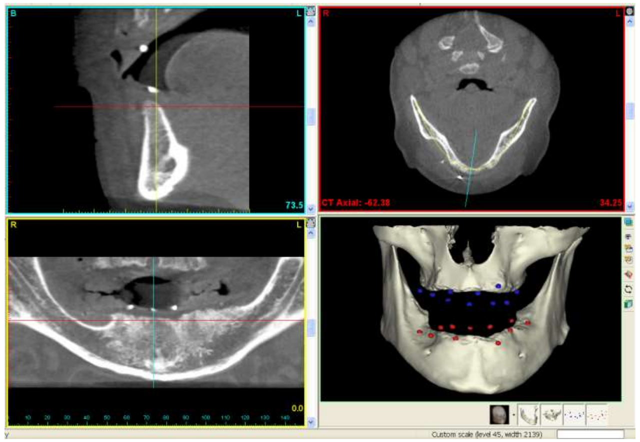
Bad Stent



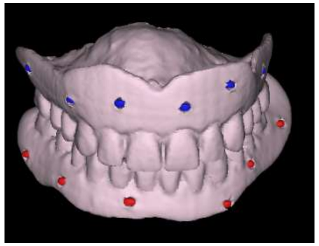


B
Terrible Stent
L
63
R
CT Axial: -25.38
R
L
0.75
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

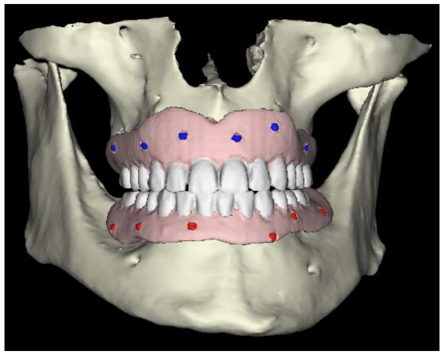
Dual Scan Technique

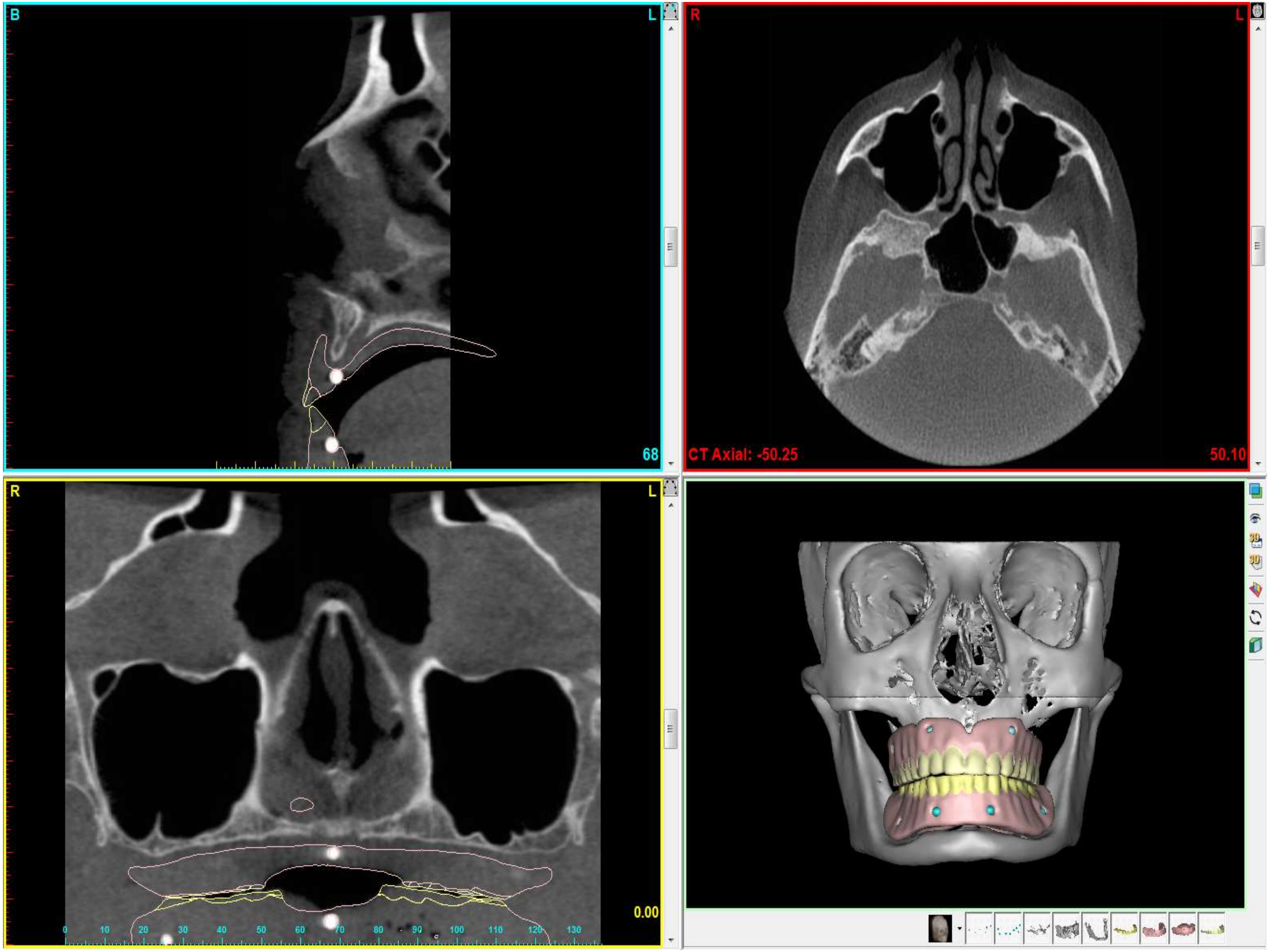


+



=




B
L
68
R
L
CT Axial: -50.25
50.10
R
L
0.00
0 10 20 30 40 50 60 70 80 90 100 110 120 130

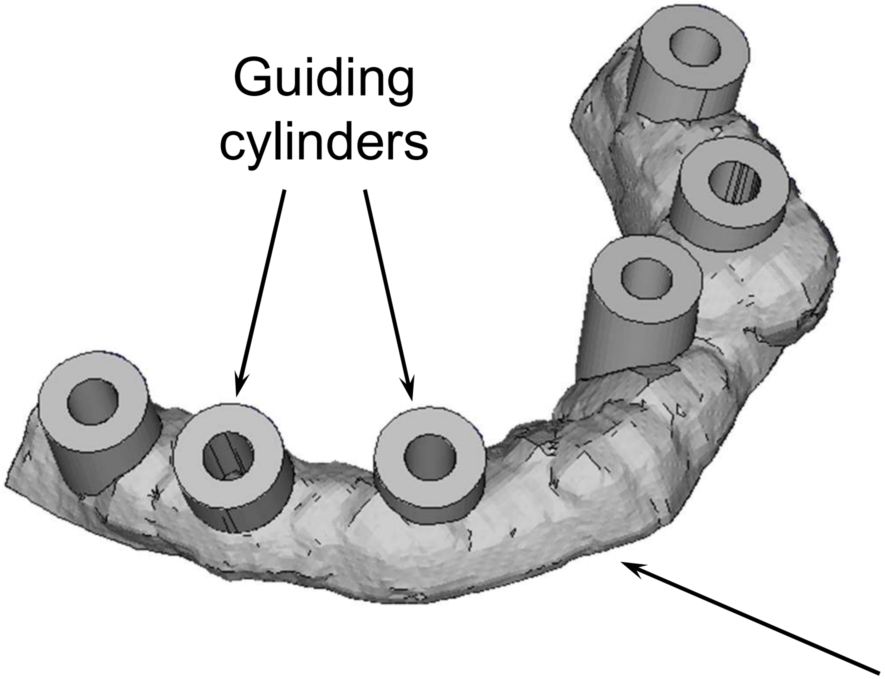
Restoration-Driven Implant Planning

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

- ✔ ***CBCT Scans***
- ✔ ***3D Treatment Planning Software***
- ✔ ***Radio-Opaque Scanning Stents***
- ***Surgical Drill Guides***

SurgiGuide
Computer Guided Implantology

SIMPLANT drill guide

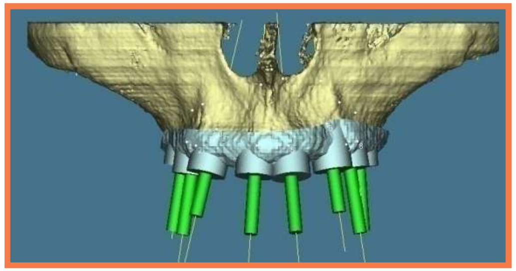


The SurgiGuide controls:
- Position
- Orientation
- Depth

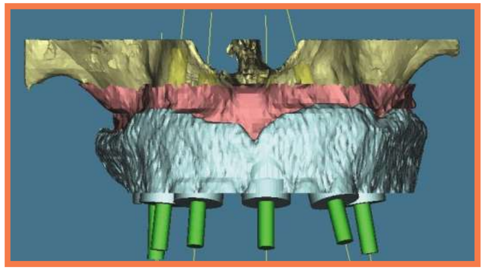
Guide resting on:
- Bone
- Mucosa
- Teeth

Simplant™ is a trademark of Dentsply Sirona

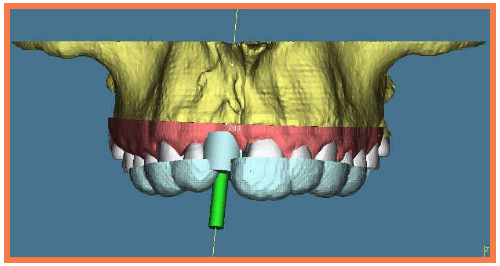
Drill Guides can be supported on



Bone



Mucosa



Teeth

Bone Supported Guides:

- Bone crest must be clearly visible in the CBCT images and ≥ 3cm long
- Works for most cases – but a flap must be raised

Mucosa Supported Guides:

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

Tooth Supported Guides:

- Tips of teeth must be clearly visible in the CBCT images
- A recent and accurate plaster cast (or intra-oral scan) will be required

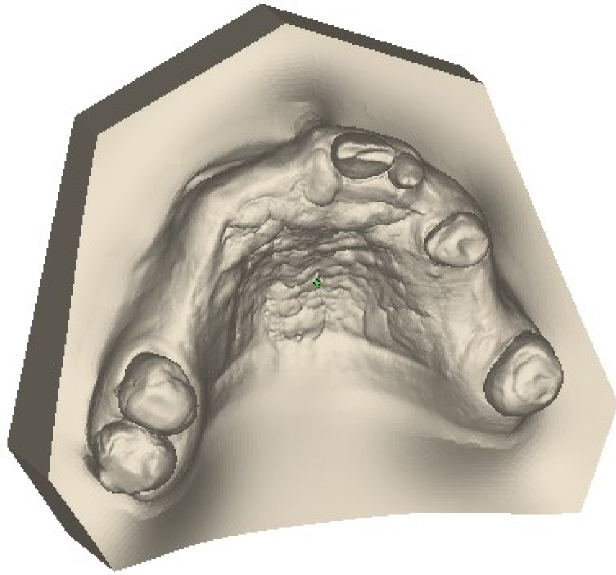
Need to think about the Guide before you request the CBCT Scan!

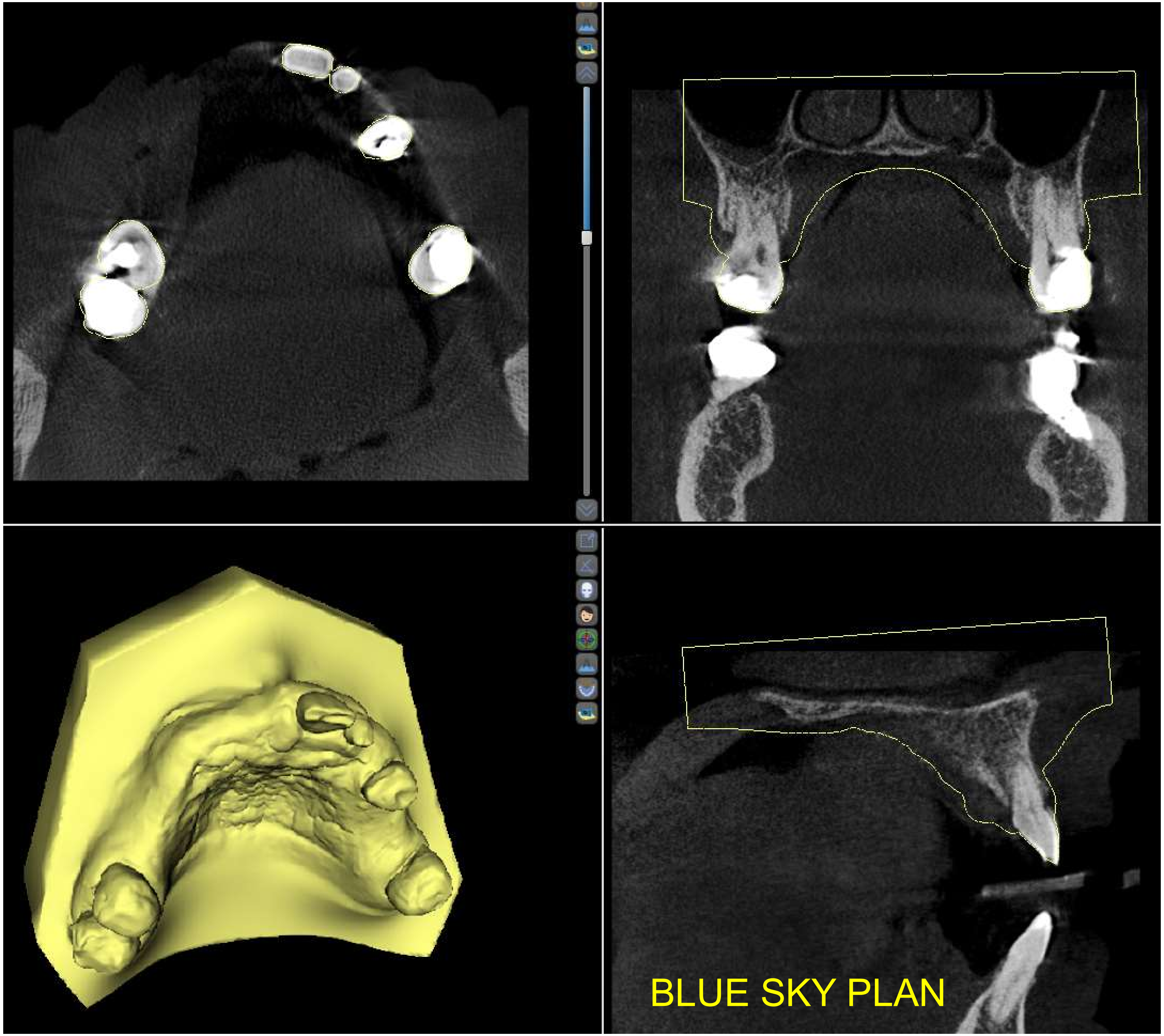
Tooth Supported Guides

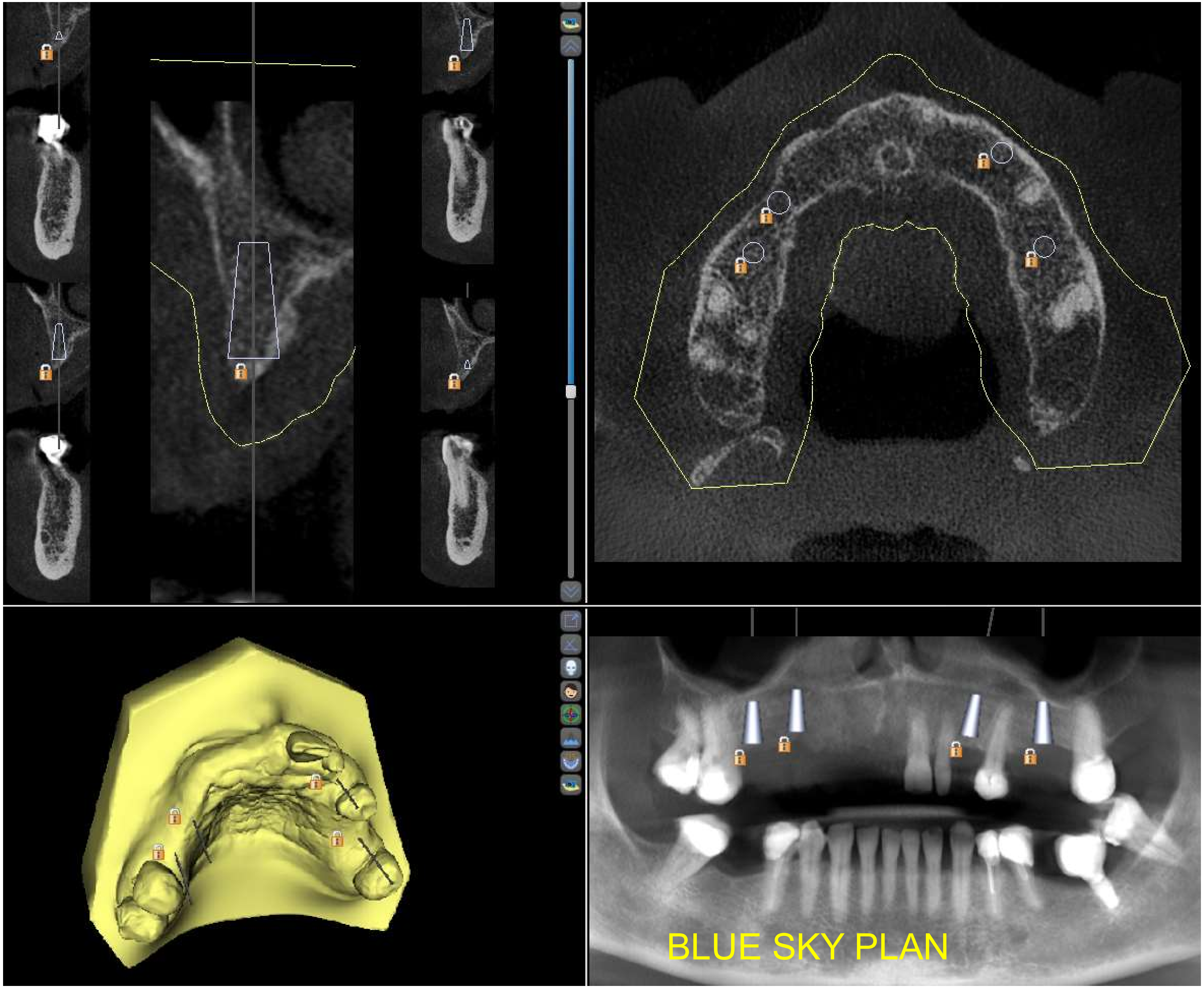
- **Drill Guide will be supported on patient’s existing teeth**
- **Need a recent and accurate impression or plaster cast**
- **Optical (laser) scan of plaster cast (or intra-oral scan)**
- **Import optical scan into the implant planning software**
- **Guide will be designed to fit the plaster cast.**

Optical Scan of Plaster Cast

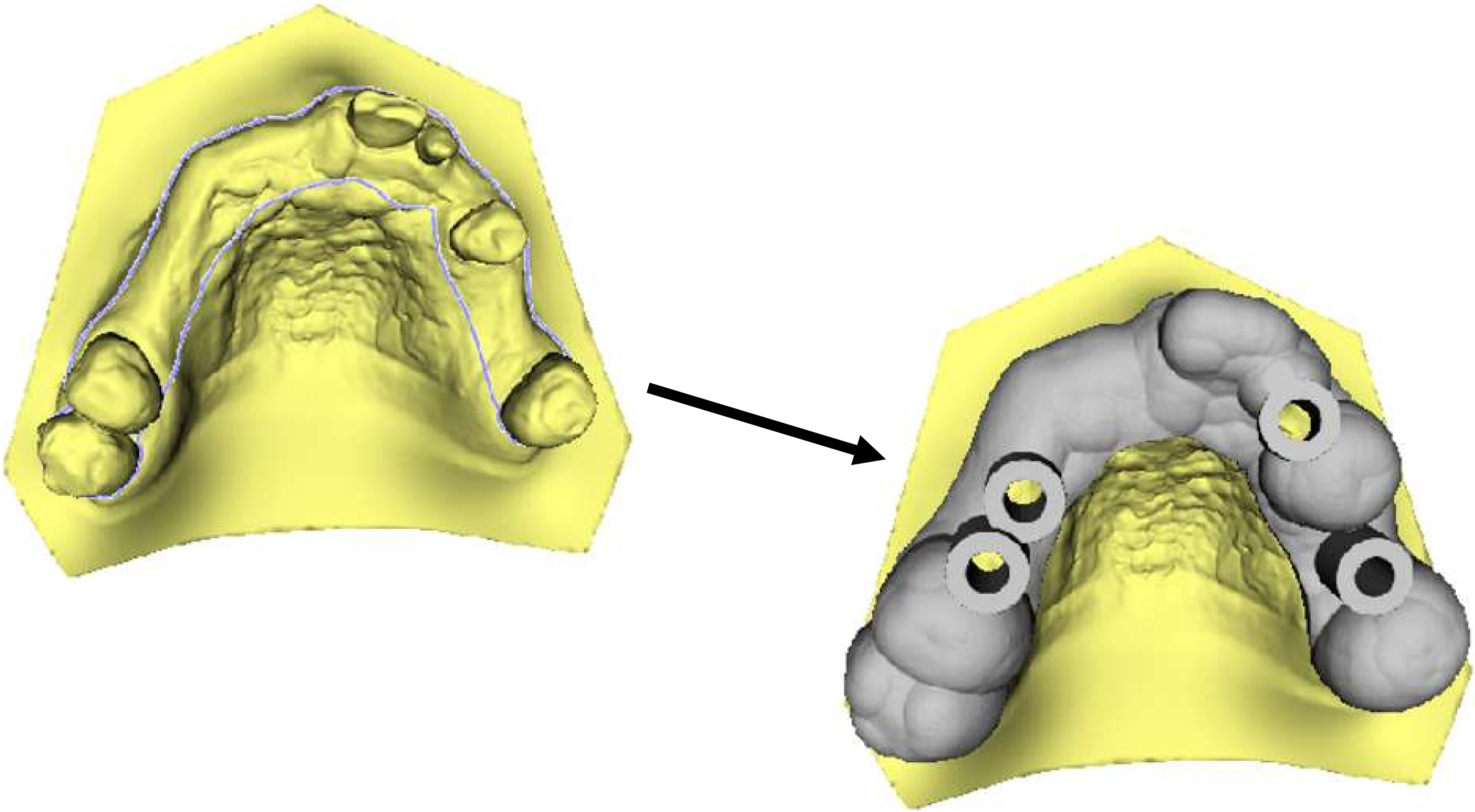
STL file




BLUE SKY PLAN


BLUE SKY PLAN

Design the Guide

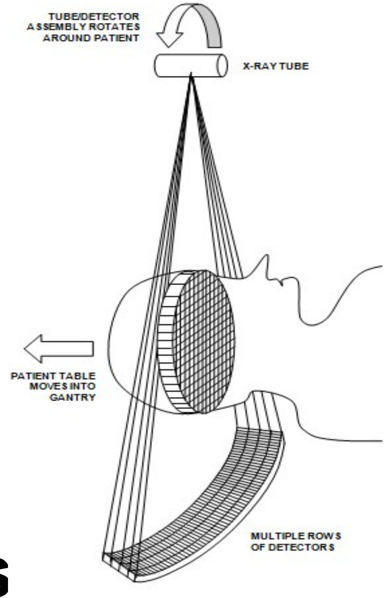


Make it on a 3D Printer

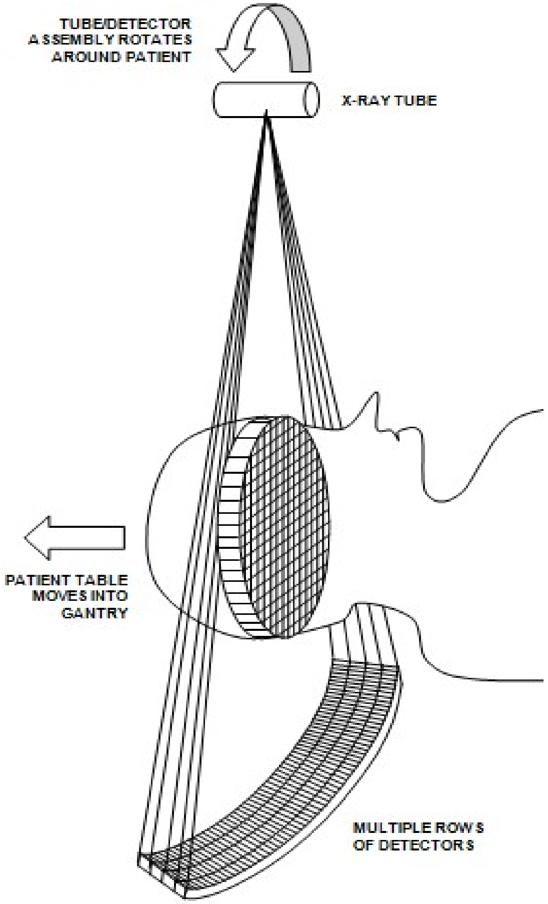
Cone Beam CT (CBCT) Scanners

Medical CT Scanners

Medical CT Scanners:

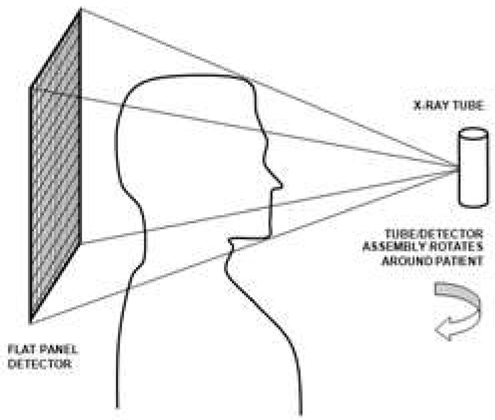


- **Fan beam geometry**
- **Rotate very rapidly**
- **Data acquired as a helix or spiral and interpolated into a set of slices**
- **Large anatomical regions can be imaged very quickly**
- **Applications in oncology, trauma, cardiology etc**



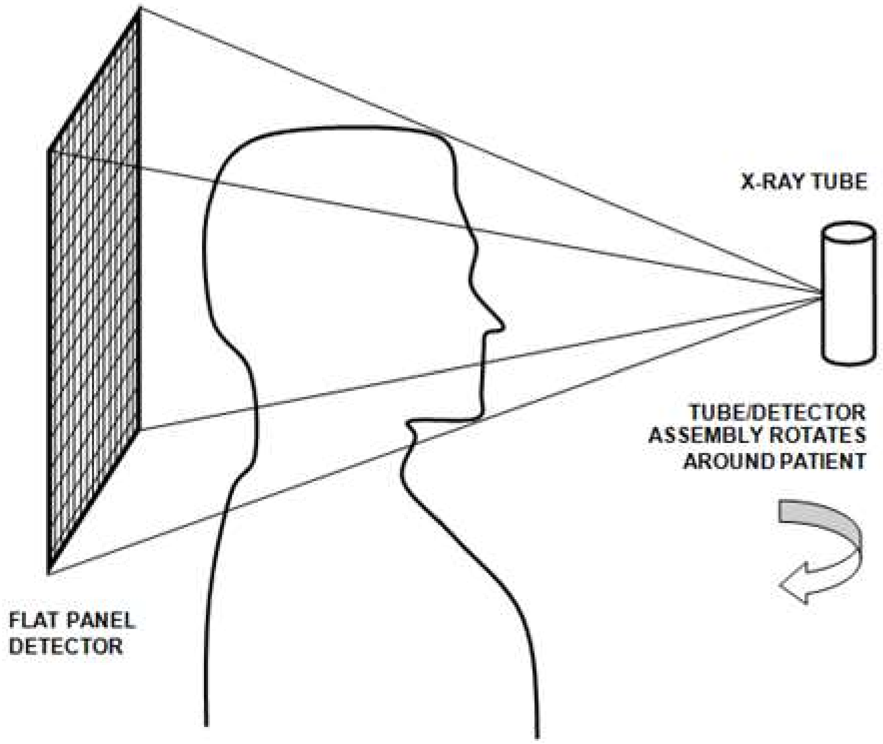
TUBE/DETECTOR
ASSEMBLY ROTATES
AROUND PATIENT
X-RAY TUBE
PATIENT TABLE
MOVES INTO
GANTRY
MULTIPLE ROWS
OF DETECTORS

Cone Beam CT Scanners:



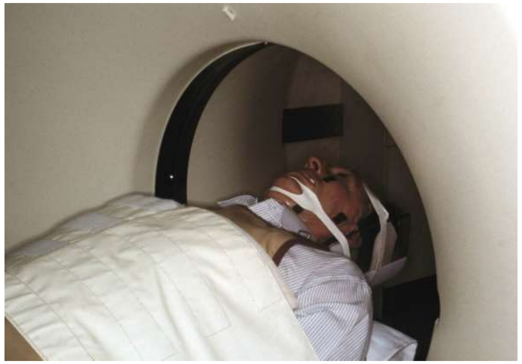
- **Cone beam geometry**
- **Rotate relatively slowly**
- **Cover a large volume with a single rotation**
- **Data acquired as 2-D projections which are reconstructed into a 3-D volume**

Cone Beam CT (CBCT) Scanner



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

Medical CT Scanners:



- Lie down geometry
- Claustrophobic for patients
- Soft tissues collapse
  + good for studying sleep apnoea?
- TMJ not in natural position
- Higher radiation dose in most cases

+ Accurate density measurements

Cone Beam CT Scanners:

+ Sitting up geometry

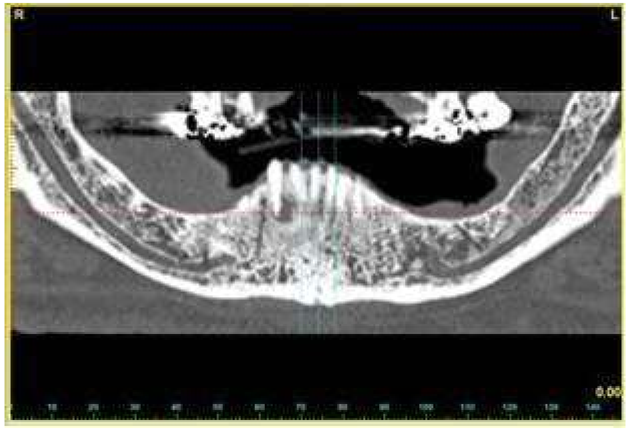
+ More comfortable for patient

+ Ability to also produce 2D DPT and Ceph

+ Lower radiation dose (up to 10x)

- Density measurements are not reliable

Image Quality



GE LightSpeed Medical CT

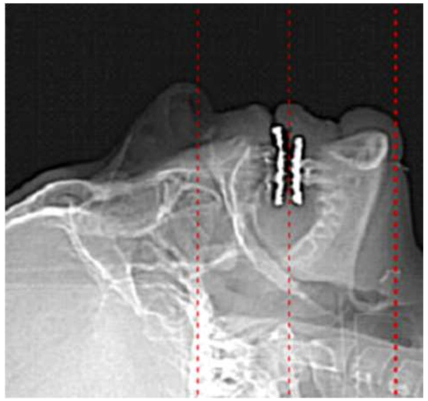
i-CAT CBCT

Medical CT versus Dental CBCT:

Medical CT:
- **Better contrast**
- **Less noise**

Dental CBCT:
- **Better resolution**
- **Lower dose**

Why is the Dose Lower with CBCT?



The dentoalveolar region has high natural contrast

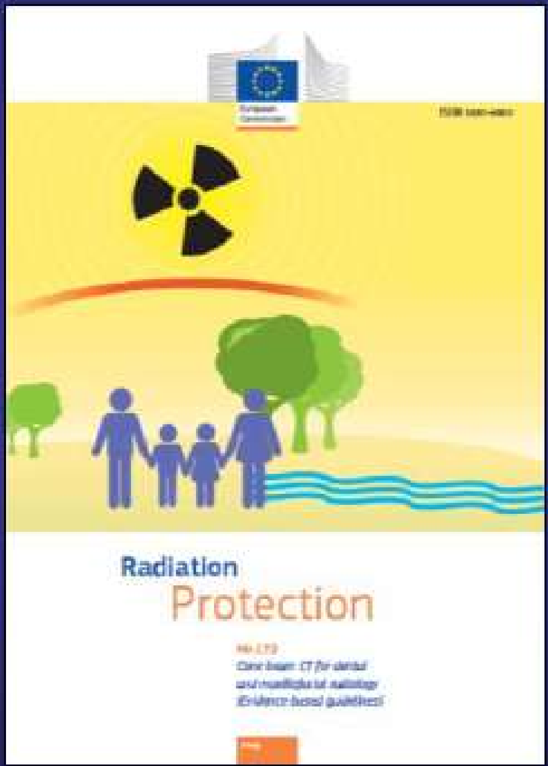
So we can get away with
- high resolution images
- low radiation dose

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
  - periapical disease
  - root canals, root fractures etc
  - impacted, supernumerary and abnormal teeth
  - maxillofacial surgery
  - cleft palate assessment
  - TMJ and airway analysis ?

- CBCT is not good for:
  - dental caries
  - soft tissue tumours

Systematic Review of Indications for CBCT



The SEDENTEXCT project (2008-2011)

4.18: Where CBCT images include the teeth, care should be taken to check for periapical disease when performing a clinical evaluation (report).

GP

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

GP

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.

GP

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.

GP

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

D

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.

C

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.

B

Prof Keith Horner

Grading systems used for levels of evidence [adapted from Scottish Intercollegiate Guidelines Network (SIGN), 2008].

Grade	
A	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
B	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+
C	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++
D	Evidence level 3 or 4; or extrapolated evidence from studies rated as 2+
GP	Good Practice (based on clinical expertise of the guideline group and Consensus of stakeholders)

(Review Paper)

ELSEVIER
SAUNDERS

THE DENTAL CLINICS OF NORTH AMERICA

Dent Clin N Am 52 (2008) 707–730

What is Cone-Beam CT and How Does it Work?

William C. Scarfe, BDS, FRACDS, MS[a,*],
Allan G. Farman, BDS, PhD, DSc, MBA[b]

[a] *Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Room 222G, 501 South Preston Street, Louisville, KY 40292, USA*

[b] *Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Room 222C, 501 South Preston Street, Louisville, KY 40292, USA*

Int. J. Oral Maxillofac. Surg. 2009; 38: 609–625
doi:10.1016/j.ijom.2009.02.028, available online at http://www.sciencedirect.com

International Journal of
Oral & Maxillofacial Surgery

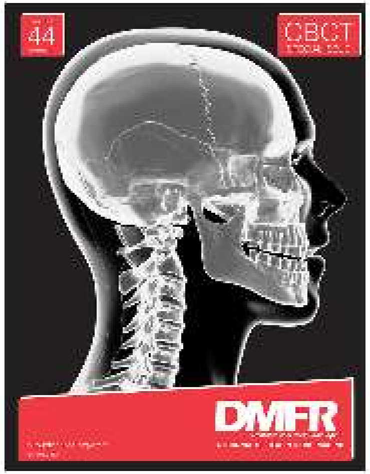
Invited Review Paper

Imaging

Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: A systematic review of the literature

W. De Vos[1], J. Casselman[2,3], G. R. J. Swennen[1,3]

[1]Division of Maxillo-Facial Surgery, Department of Surgery, General Hospital St-Jan Bruges, Ruddershove 10, 8000 Bruges, Belgium; [2]Department of Radiology and Medical Imaging, General Hospital St-Jan Bruges, Ruddershove 10, 8000 Bruges, Belgium; [3]3-D Facial Imaging Research Group, (3-D FIRG), GH St-Jan, Bruges and Radboud University, Nijmegen, 3-D FIRG, Ruddershove 10, 8000 Bruges, Belgium



DentoMaxilloFacial Radiology

CBCT Special Issue

VOLUME 44, ISSUE 1, 2015

Dentomaxillofacial Radiology (2015) 44, 20140224

birpublications.org/dmfr

CBCT SPECIAL ISSUE: REVIEW ARTICLE

Technical aspects of dental CBCT: state of the art

[1]R Pauwels, [2]K Araki, [3]J H Siewerdsen and [4]S S Thongvigitmanee

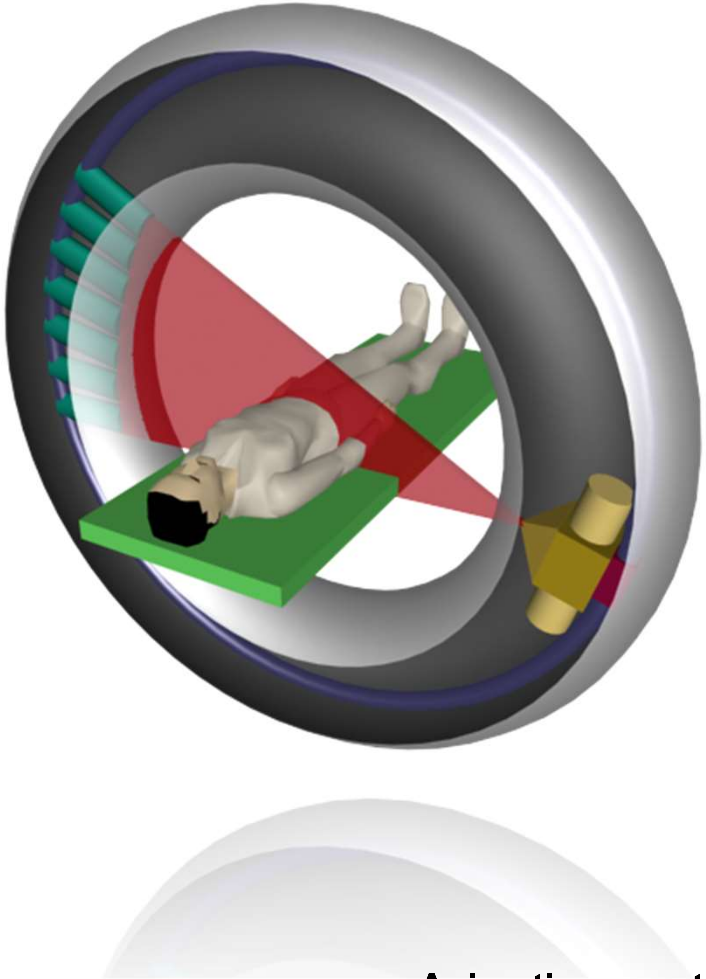
[1]Department of Radiology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand; [2]Department of Oral Diagnostic Sciences, Showa University School of Dentistry, Tokyo, Japan; [3]Department of Biomedical Engineering The I-STAR Laboratory, Johns Hopkins University, Baltimore, MD, USA; [4]X-Ray CT and Medical Imaging Laboratory, Biomedical Electronics and Systems Development Unit, National Electronics and Computer Technology Center, National Science and Technology Development Agency, Pathumthani, Thailand

how CT works…

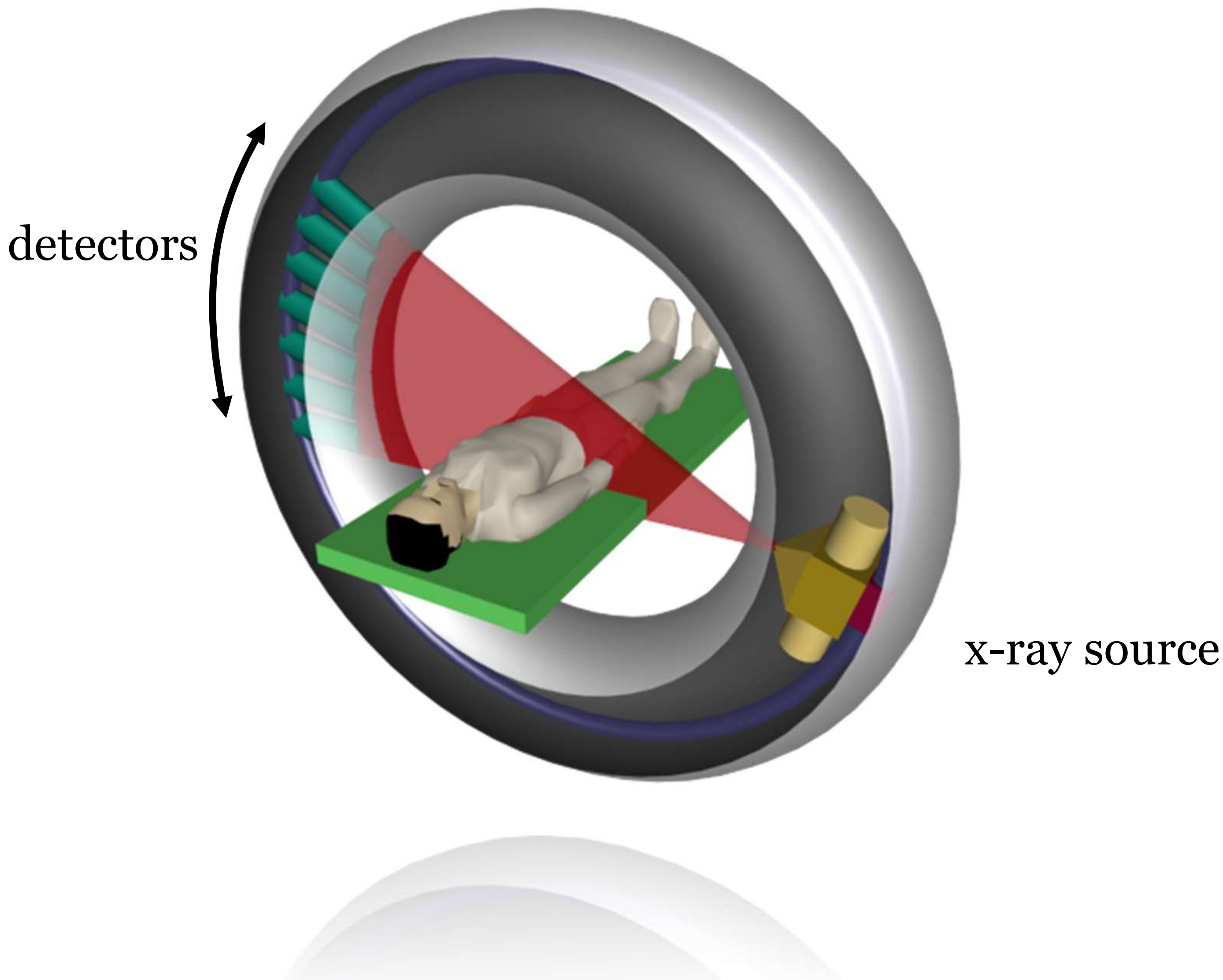
Godfrey Hounsfield

Allan Cormack

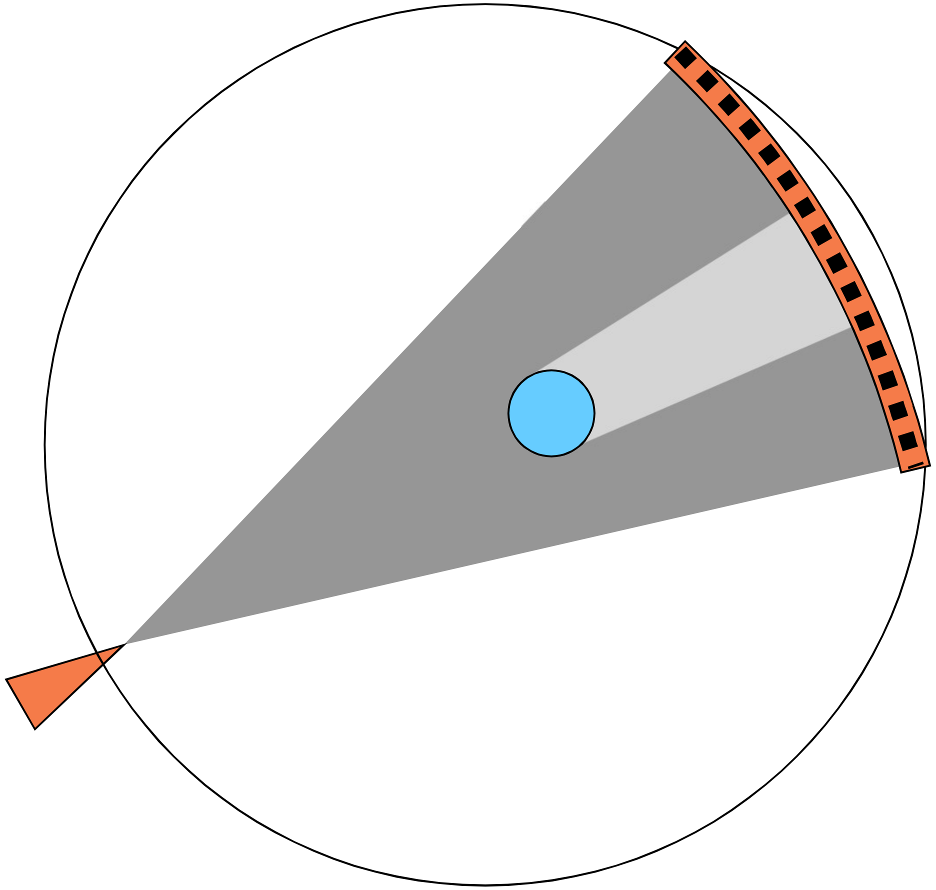
Nobel prize in Medicine, 1979



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

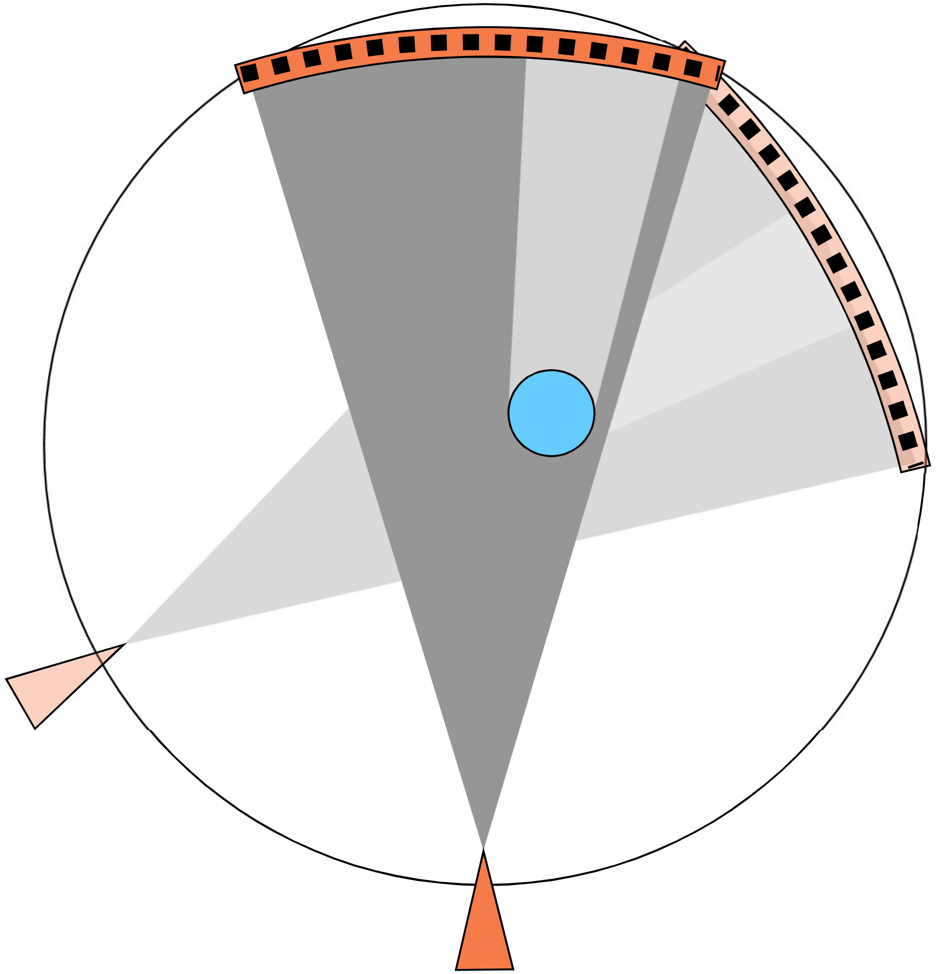

detectors
x-ray source

acquisition



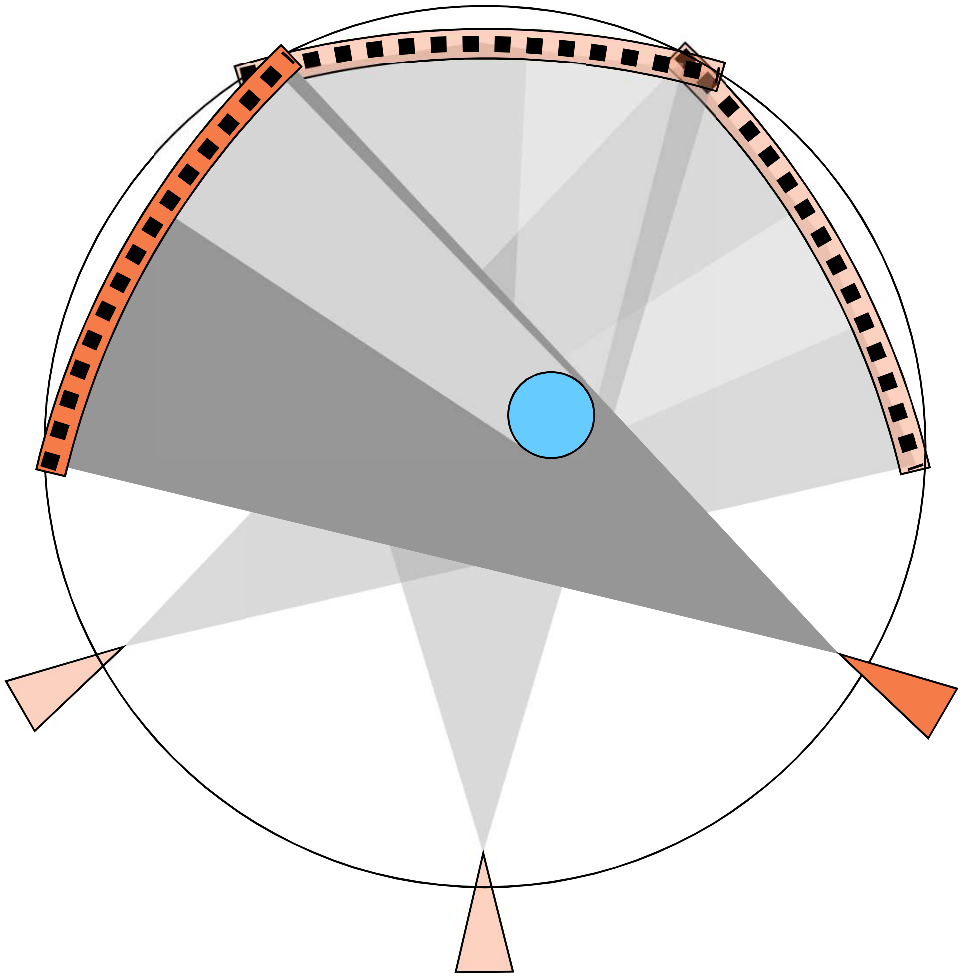
Animation courtesy of
Demetrios J. Halazonetis

acquisition



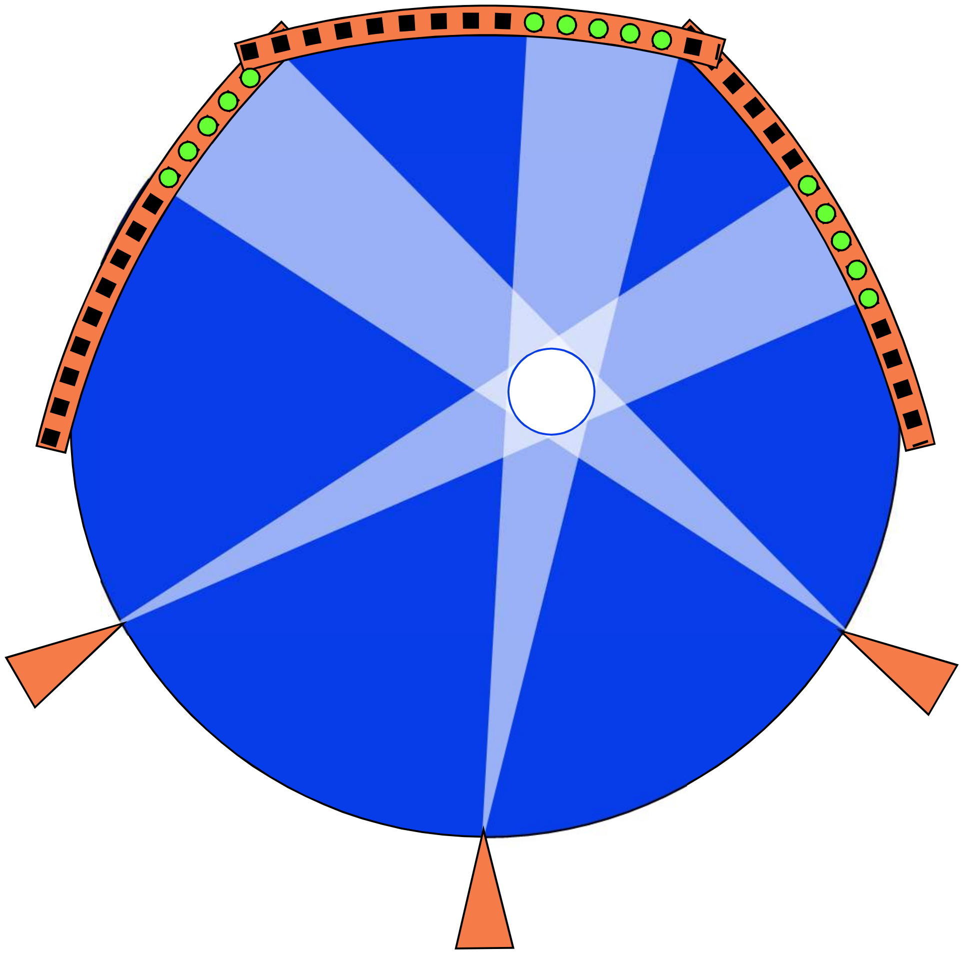
Animation courtesy of
Demetrios J. Halazonetis

acquisition



Animation courtesy of
Demetrios J. Halazonetis

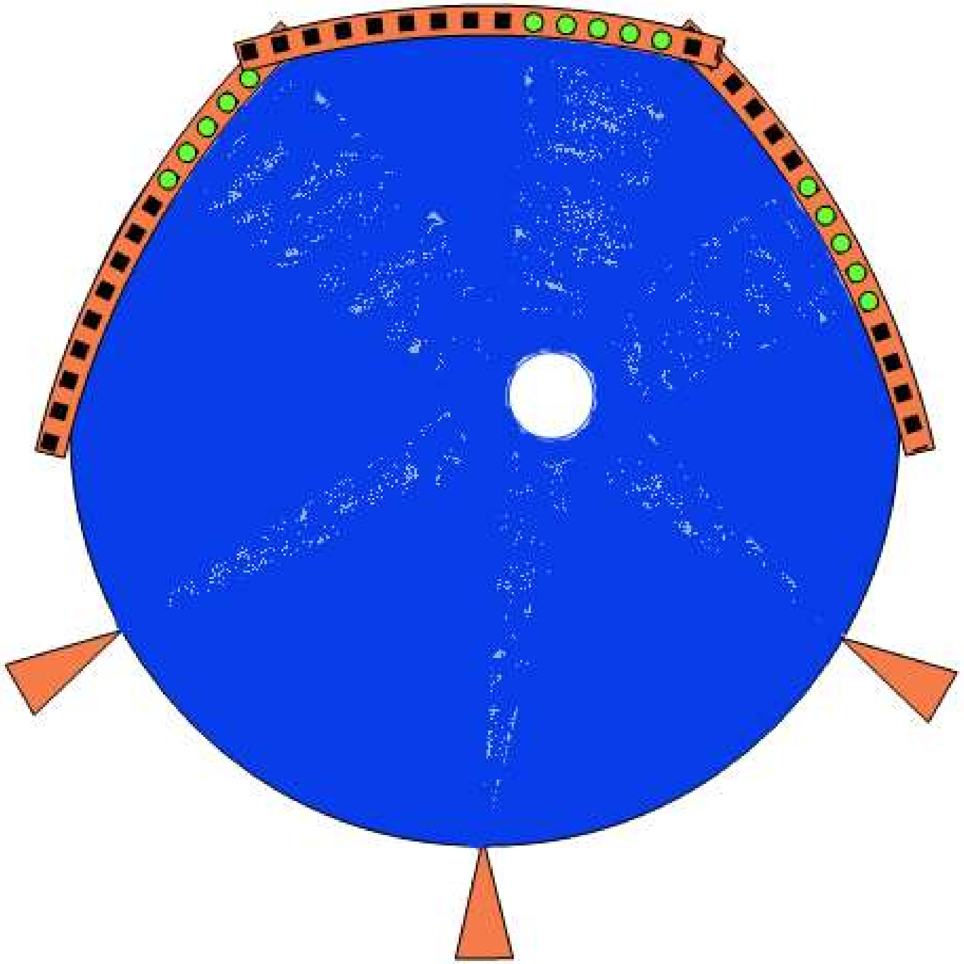
Reconstruction – filtered backprojection



Back Projection

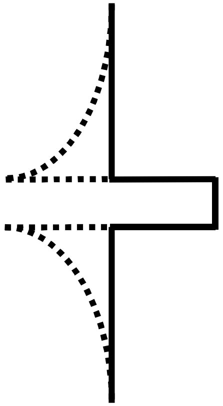
Animation courtesy of Demetrios J. Halazonetis

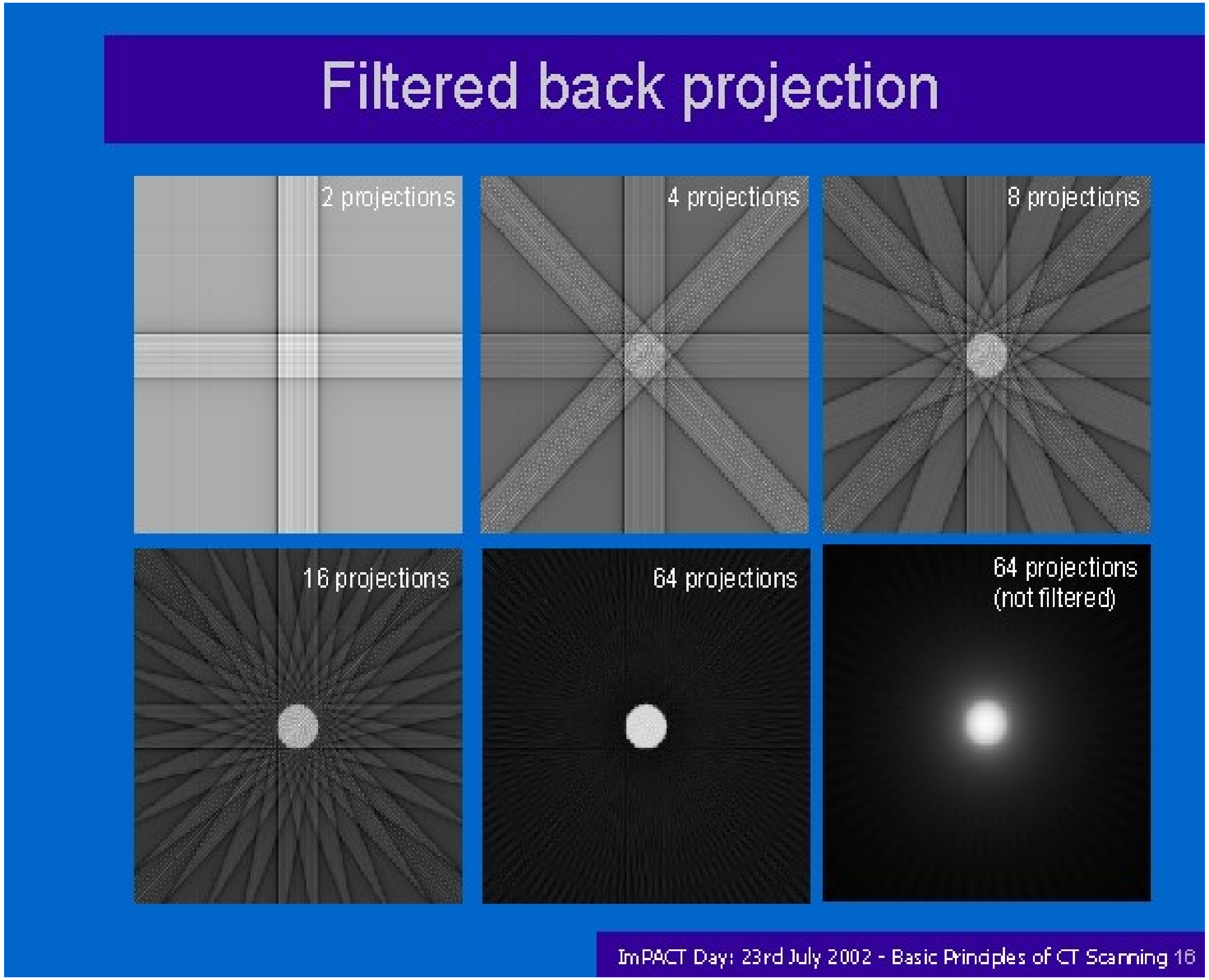
Reconstruction – filtered backprojection



Filtered Back Projection

Animation courtesy of Demetrios J. Halazonetis

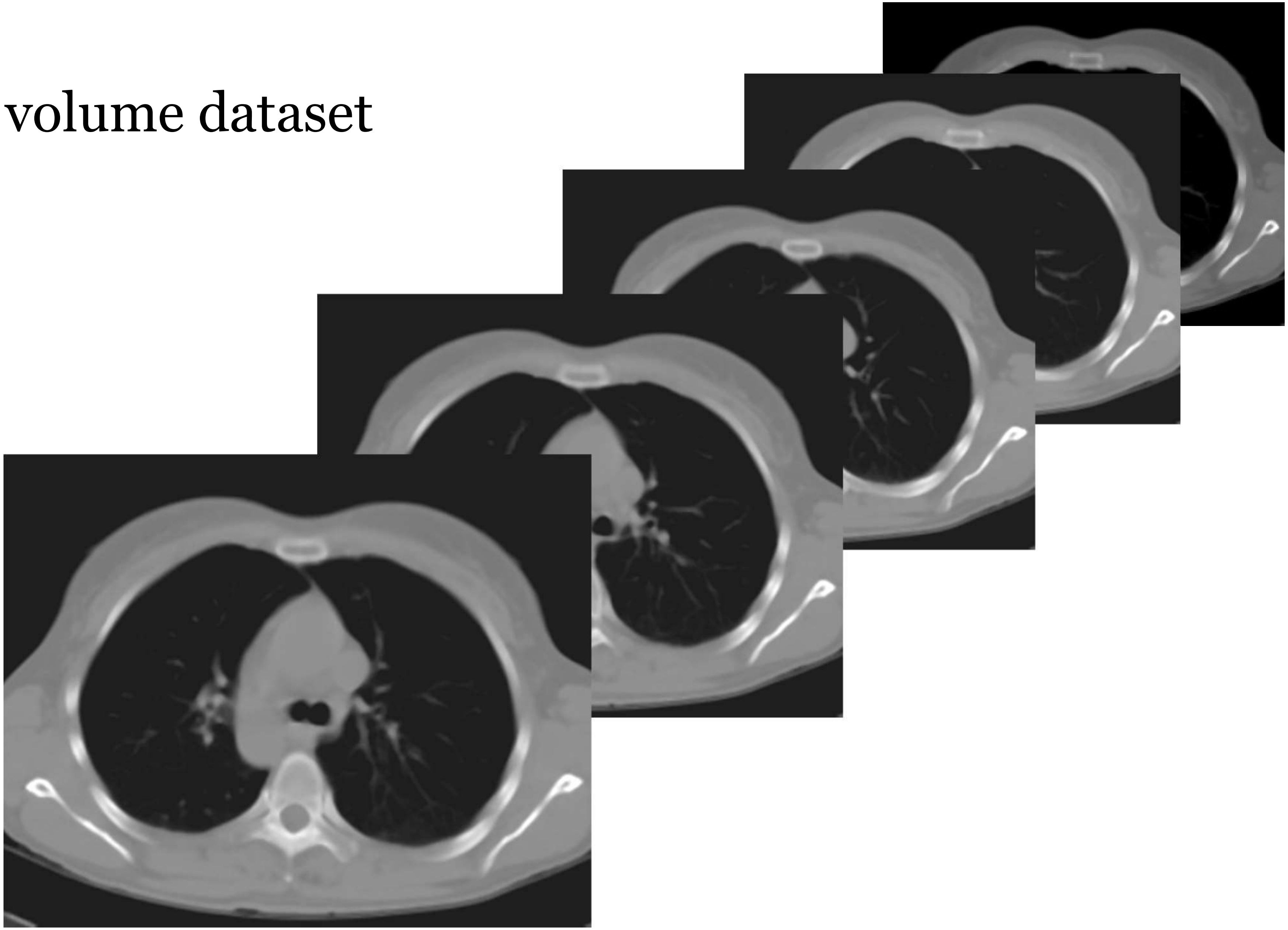




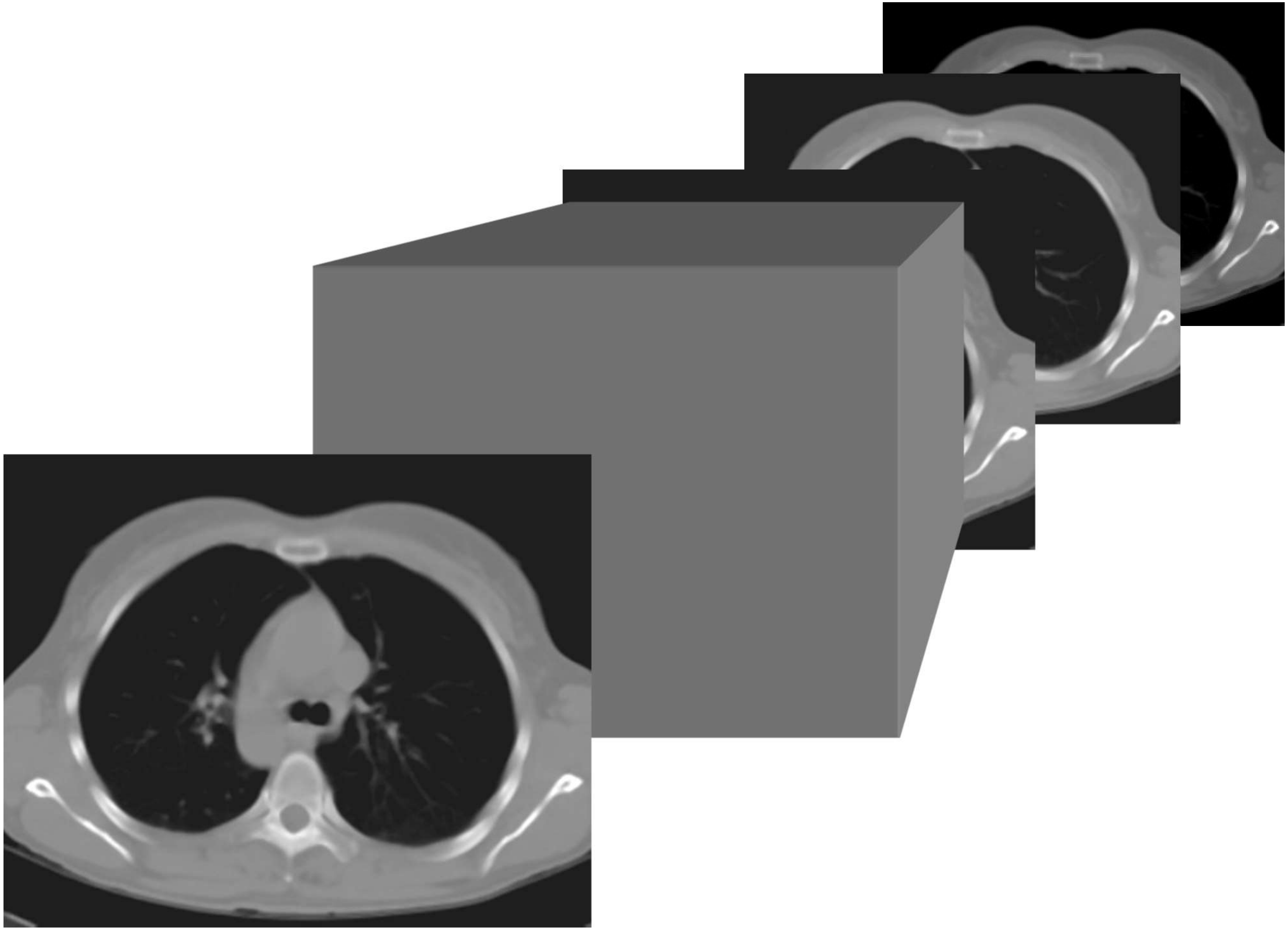
Also known as: "Convolution & Back Projection"

Slide from: http://www.impactscan.org

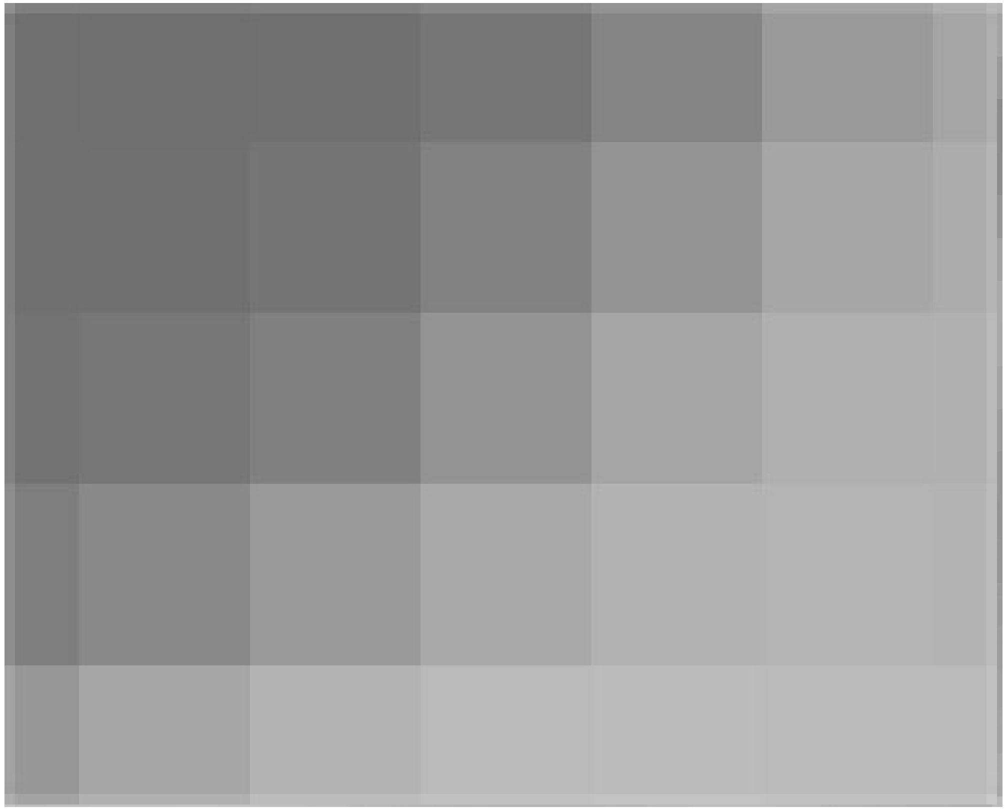
volume dataset



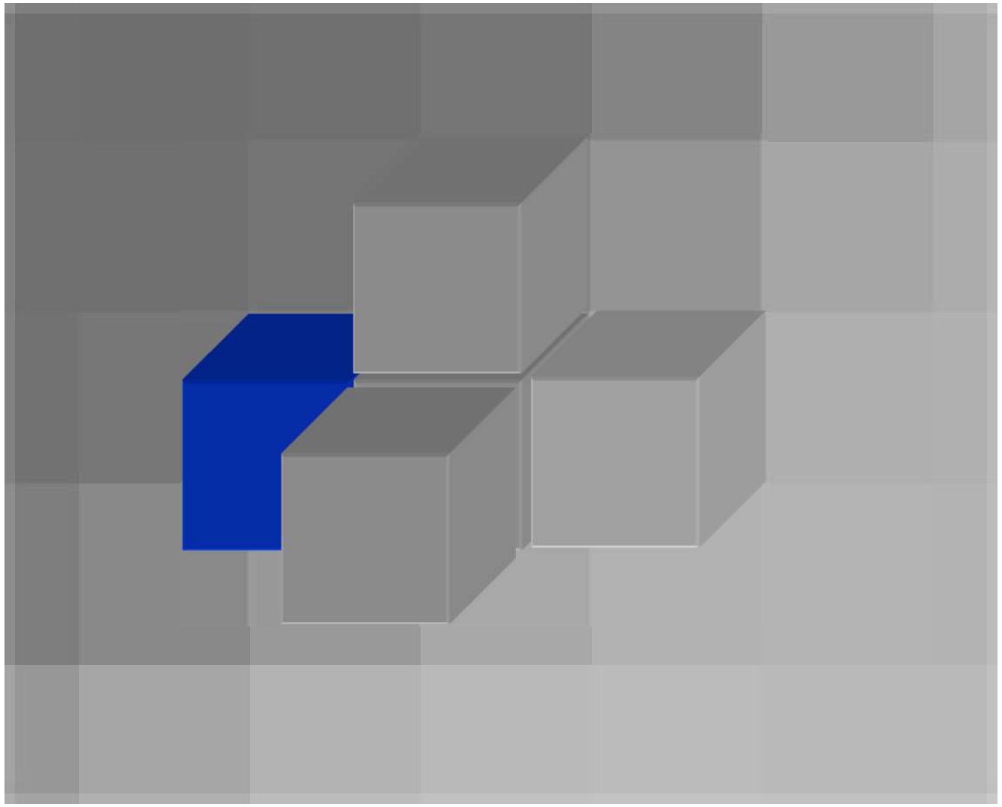
Animation courtesy of
Demetrios J. Halazonetis



Animation courtesy of
Demetrios J. Halazonetis

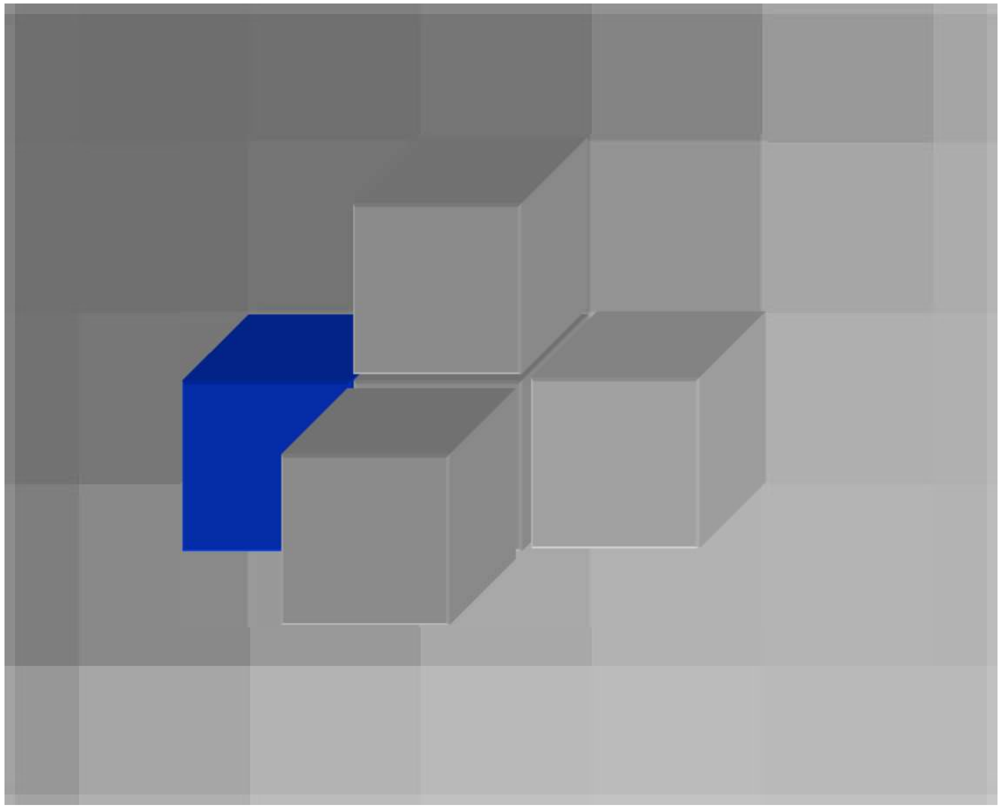


Animation courtesy of Demetrios J. Halazonetis



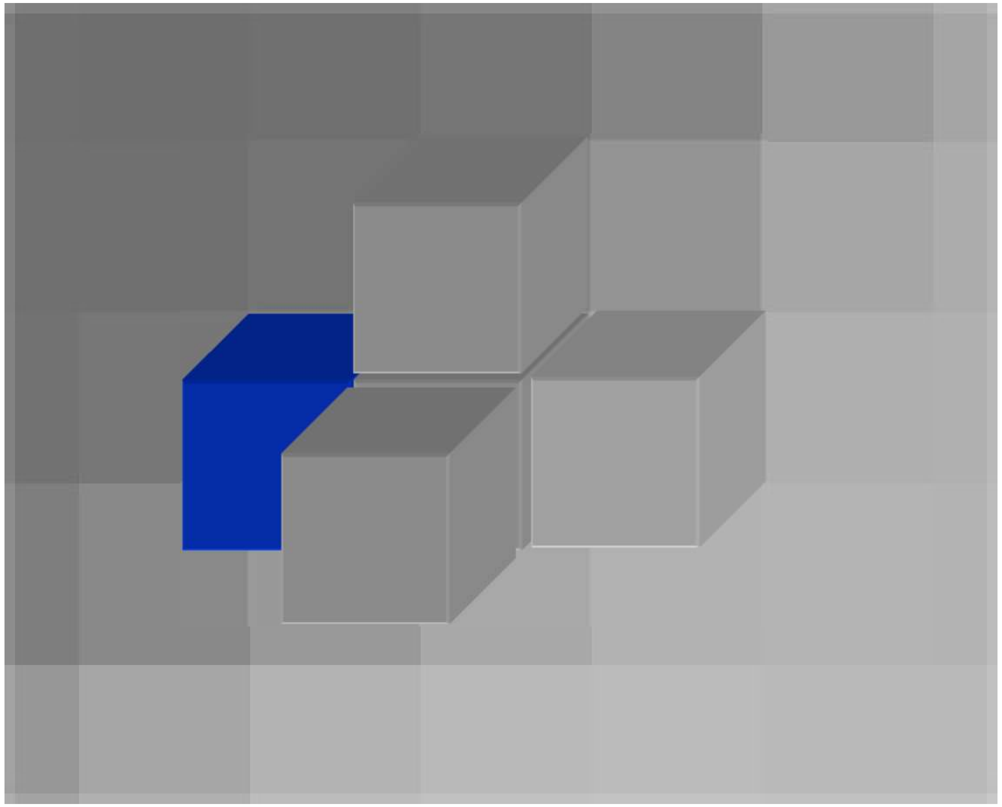
Animation courtesy of
Demetrios J. Halazonetis

Voxels (**Vo**lume **el**ements)



Animation courtesy of
Demetrios J. Halazonetis

Voxels (**Vo**lume **el**ements)

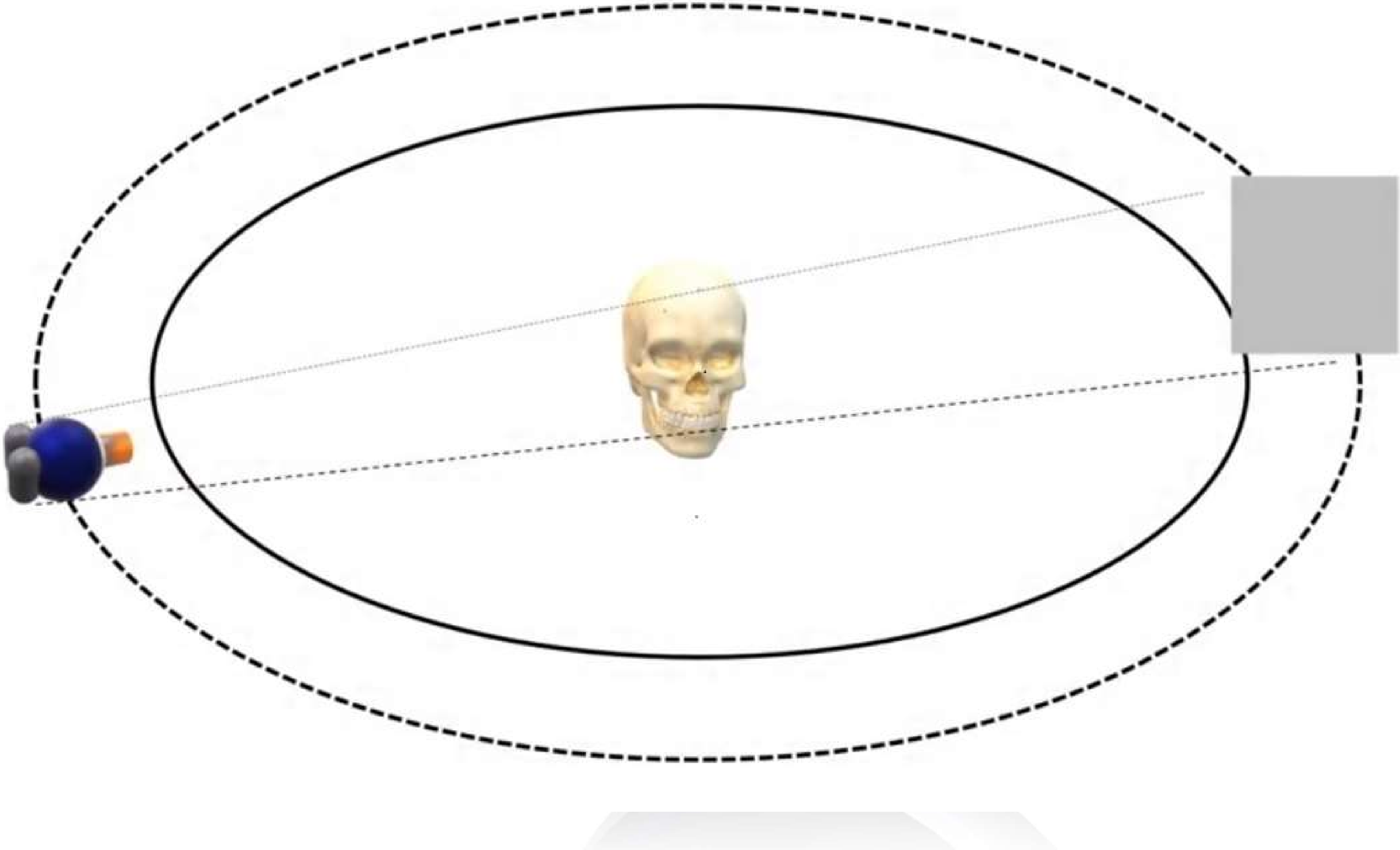


density:
0 - 4095

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

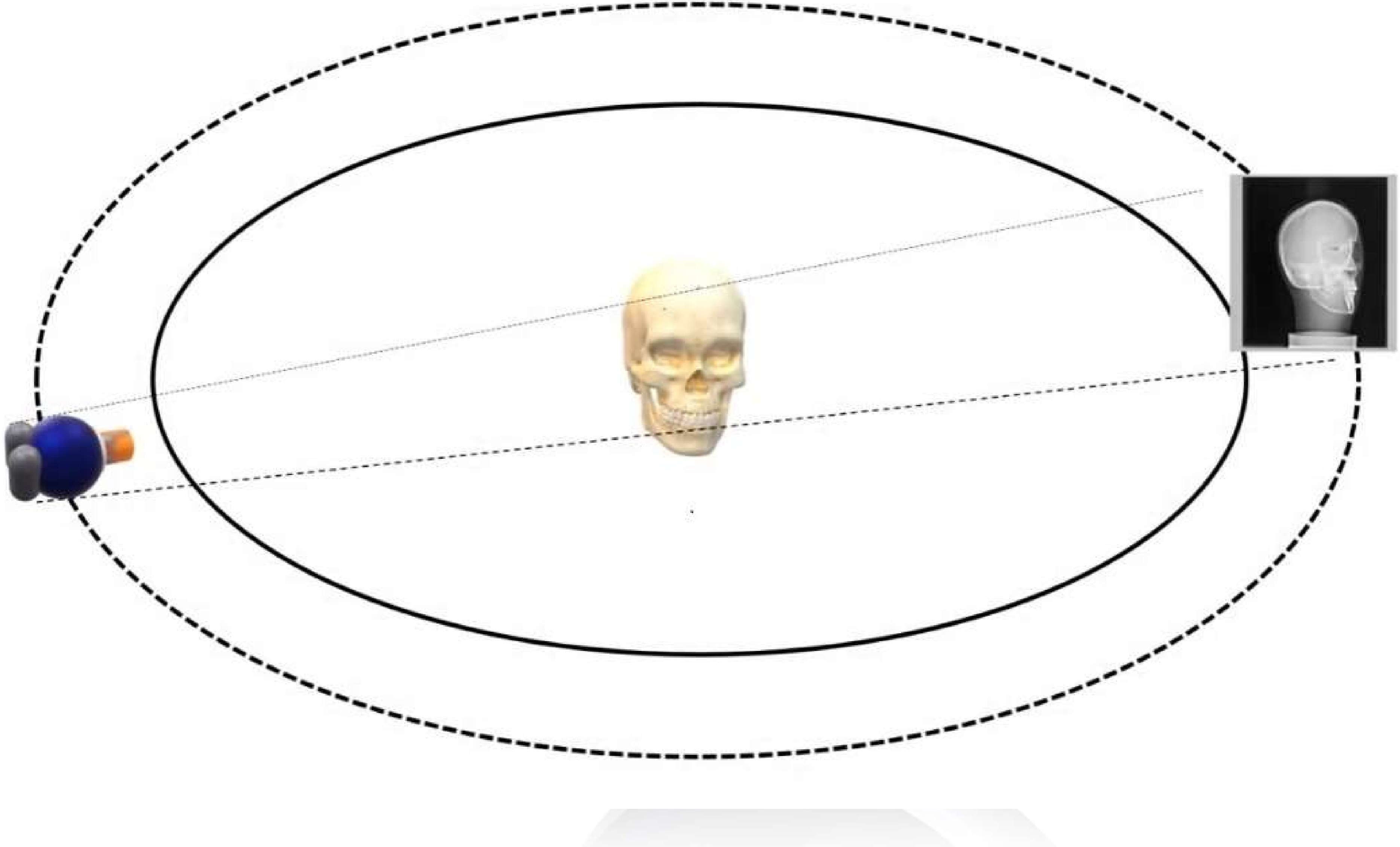
Animation courtesy of Demetrios J. Halazonetis

CBCT



cone-beam CT (CBCT)
patient sitting or standing

Acknowledgements to
Maxwell Dziku



cone-beam CT (CBCT)
patient sitting or standing

Acknowledgements to
Maxwell Dziku

YouTube Videos

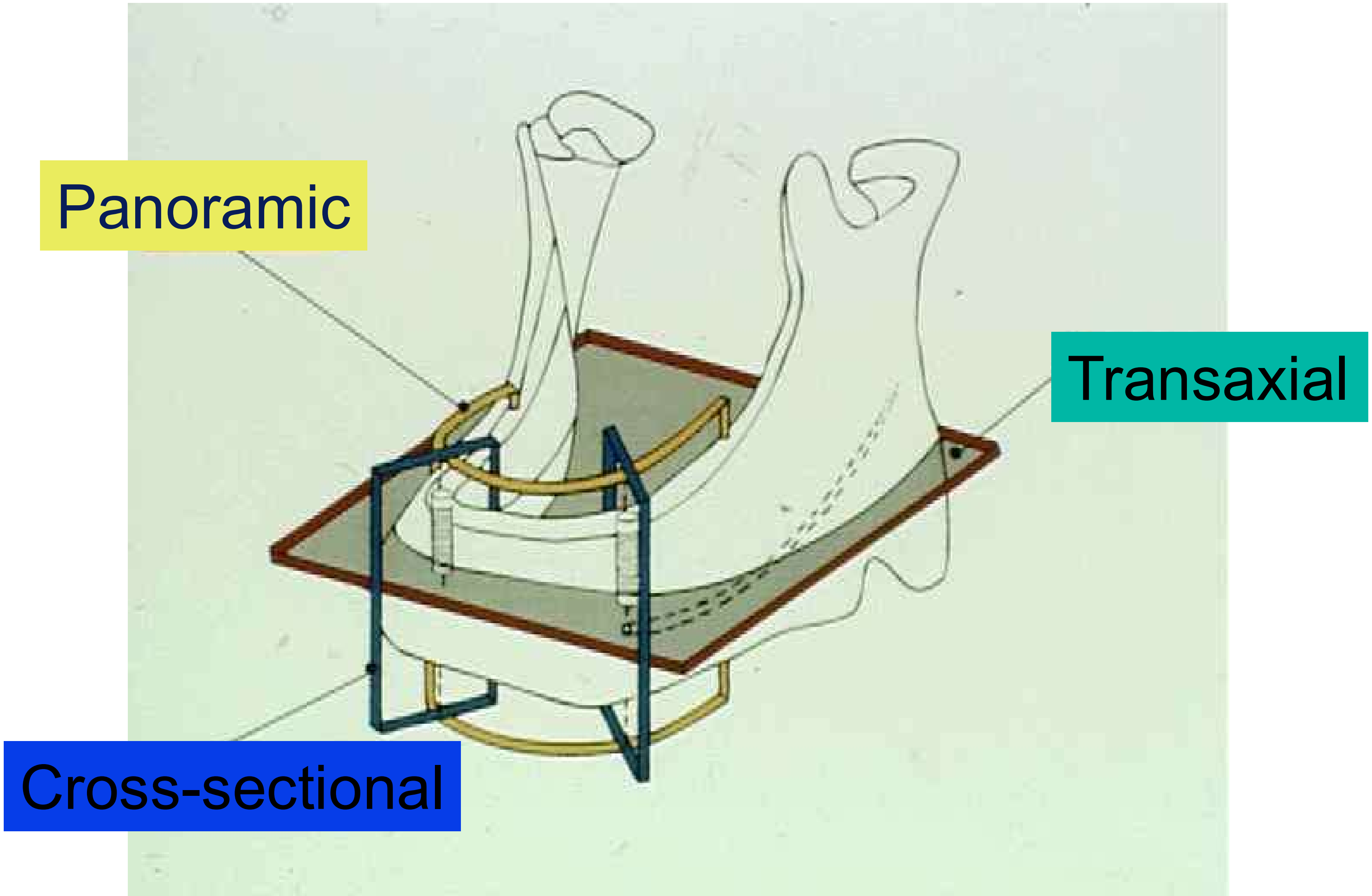
Filtered back-projection reconstruction of head slice - Samuli Siltanen

NewTom VGi evo

CBCT scans explained - Atlanta Endodontics

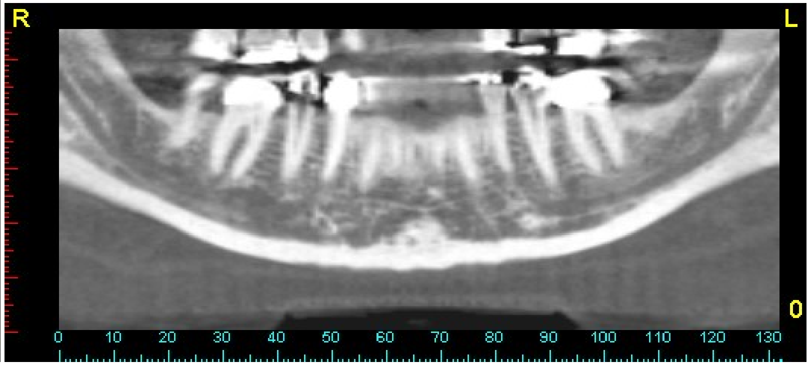
CBCT animation video - Maxwell Dziku

Basic CBCT images



Basic CBCT images

Axials



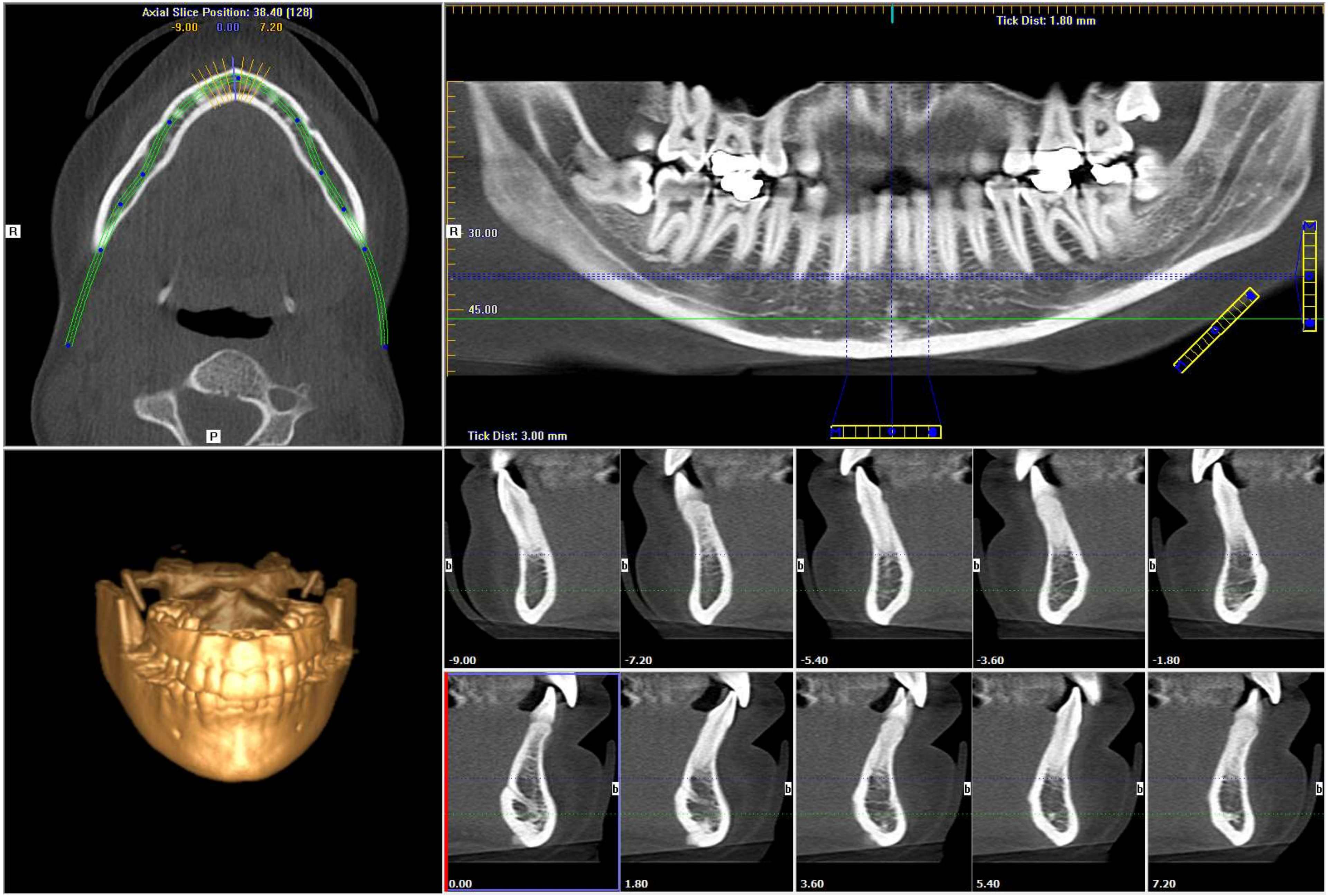
Panoramics

Cross Sections

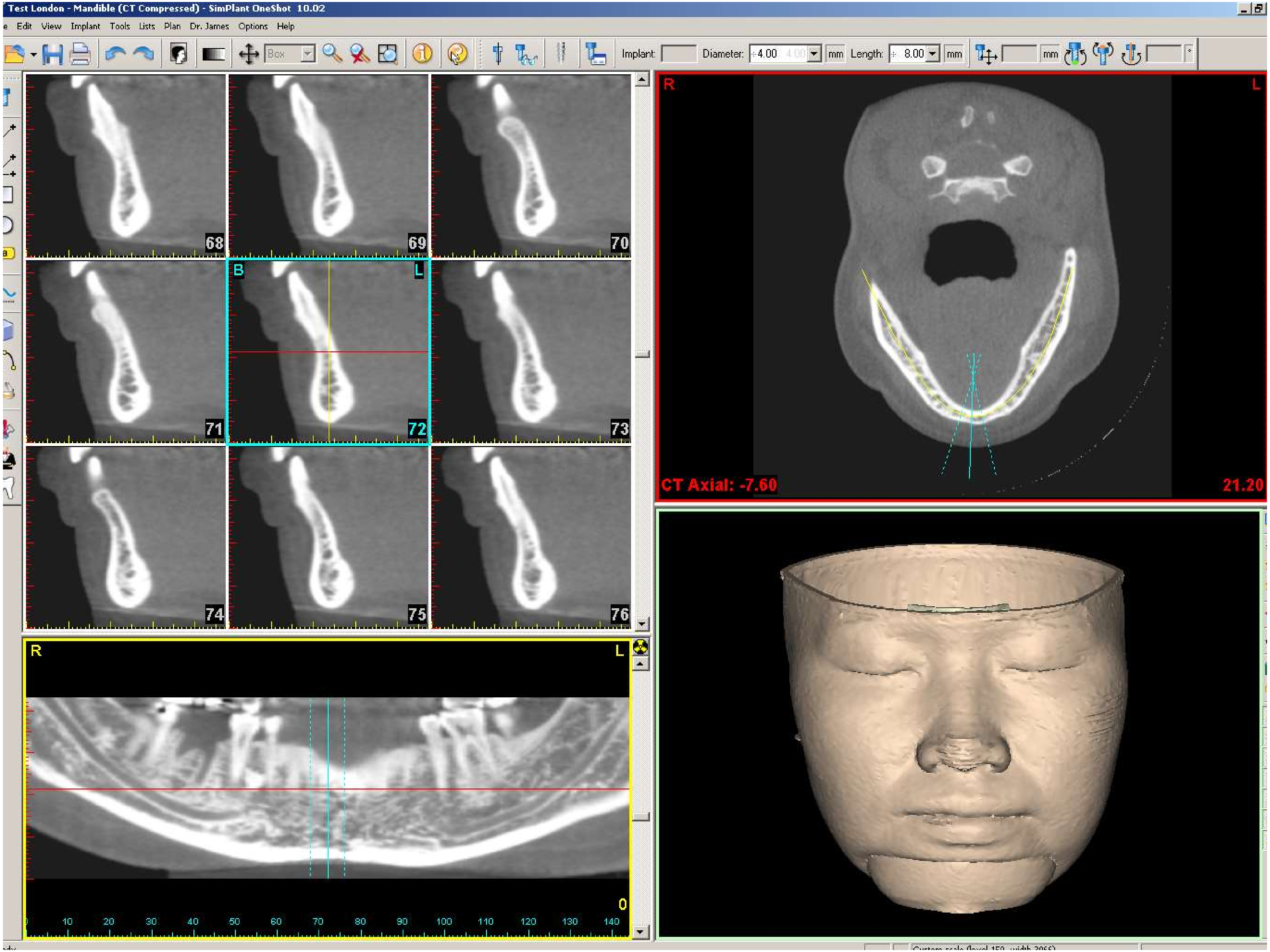
Sagittal

Coronal

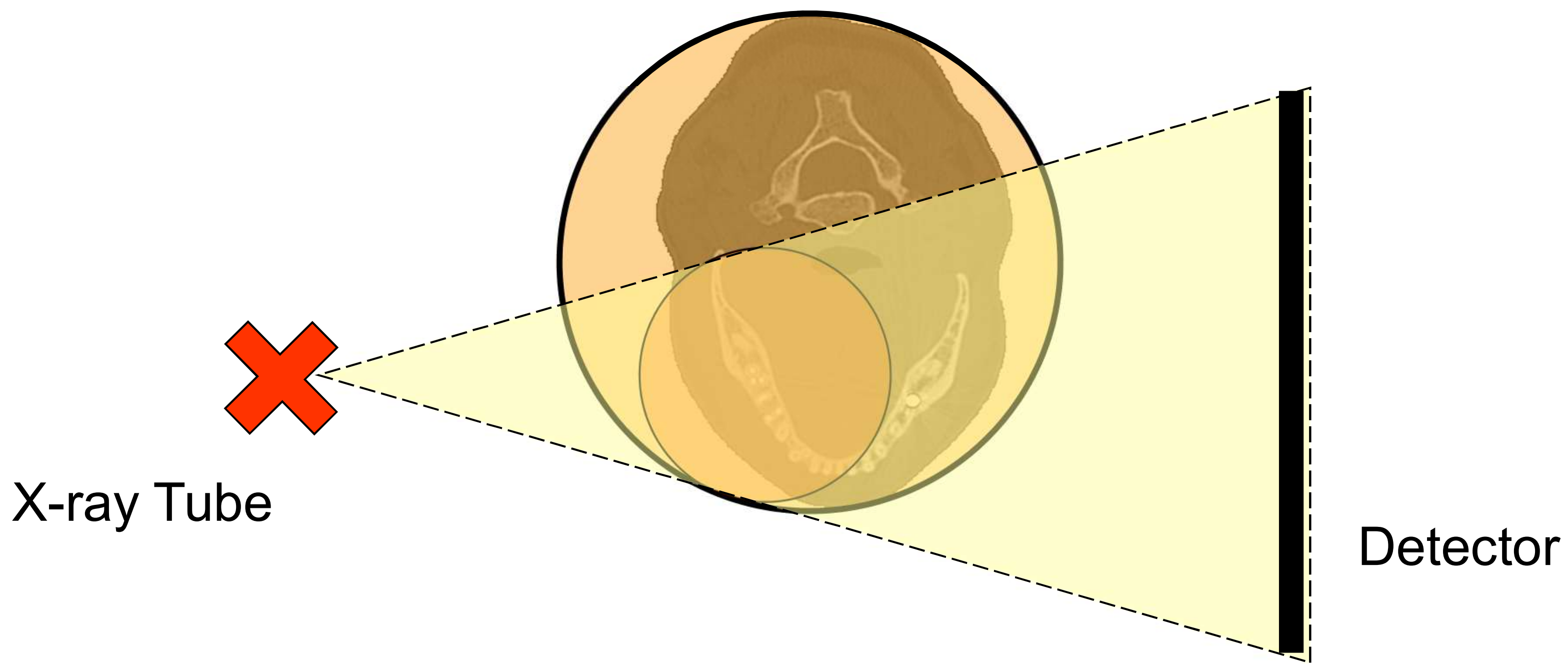
i-CATVision™



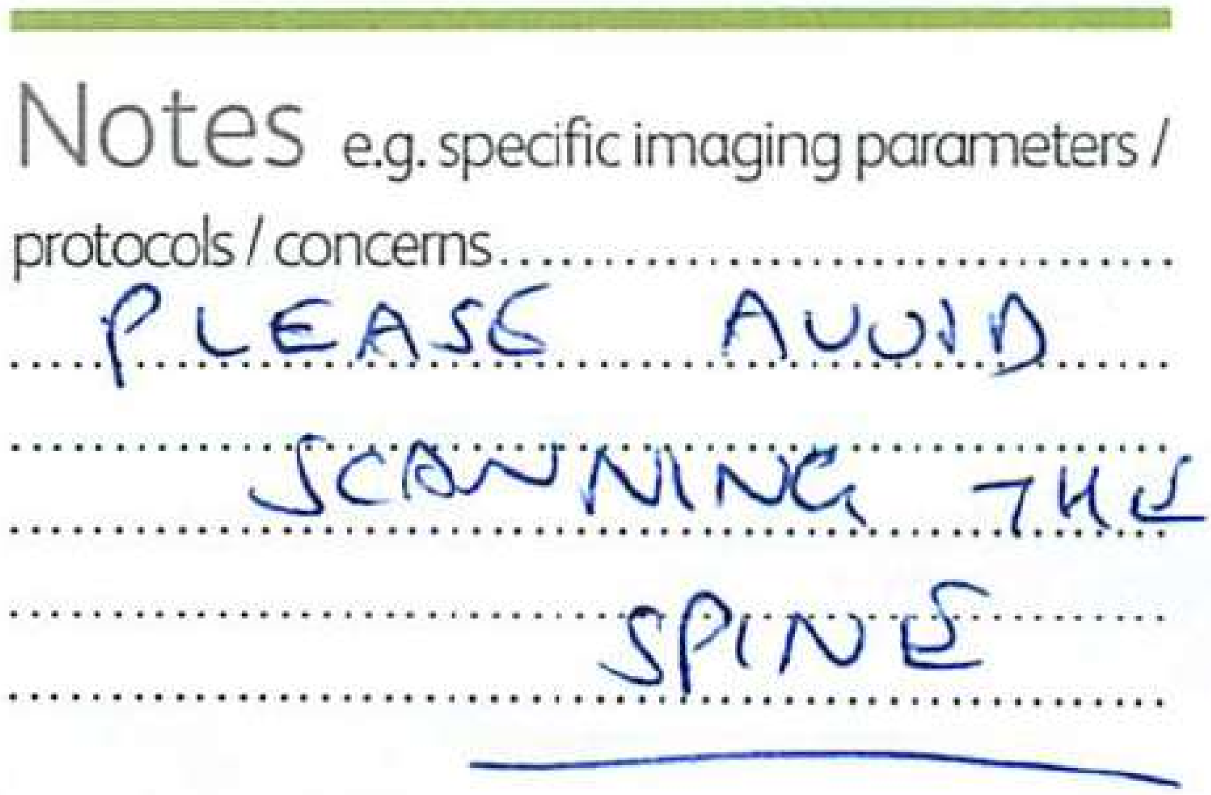
Axial Slice Position: 38.40 (128)
-9.00 0.00 7.20
R
P
Tick Dist: 1.80 mm
R
30.00
45.00
Tick Dist: 3.00 mm
-9.00
-7.20
-5.40
-3.60
-1.80
0.00
1.80
3.60
5.40
7.20


Test London - Mandible (CT Compressed) - SimPlant OneShot 10.02
Edit View Implant Tools Lists Plan Dr. James Options Help
Box
Implant:
Diameter: 4.00
mm
Length: 8.00
mm
mm
68
69
70
B
L
71
72
73
74
75
76
R
L
CT Axial: -7.60
21.20
R
L
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140

Small Field Of View CBCT (sectional scans)



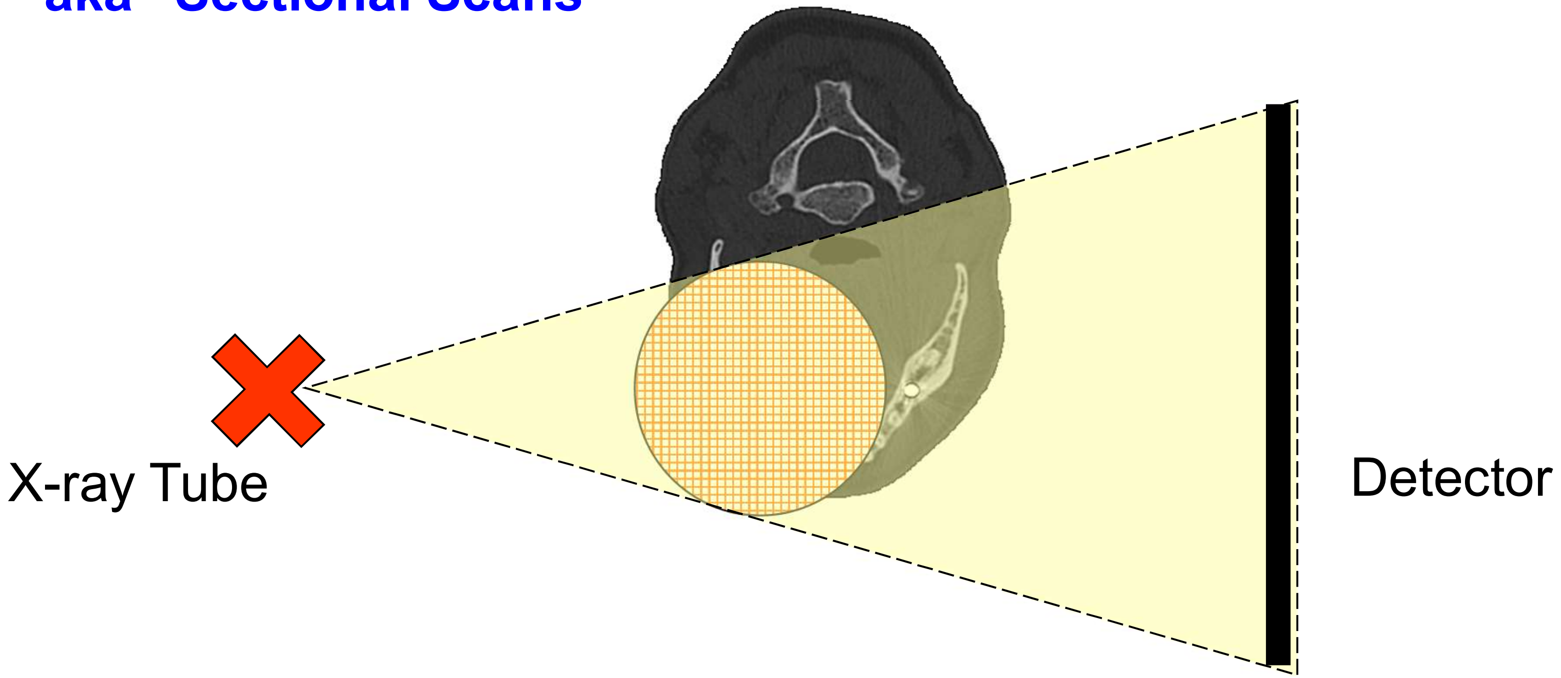
The parts you can't see receive a low dose (but it is not zero)


Notes e.g. specific imaging parameters / protocols / concerns
PLEASE AVOID SCANNING THE SPINE

"Sorry mate – no can do!"

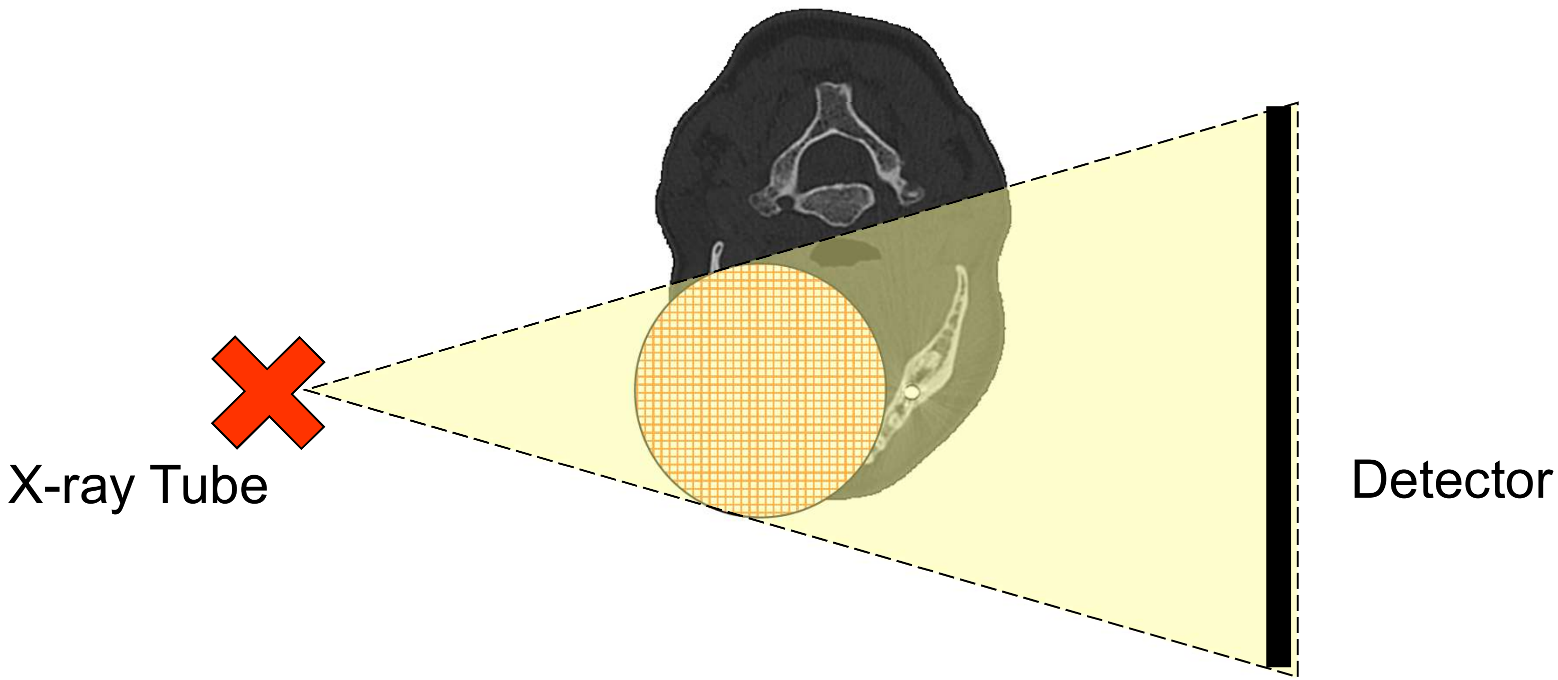
Advantages of Small Field Of View CBCT

aka "Sectional Scans"



- **Lower dose**
- **Less data to Report on**
- **Smaller detectors means lower cost**
- **Smaller voxels for the same amount of data storage**

Limitations of Small Field Of View CBCT



- 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
- Densities may change with size of Field Of View

4cm x 4cm

6cm x 4cm

8cm x 5cm

10cm x 6cm

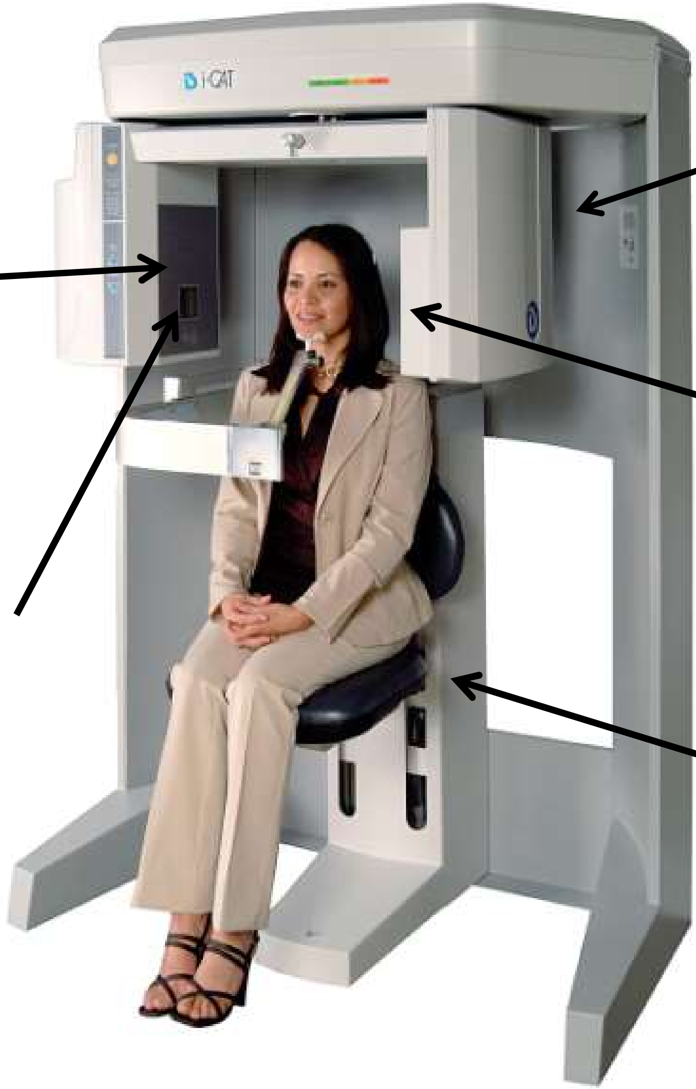
Outline of Lectures

- ✔ Introduction / Disclosures
- ✔ Principles of CBCT Imaging
- ✔ CBCT Image Acquisition and Processing
- Apparatus and Equipment
- Radiation Physics in relation to CBCT
- Radiation Protection in relation to CBCT
- Quiz

Top of the Line Cone Beam CT Scanner

pulsed x-ray tube

adjustable collimator 4 to 10cm height



fast scan time low dose

Typical Mn 35μSv

large detector

adjustable chair

Around £125K

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

Entry Level Cone Beam CT Scanner

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

Typical Mn 50µSv

small detector

x-ray tube
may or may not
be pulsed

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

Around £40K

no chair

You get what you pay for !

Image Quality in CBCT scans

- Noise

- *electronic noise (dark current)*
- *photon noise (not enough dose)*

- Artefact

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

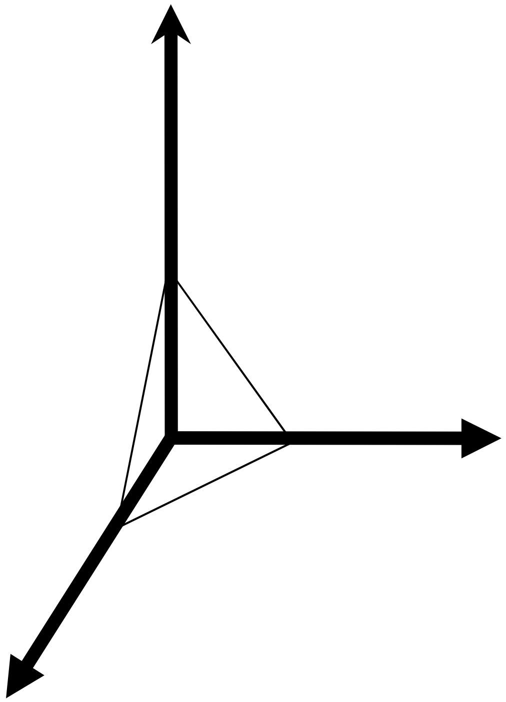
- Spatial Resolution (resolution at high contrast)

- *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)*

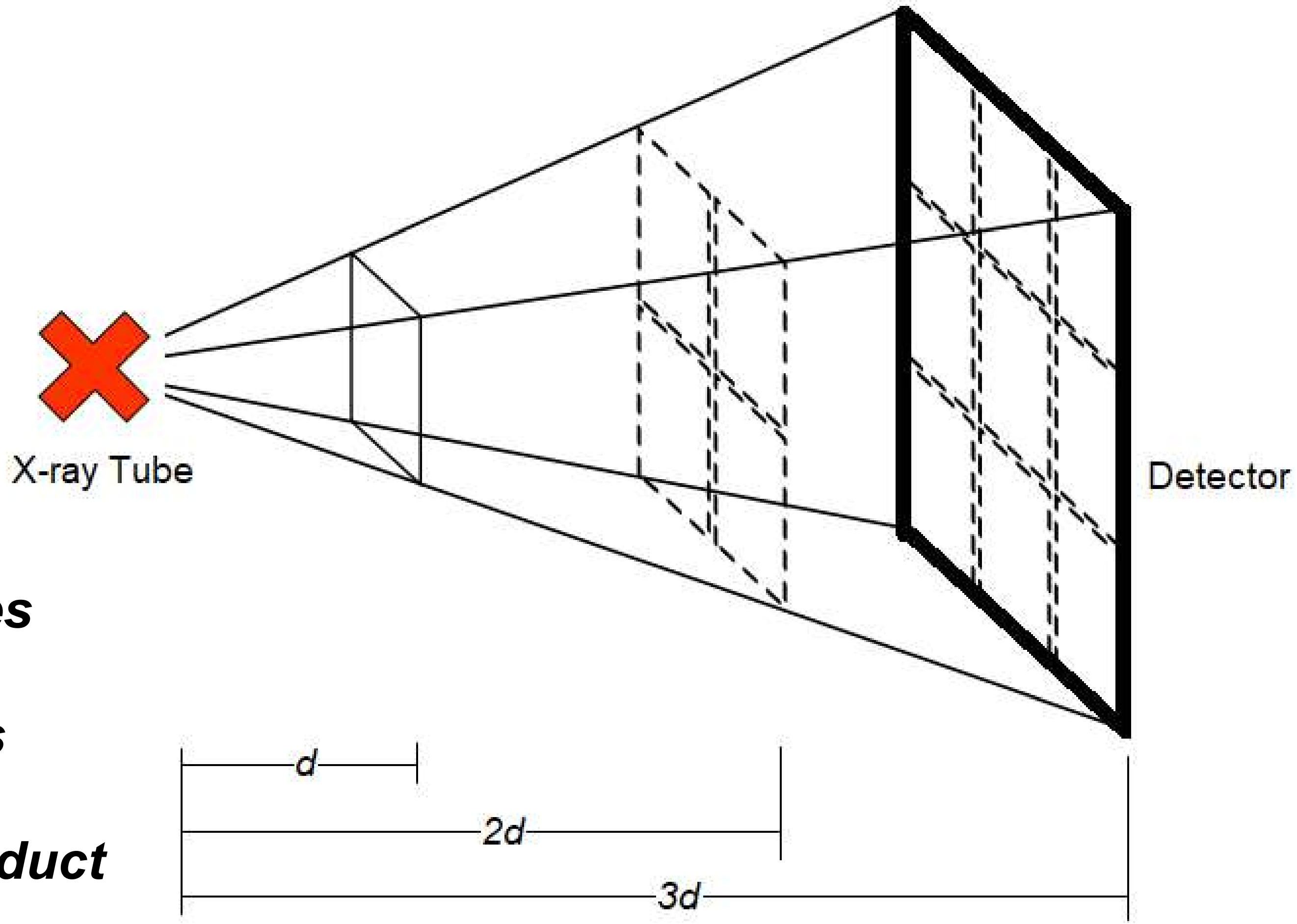
The impossible dream



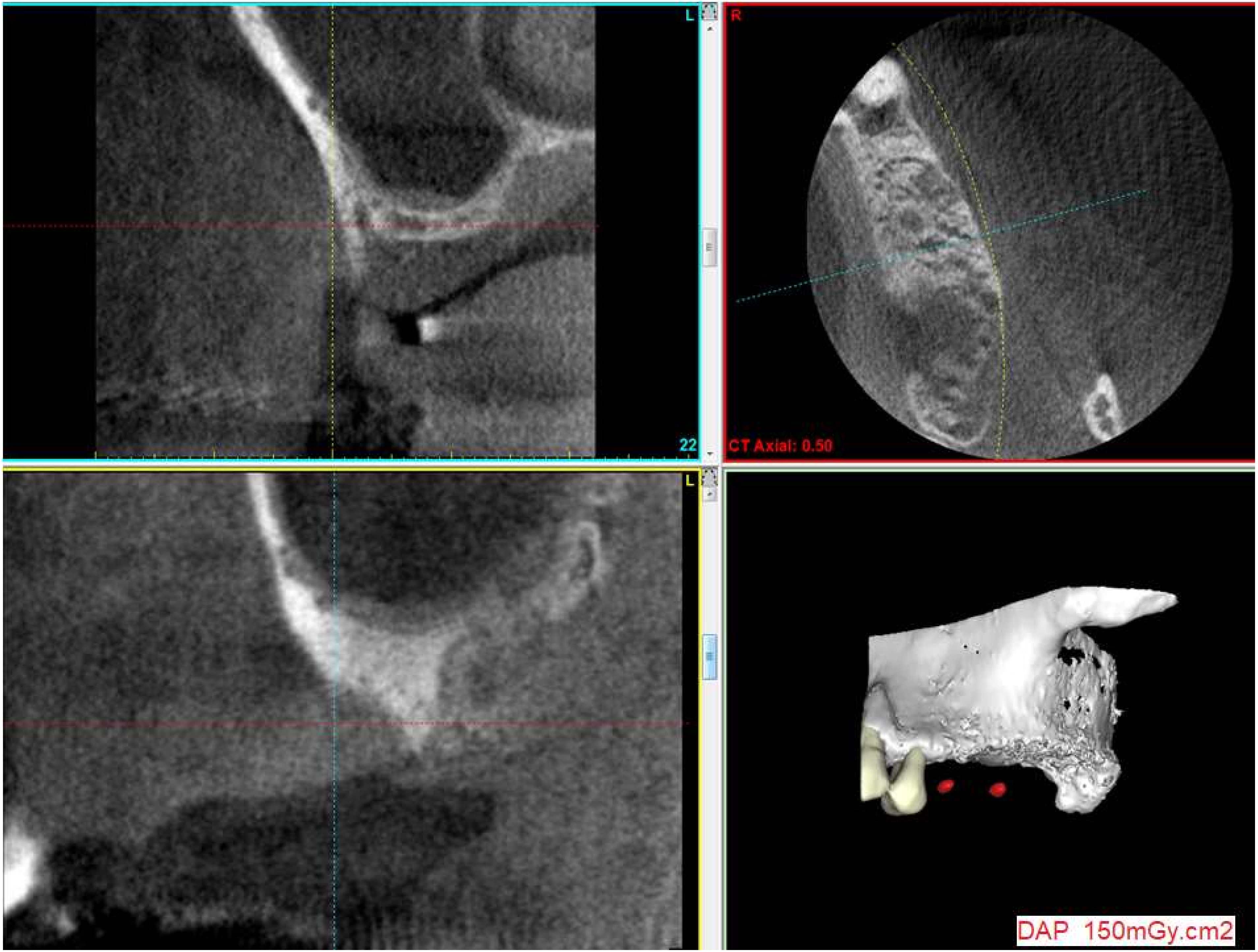
A good scanner will offer a range of voxel sizes, mAs and field sizes to suit the imaging task at hand.

Dose Area Product (DAP)

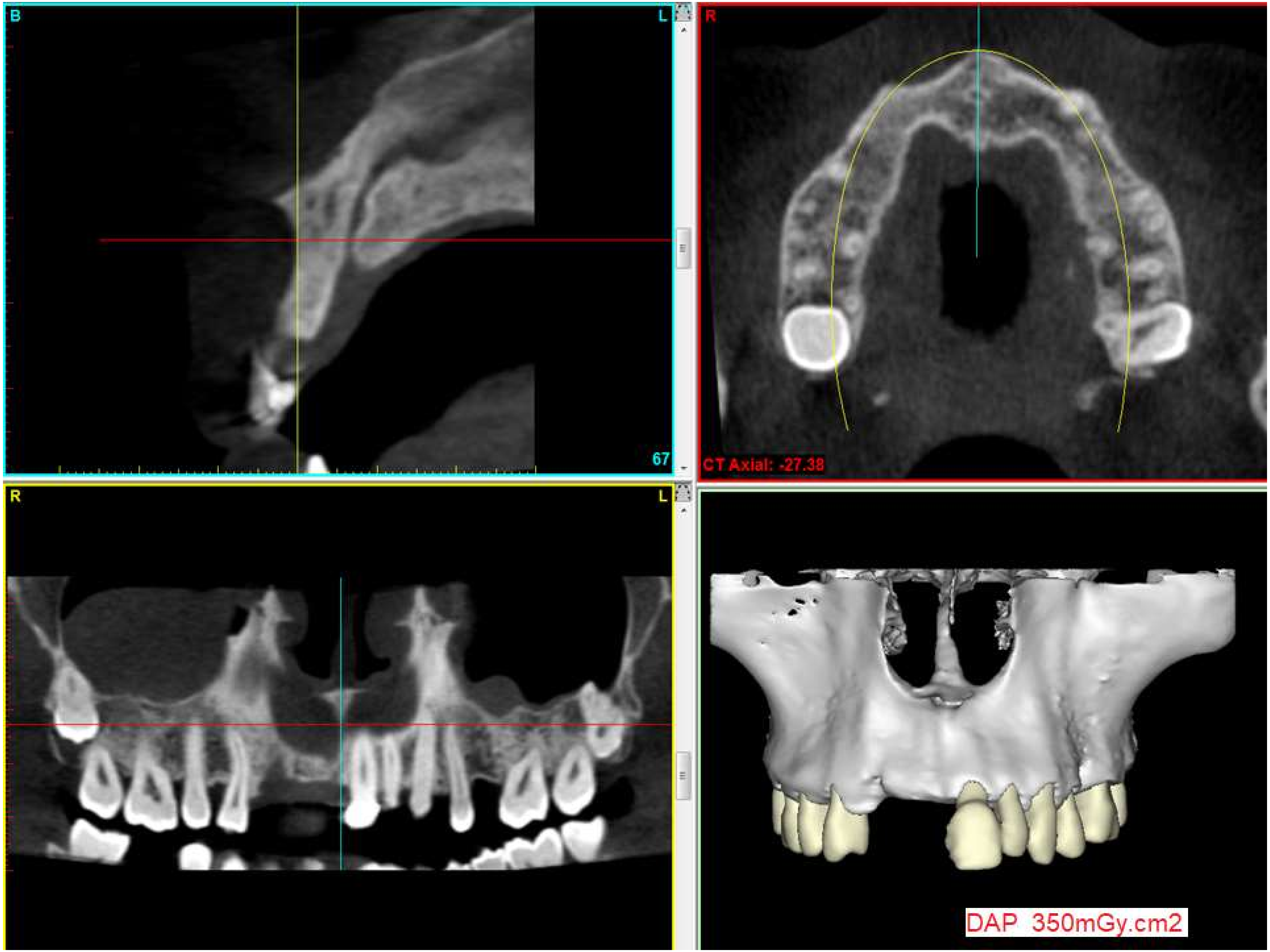
measured in mGy.cm²

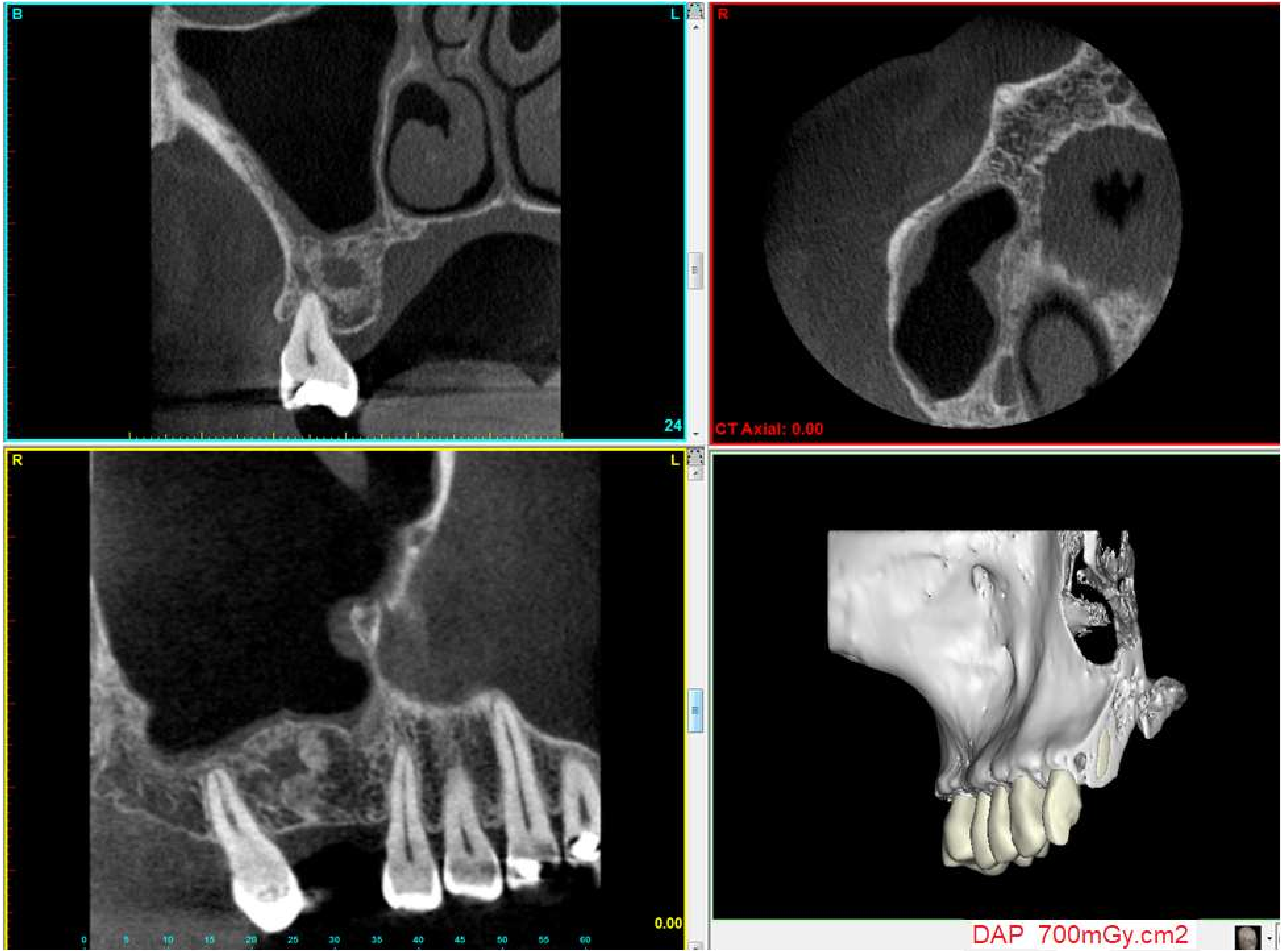


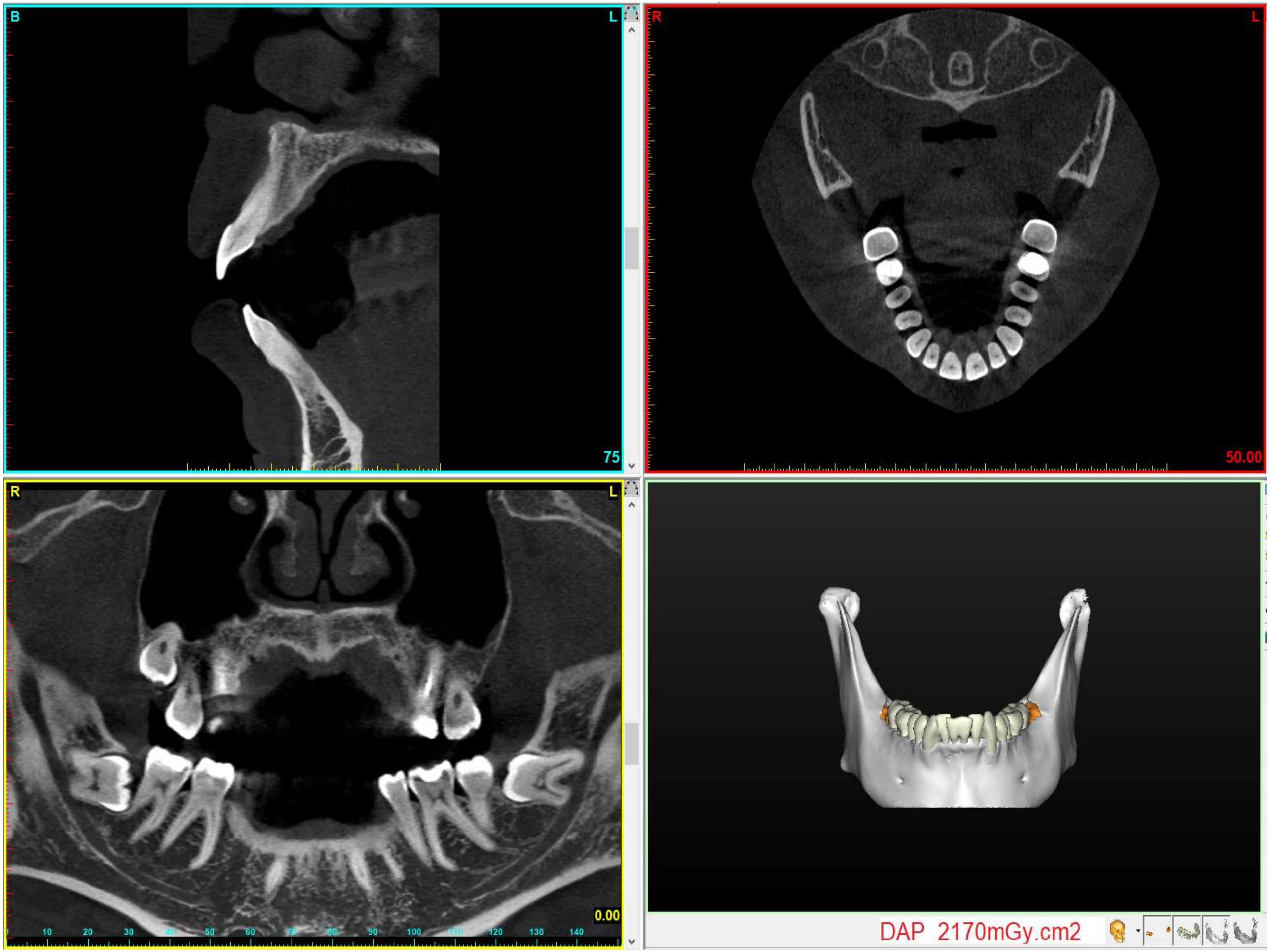
- ***The Dose decreases as $1/d^2$***
- ***The Area increases as $1/d^2$***
- ***The Dose Area Product remains constant***


L
22
R
CT Axial: 0.50
L
DAP 150mGy.cm2


64.00
CT Axial: -24.30
24.40
L
0.00
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
DAP 250mGy.cm2


B
L
67
R
CT Axial: -27.38
R
L
DAP 350mGy.cm2


B
L
24
R
CT Axial: 0.00
R
L
0.00
0 5 10 15 20 25 30 35 40 45 50 55 60
DAP 700mGy.cm2


B
L
75
R
L
50.00
R
L
0.00
10
20
30
40
50
60
70
80
90
100
110
120
130
140
DAP 2170mGy.cm2

Reasonable DAP Values

ONE QUADRANT – around 150 - 250mGy.cm^2

ONE JAW – around 350 – 500mGy.cm^2

BOTH JAWS – around 650 – 1000mGy.cm^2

Should set up Diagnostic Reference Levels (DRLs) for each x-ray procedure (not just cone beam)

Diagnostic Reference Levels

- **DRLs are dose levels which are not expected to be exceeded for standard procedures (they are not Dose Limits – they are guidelines)**
- **Local DRLs should be set for each type of x-ray procedure**
- **Local DRLs should not normally exceed National DRLs.**

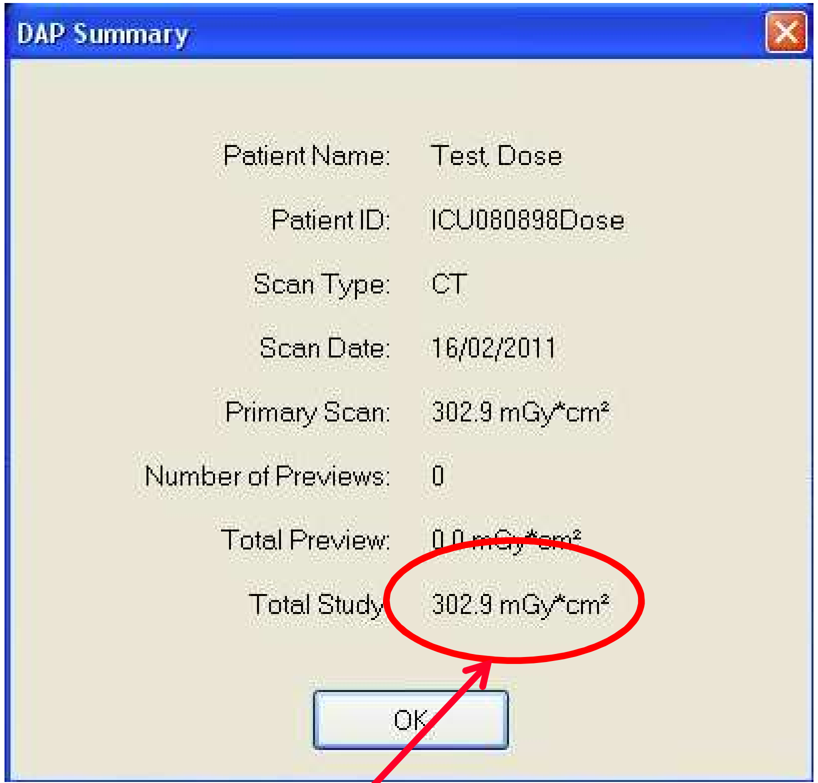
UK National DRLs

- **For intra-orals the National DRLs are 1.2 mGy for adults and 0.7 mGy for children (entrance doses)**

- **For DPTs the National DRLs are 81 $mGy.cm^2$ for adults and 60 $mGy.cm^2$ for children (Dose Area Product, DAP)**

- **For CBCT the National DRLs are 265 mGy.cm2 for adults (maxillary molar implant) and 170 mGy.cm2 for children (impacted maxillary canine) (Dose Area Product, DAP) THIS IS FOR 1 QUADRANT (Small Field Of View scan)**

Estimating the Effective Dose from the DAP

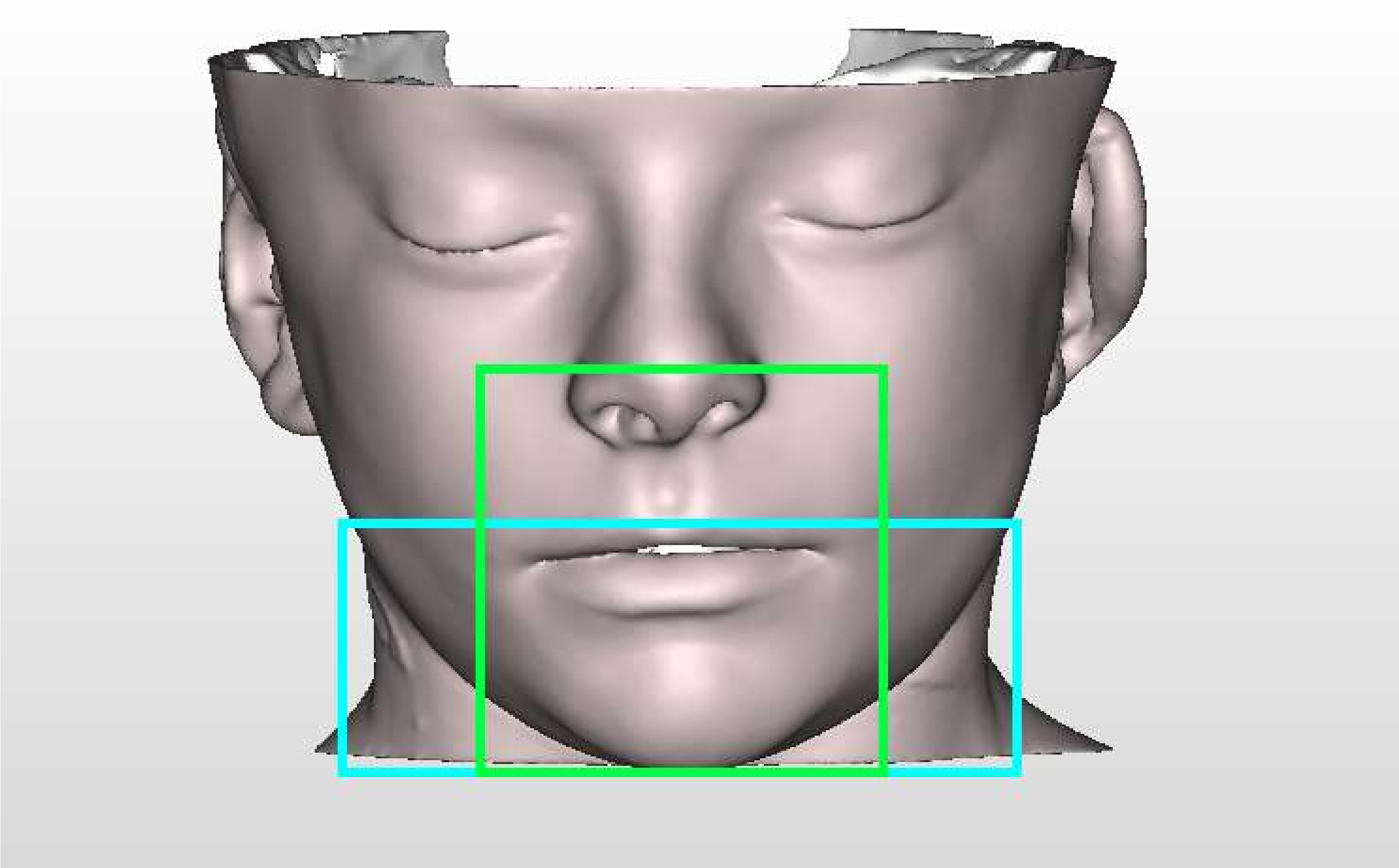


Multiply DAP by 0.1 for Maxilla or 0.15 for Mandible to get the Effective Dose in microSieverts (µSv)

ROUGHLY

Accuracy: ±50% **Mx 30µSv or Mn 45µSv**

Use the DAP with caution!



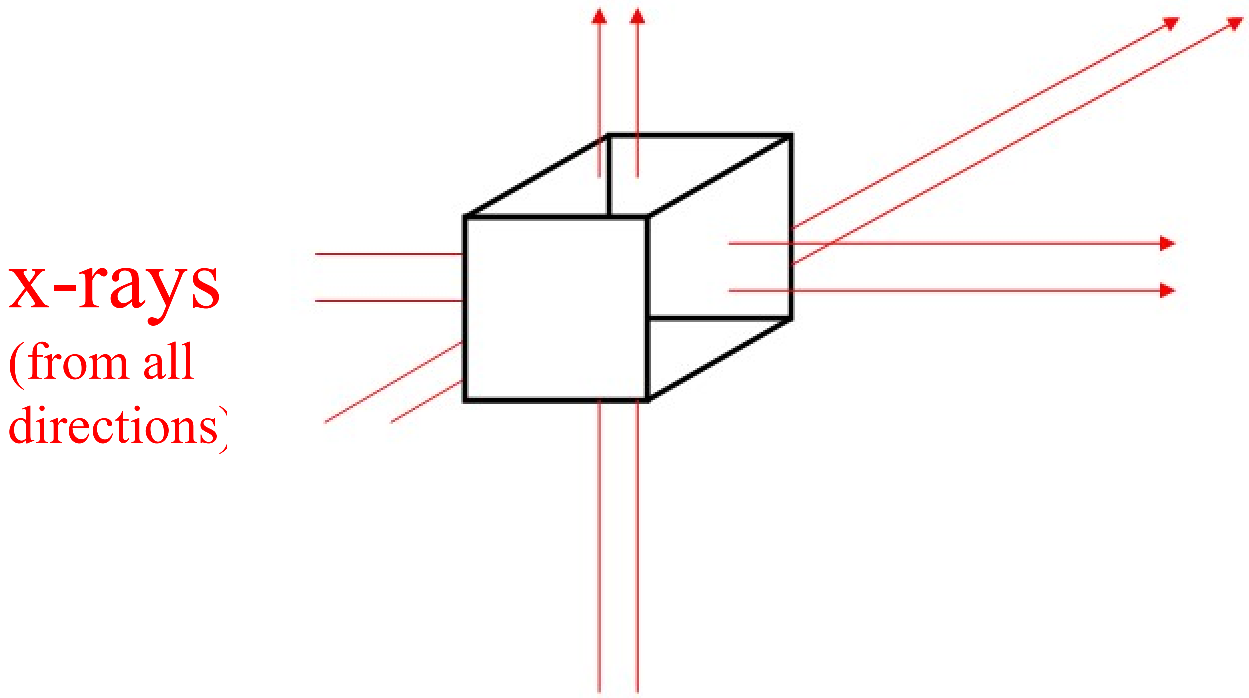
- **Same DAP**
- **Different Dose**

Noise in CT / CBCT images

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

- **Electronic noise (dark current)**
- **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



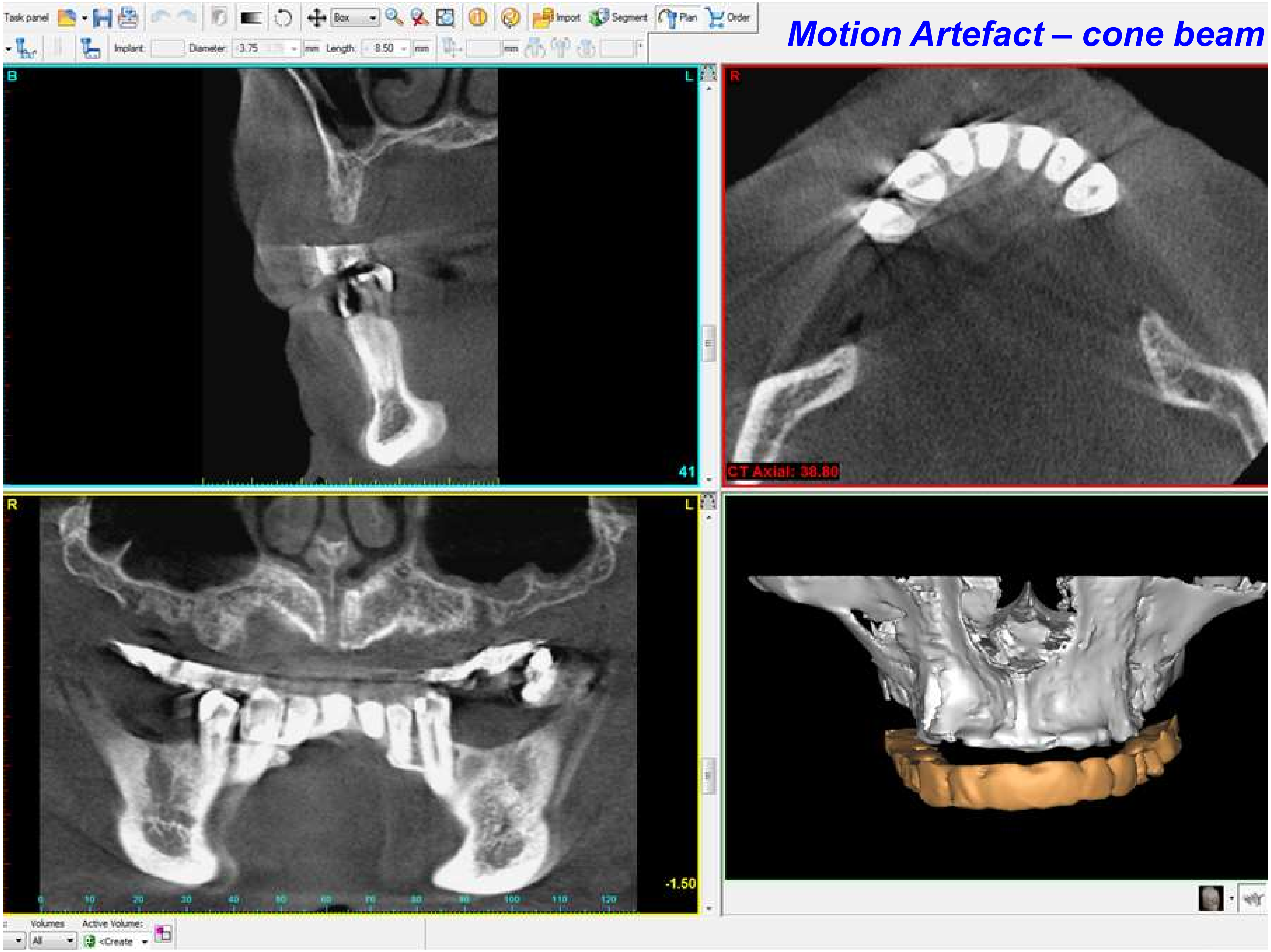
If you halve (1/2) each side of a cube e.g. from 0.4mm to 0.2mm
Number of x-ray photons passing through it goes down by 8 (i.e. 1/8)
Noise goes up by $\sqrt{8}$ = 2.83
mAs (dose) may have to be increased to compensate

Artefacts in CT / CBCT images

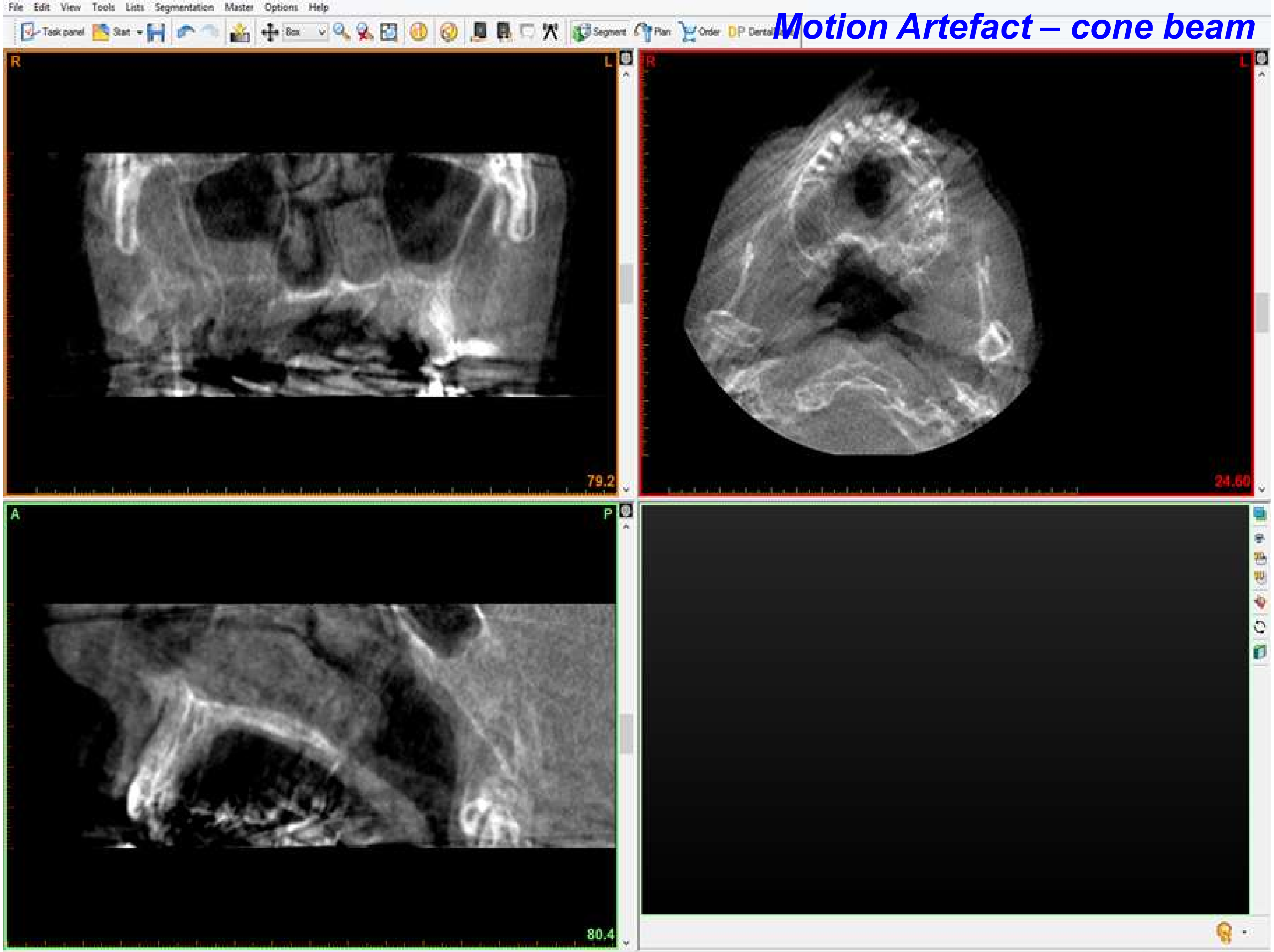
Artefact = structured contribution to the image which has no counterpart in the object.

- **Motion artefact**
- **Cone beam artefacts**
- **Ring artefacts**
- **Starburst (streak) artefact**
- **Beam hardening**

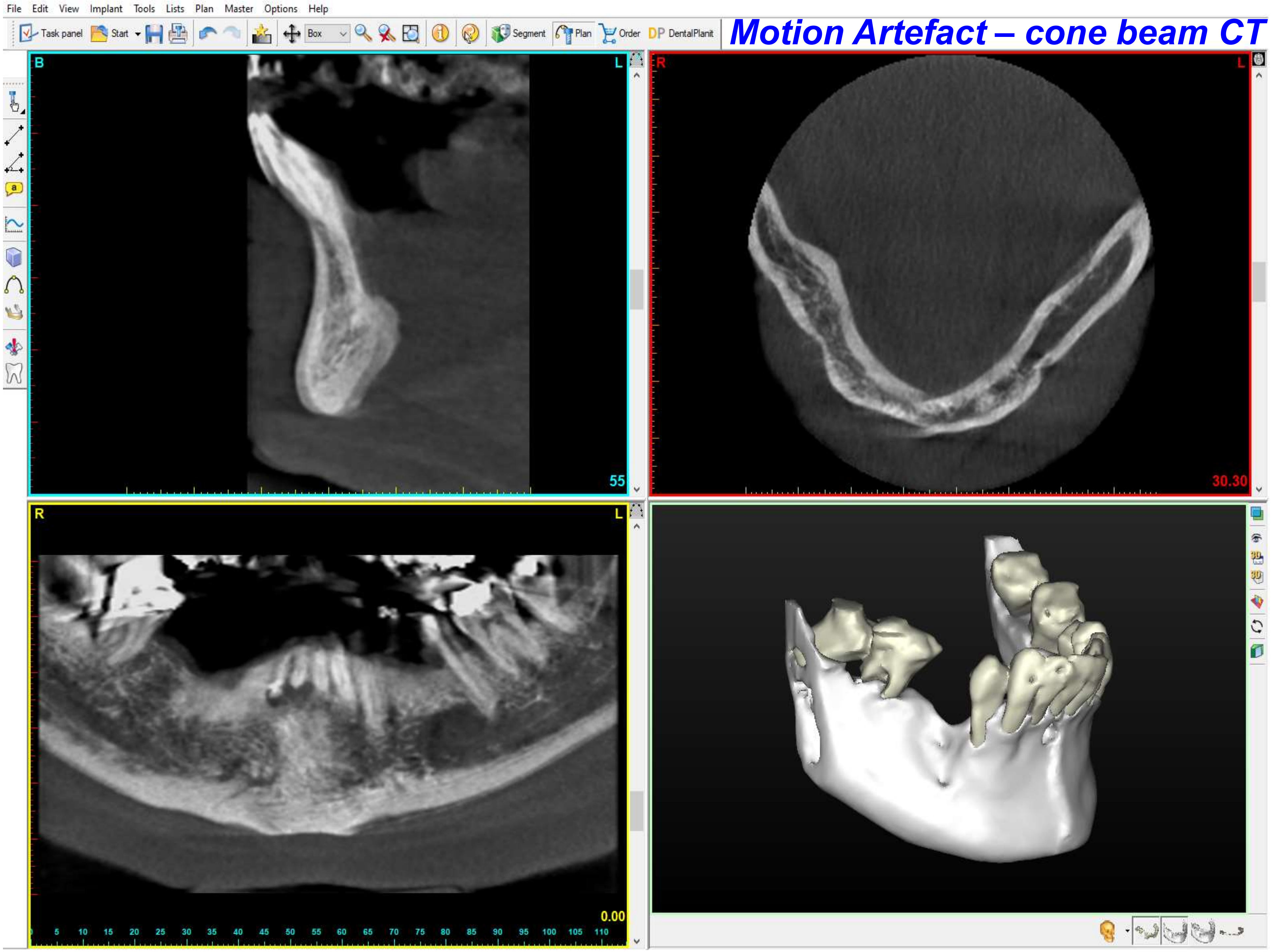
Motion Artefact – cone beam

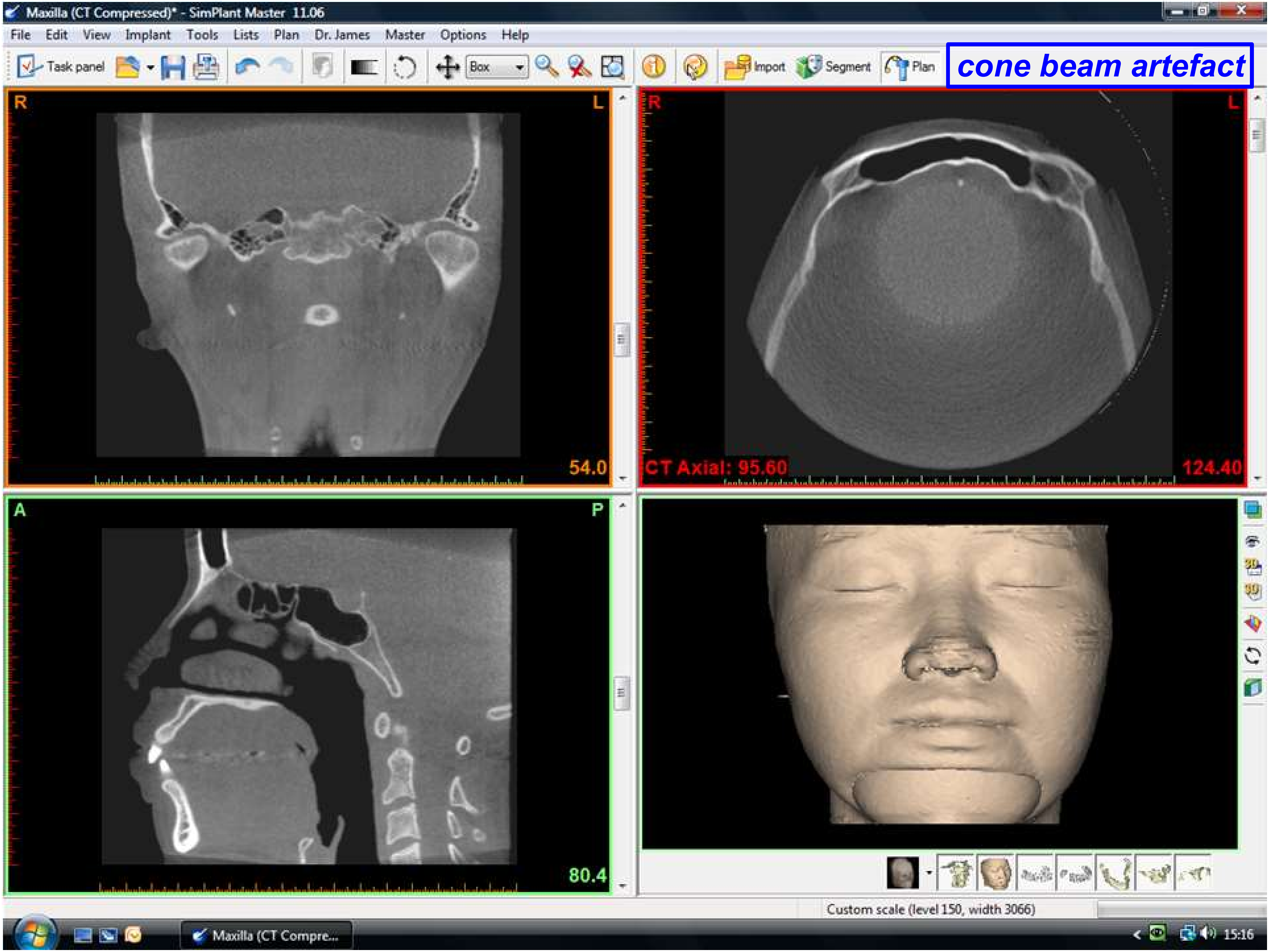


Motion Artefact – cone beam

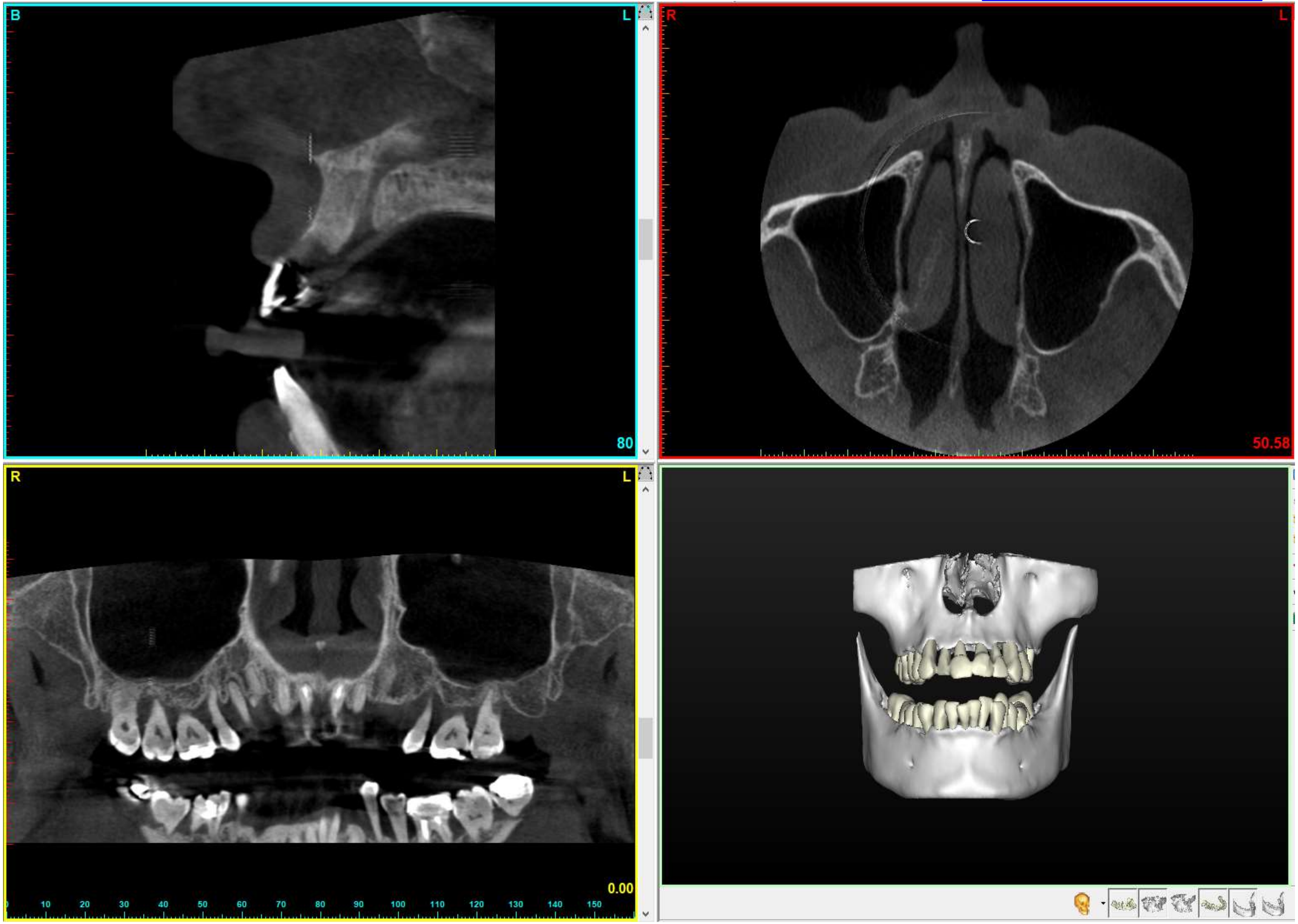


Motion Artefact – cone beam CT




Maxilla (CT Compressed)* - SimPlant Master 11.06
File Edit View Implant Tools Lists Plan Dr. James Master Options Help
Task panel
Box
Import
Segment
Plan
cone beam artefact
R
L
54.0
R
L
CT Axial: 95.60
124.40
A
P
80.4
Custom scale (level 150, width 3066)
Maxilla (CT Compre...
15:16

ring artefact



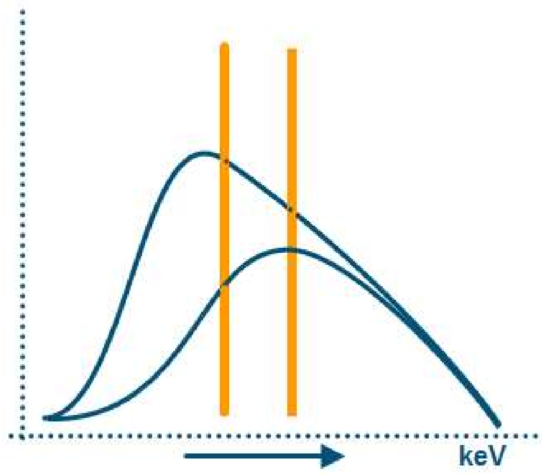
STARBURST ARTEFACT

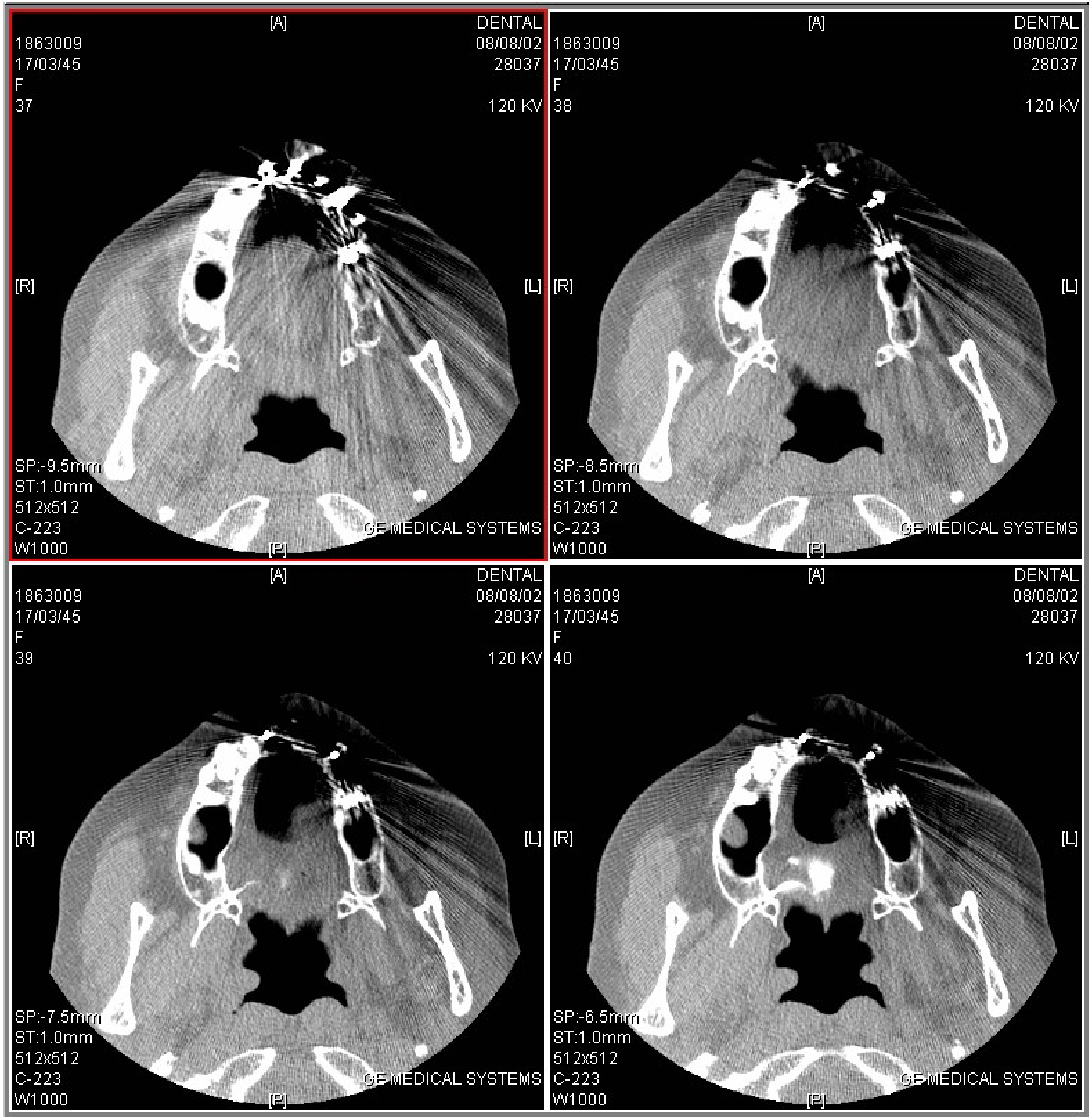
- **Starburst (streak) artefacts arise in CT scans when sharp changes in density are present, e.g. between air and bone or between bone and dense metals**
- **Starburst artefacts are caused by limitations in high frequency sampling**
  - **partial volume effect**
  - **beam hardening**
- **Starburst artefacts are not caused by scattered radiation**

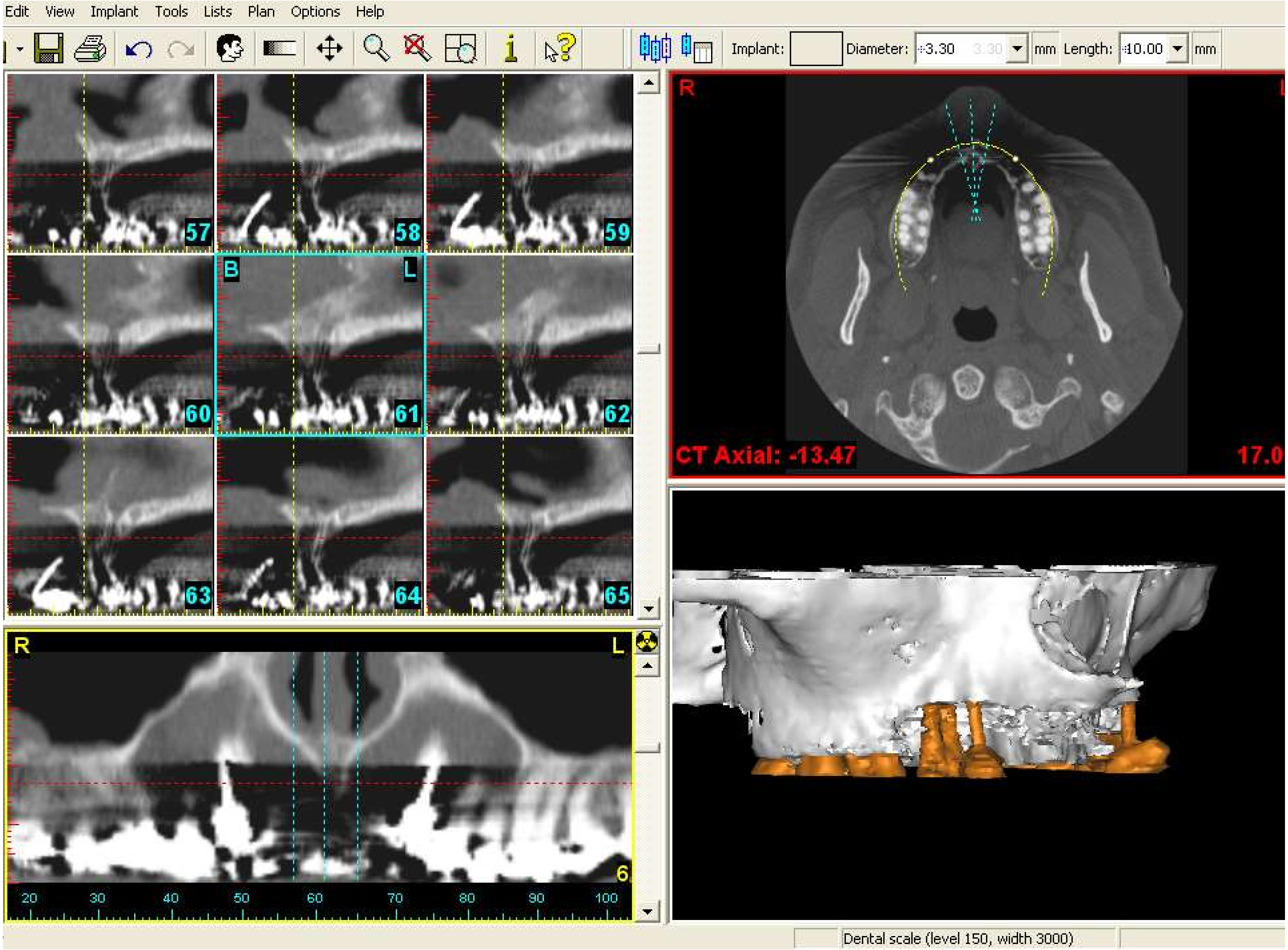

1.00X
1.00X
R
L
11:36:29 5
R
L
11:37:40 12
R
L
11:38:37 19

BEAM HARDENING ARTEFACT

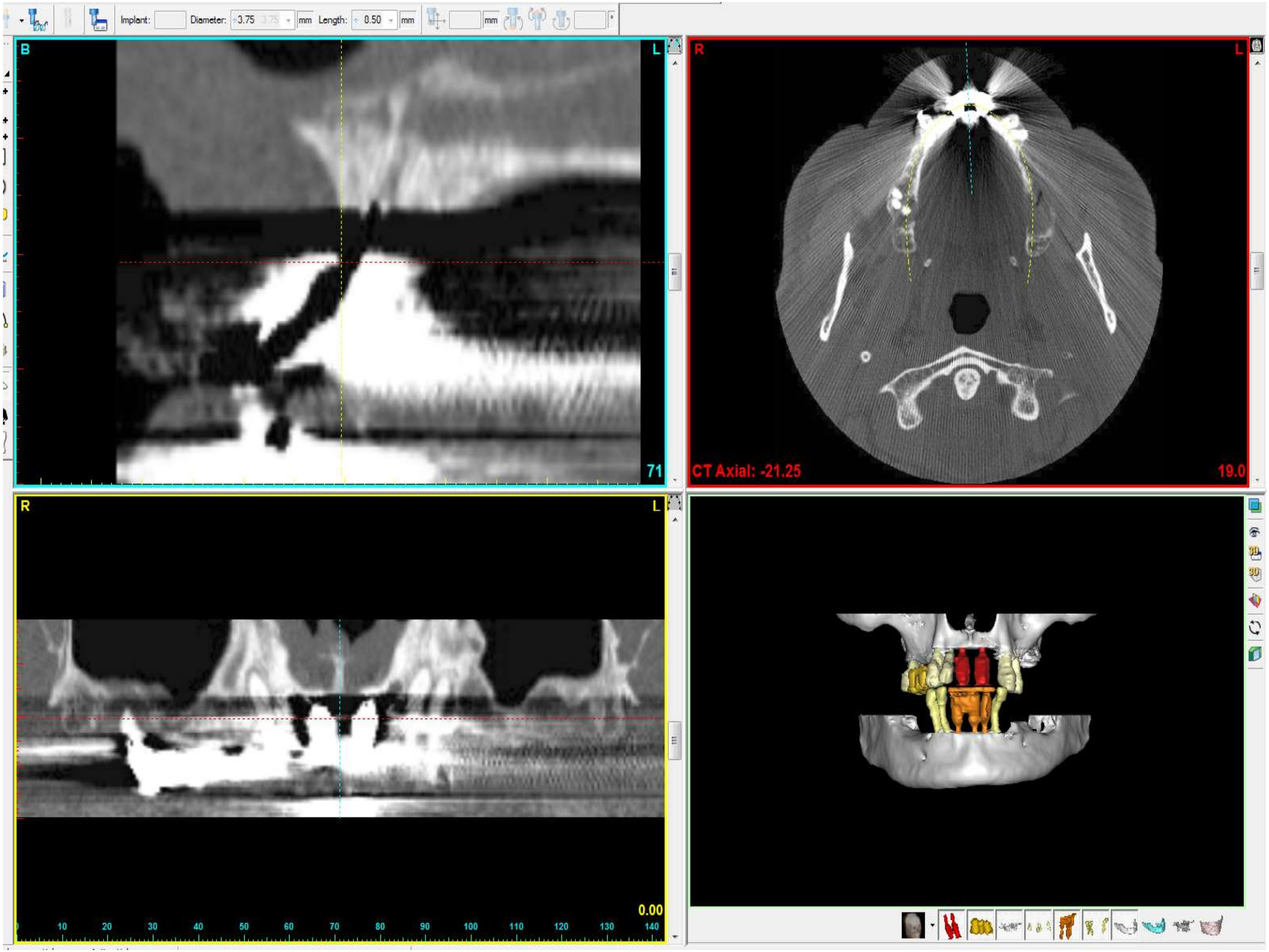
- **Beam Hardening artefacts occur in CT scans when metals are present**
- **Metals cause the low energy x-rays to be filtered out of the x-ray beam**
- **The average energy becomes higher**
- **The CT numbers become lower**
- **Parts of the image appear black**



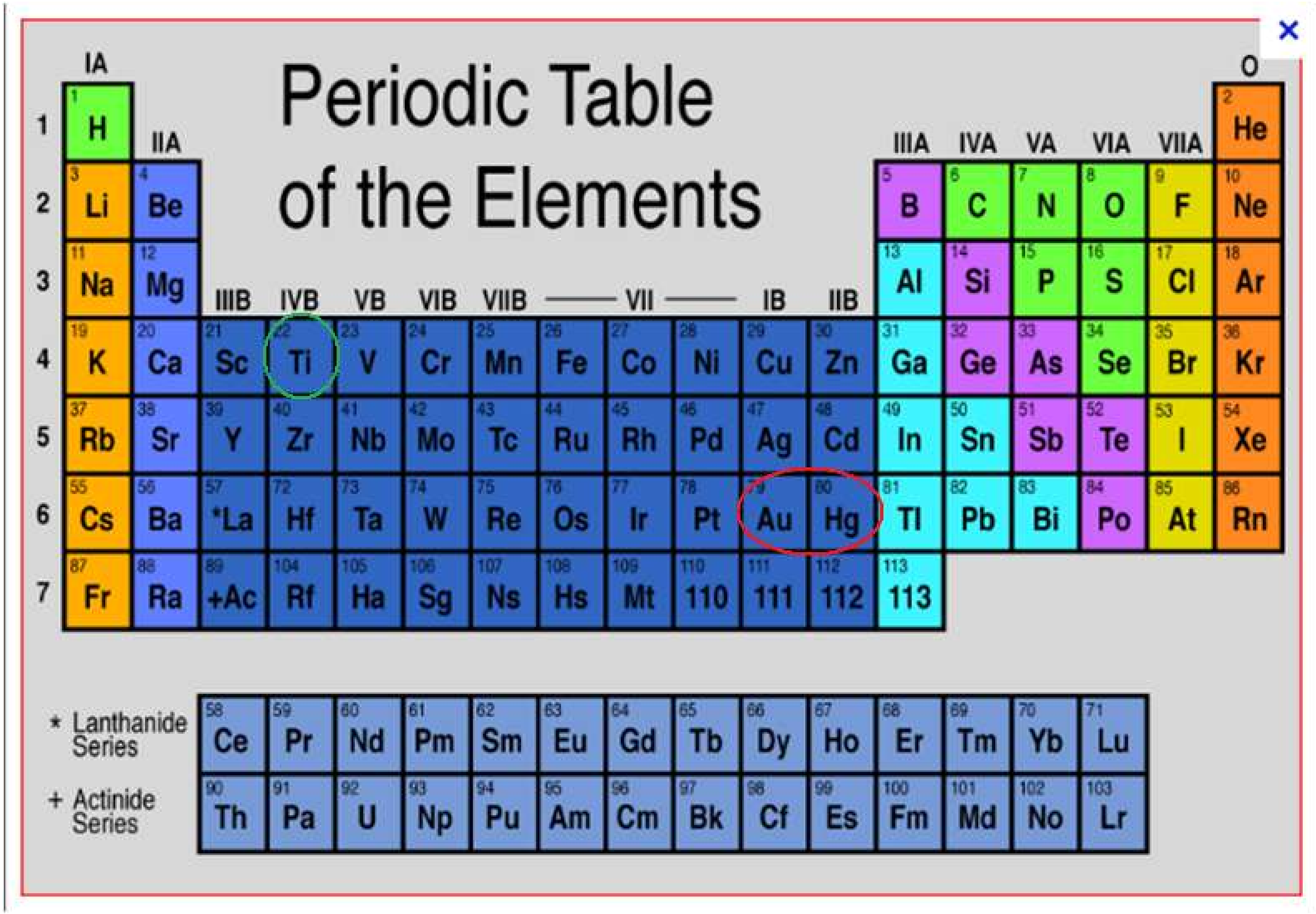

[A]
DENTAL
1863009
08/08/02
17/03/45
28037
F
37
120 KV
[R]
[L]
SP:-9.5mm
ST:1.0mm
512x512
C-223
GE MEDICAL SYSTEMS
W1000
[P]
[A]
DENTAL
1863009
08/08/02
17/03/45
28037
F
38
120 KV
[R]
[L]
SP:-8.5mm
ST:1.0mm
512x512
C-223
GE MEDICAL SYSTEMS
W1000
[P]
[A]
DENTAL
1863009
08/08/02
17/03/45
28037
F
39
120 KV
[R]
[L]
SP:-7.5mm
ST:1.0mm
512x512
C-223
GE MEDICAL SYSTEMS
W1000
[P]
[A]
DENTAL
1863009
08/08/02
17/03/45
28037
F
40
120 KV
[R]
[L]
SP:-6.5mm
ST:1.0mm
512x512
C-223
GE MEDICAL SYSTEMS
W1000
[P]



Edit View Implant Tools Lists Plan Options Help
Implant:
Diameter: 3.30
mm
Length: 10.00
mm
57
58
59
B
L
60
61
62
63
64
65
R
CT Axial: -13.47
17.0
R
L
6
20
30
40
50
60
70
80
90
100
Dental scale (level 150, width 3000)


Implant:
Diameter: 3.75
mm
Length: 0.50
mm
B
L
71
R
L
CT Axial: -21.25
19.0
R
L
0.00
10
20
30
40
50
60
70
80
90
100
110
120
130
140

High-Z materials cause the worst artefacts

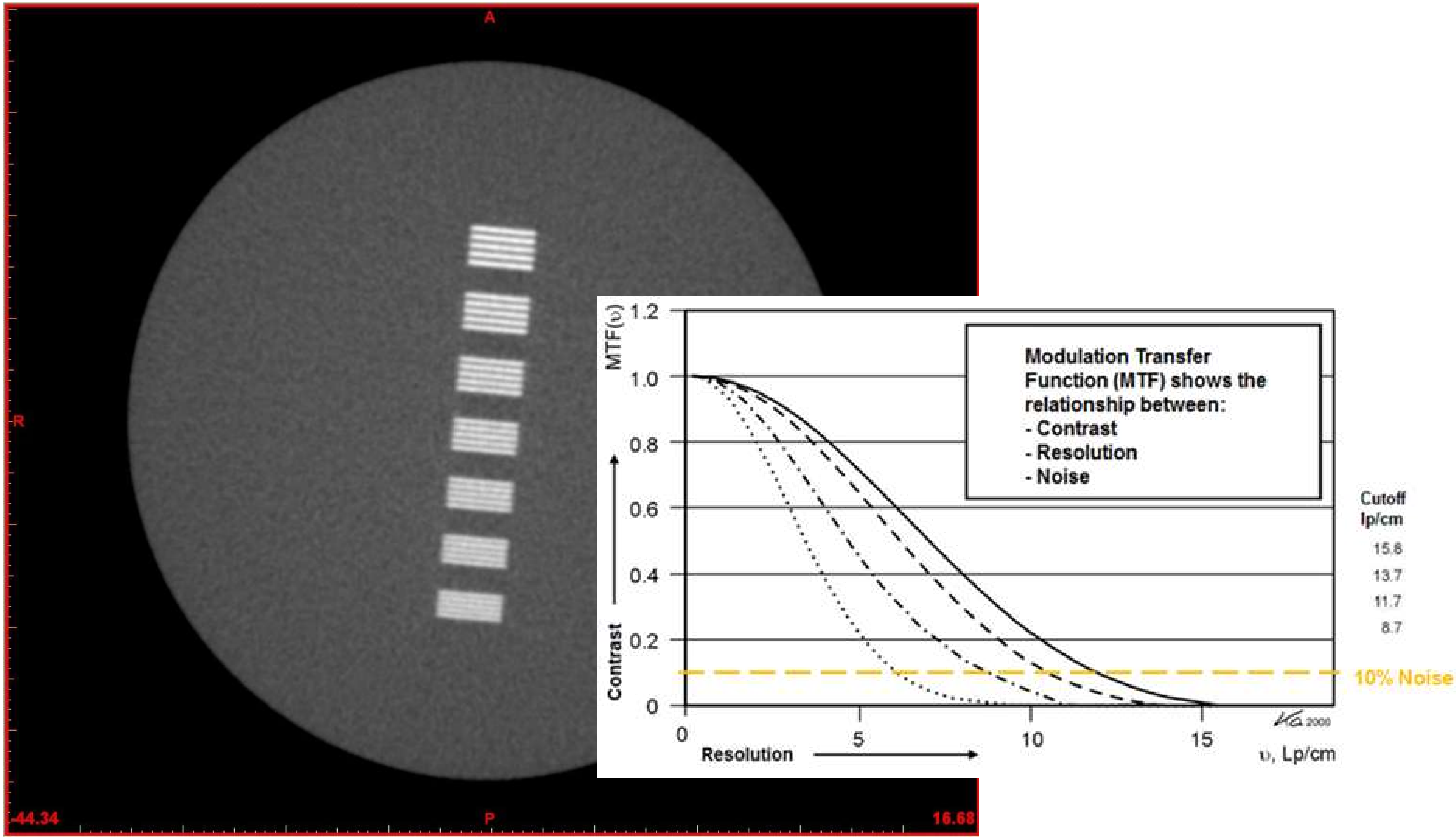


HOW TO AVOID ARTEFACTS

- **Titanium implants produce little artefact, gold produces a lot**
- **Remove dentures or other fixtures that include metal**
- **Consider replacing amalgam with composites**
- **Consider extracting teeth that will be sacrificed anyway.**

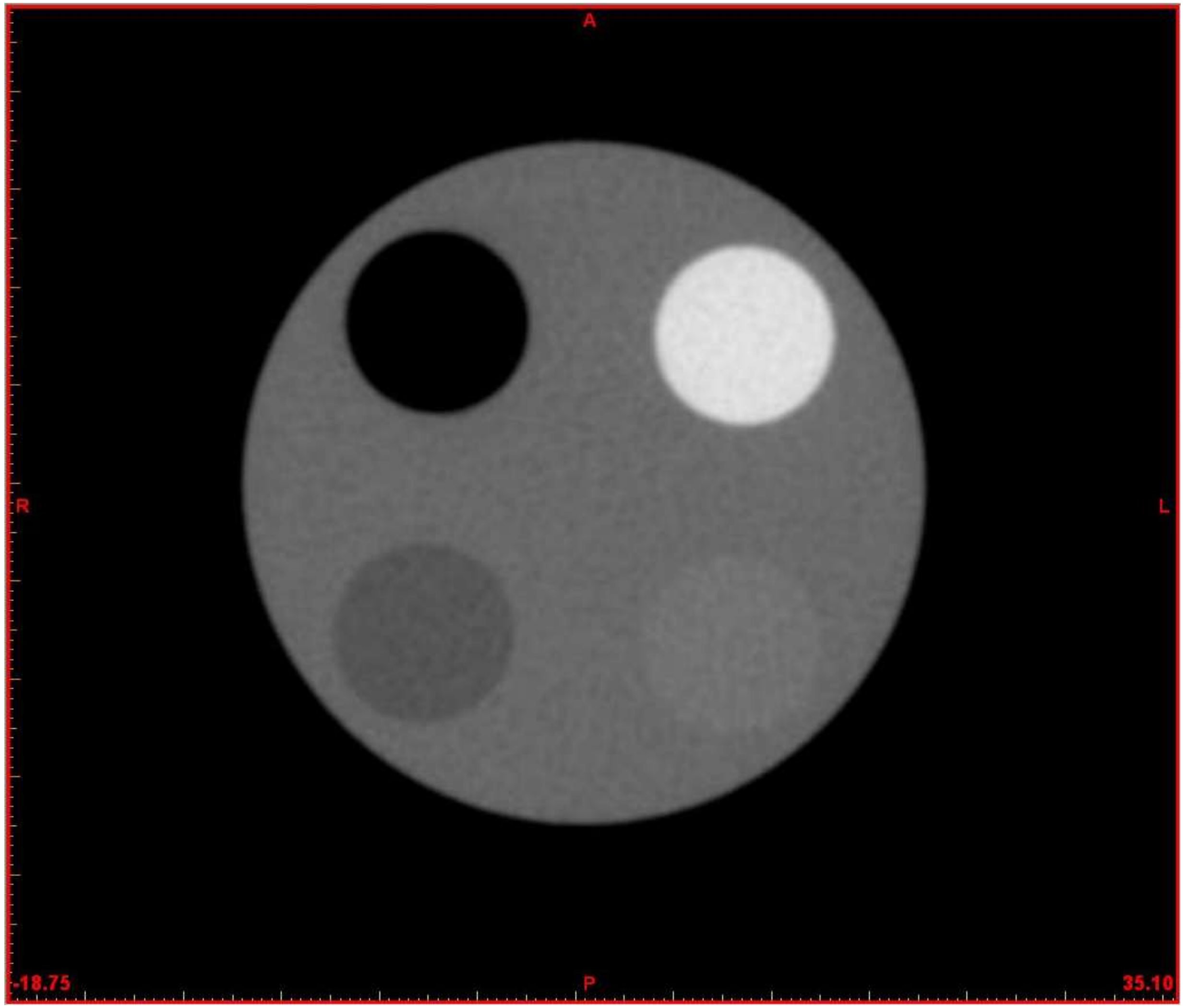
Spatial Resolution

Detail at high contrast



Contrast Resolution

Detail at low contrast



Spatial and Contrast Resolution

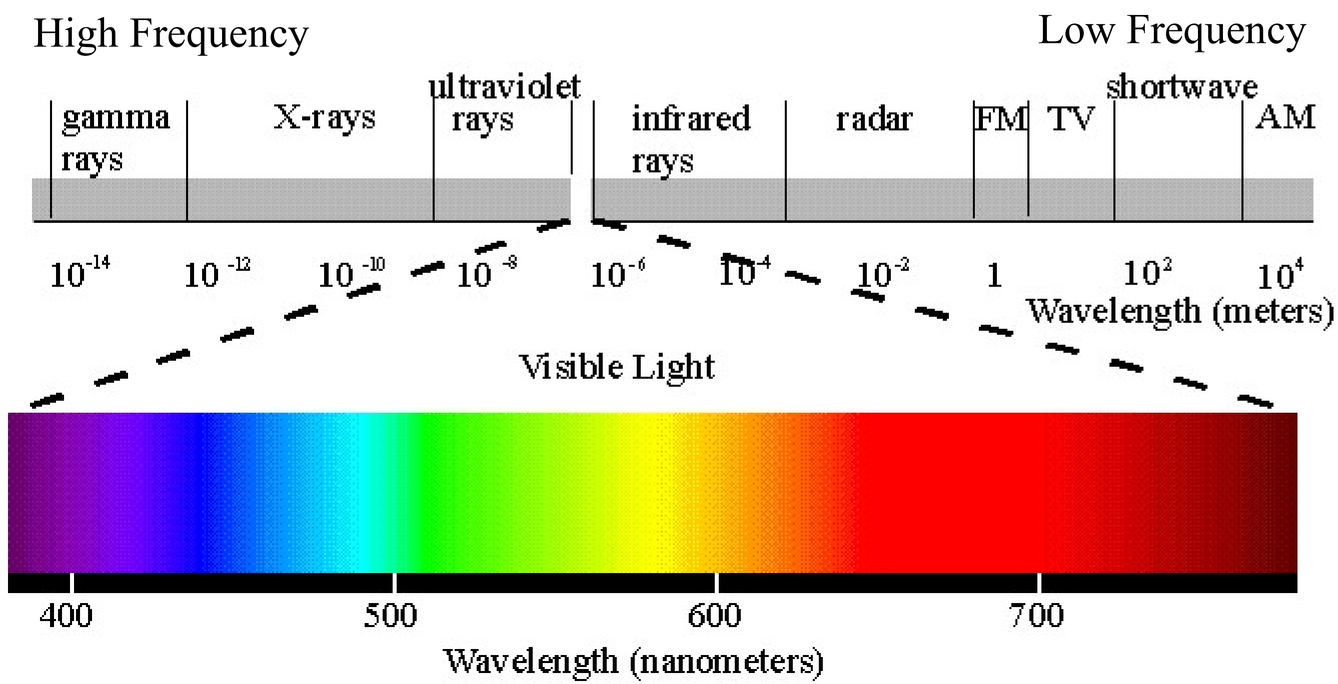
Outline of Lectures

- ✔ Introduction / Disclosures
- ✔ Principles of CBCT Imaging
- ✔ CBCT Image Acquisition and Processing
- ✔ Apparatus and Equipment
- Radiation Physics in relation to CBCT
- Radiation Protection in relation to CBCT

What is Radiation?

- **Energy travelling through space**
- **Sunshine is a familiar example**
  - **A small amount is beneficial**
  - **Too much can be harmful**

The Electro-Magnetic Spectrum

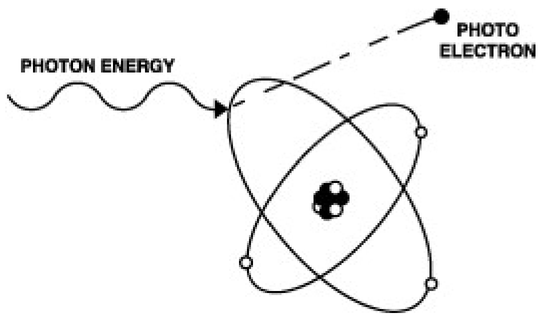


from **http://www.yorku.ca/eye/spectru.htm**

Energy depends on the frequency E = hν

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.**

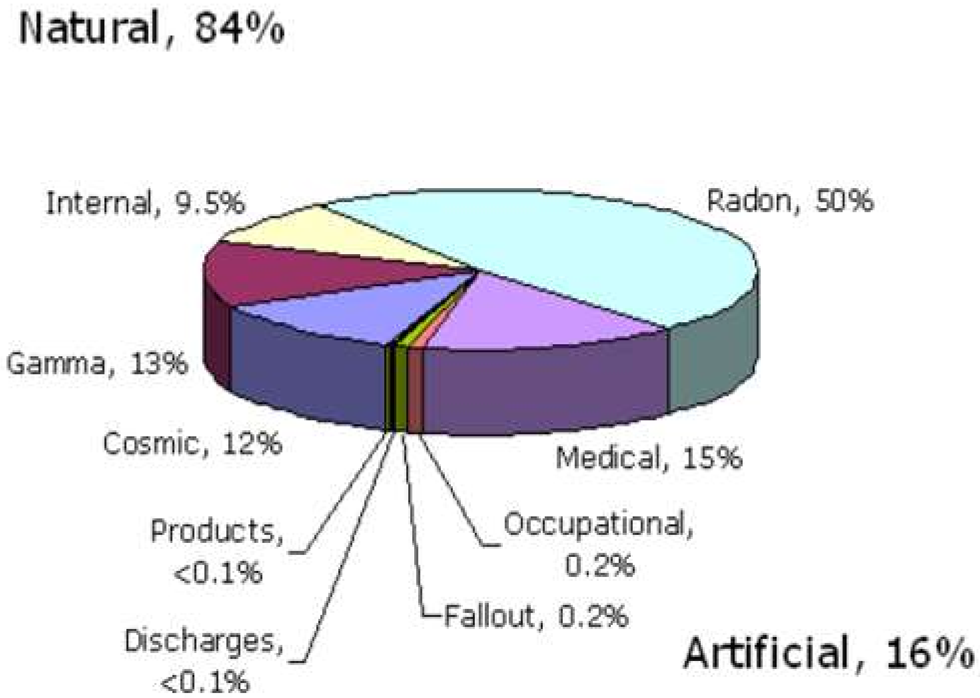


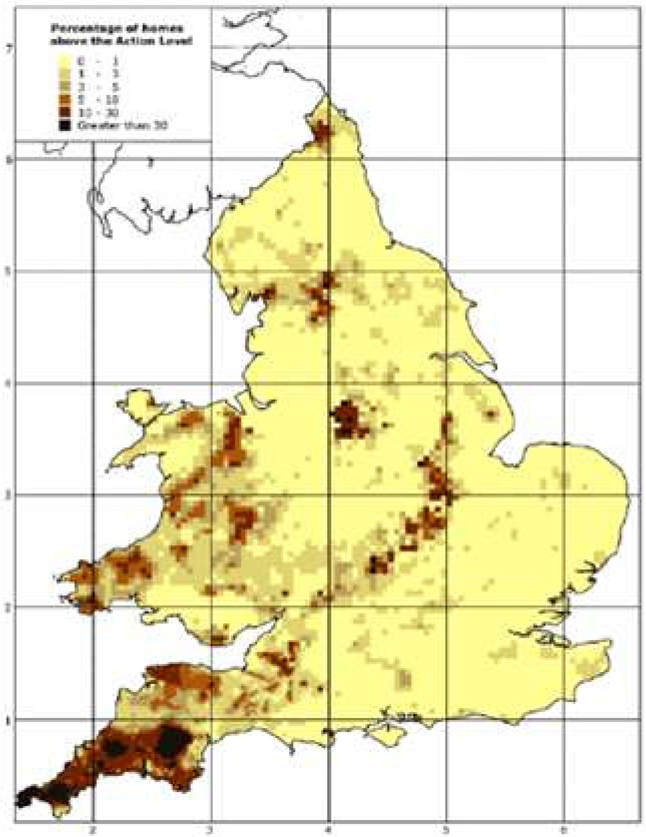
Sources of Ionising Radiation

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**

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)**

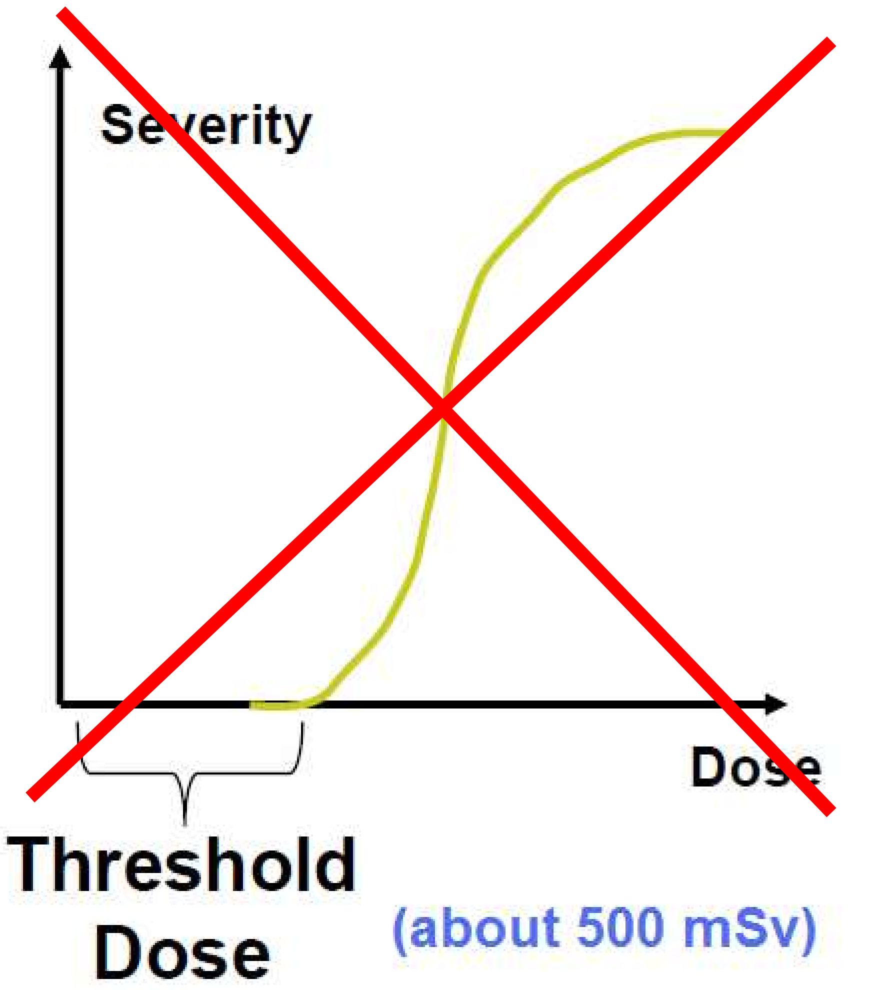
We should never see any of these effects in a dental practice!

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.**

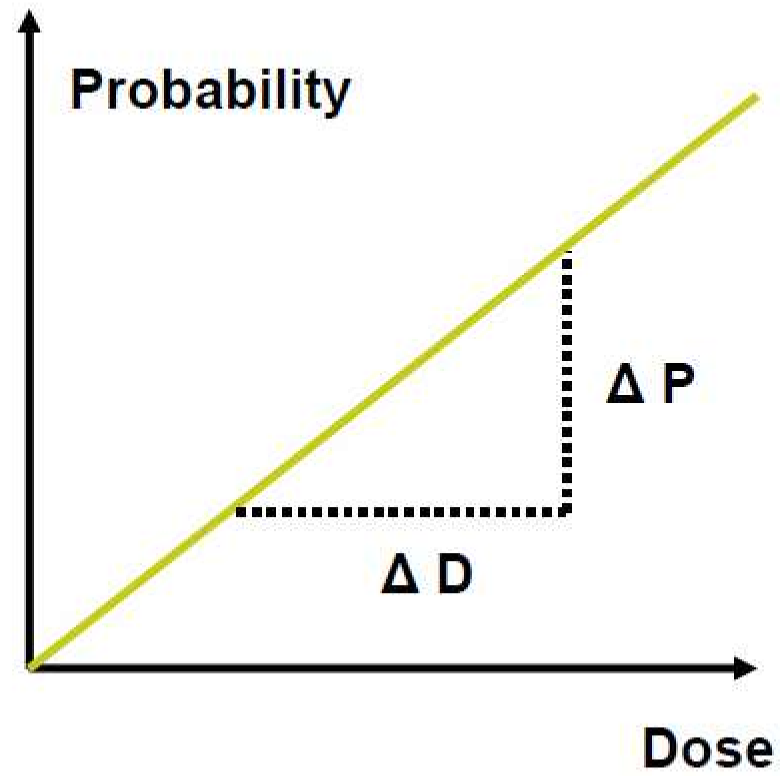
- **For a low dose of radiation, we think that cancer may be induced (maybe many years after exposure) but we don't know for sure.**

Deterministic Effects | **Stochastic Effects**



(about 500 mSv)

Should not see in dental practice!



Risk Factor = Δ P / Δ D

(about 5% per Sievert)

Linear No-Threshold (LNT) model

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 of the region and the body parts irradiated into account.**

Dose Terminology

Absorbed Dose
Energy absorbed by tissue
(Gray, Gy)

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

Equivalent Dose H_T
(Sievert, Sv)

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

Effective Dose E
(Sievert, Sv)

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"

Annals of the ICRP

PUBLICATION 103

The 2007 Recommendations of the International Commission on Radiological Protection

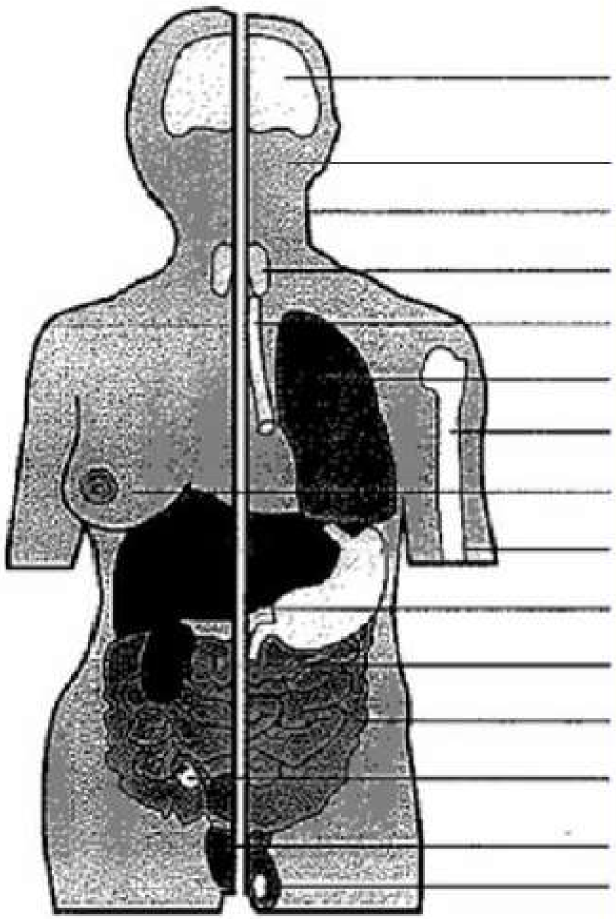
Editor
J. VALENTIN

PUBLISHED FOR

The International Commission on Radiological Protection

by

ELSEVIER



	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

Tissue Weighting Factors from ICRP 103

To obtain the Effective Dose:

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.**

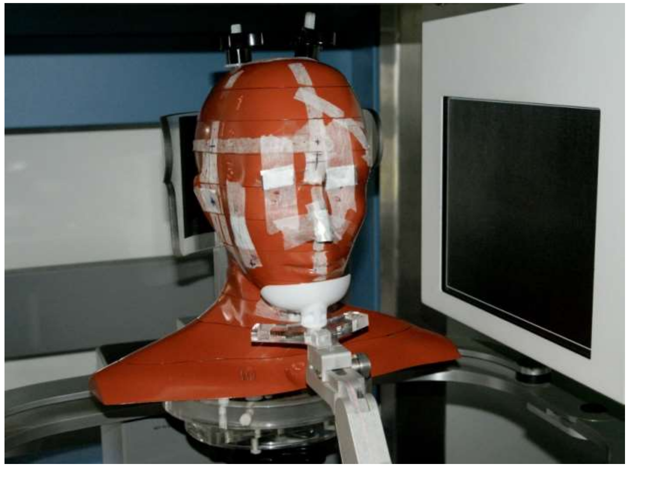
Effective Dose (E)

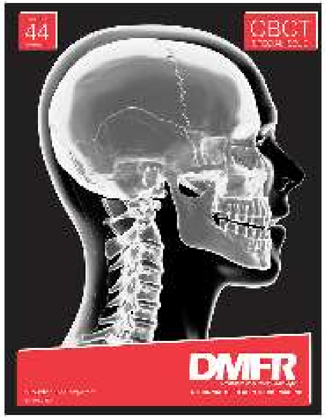
$$E = \sum_T H_T w_T$$

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





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

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]

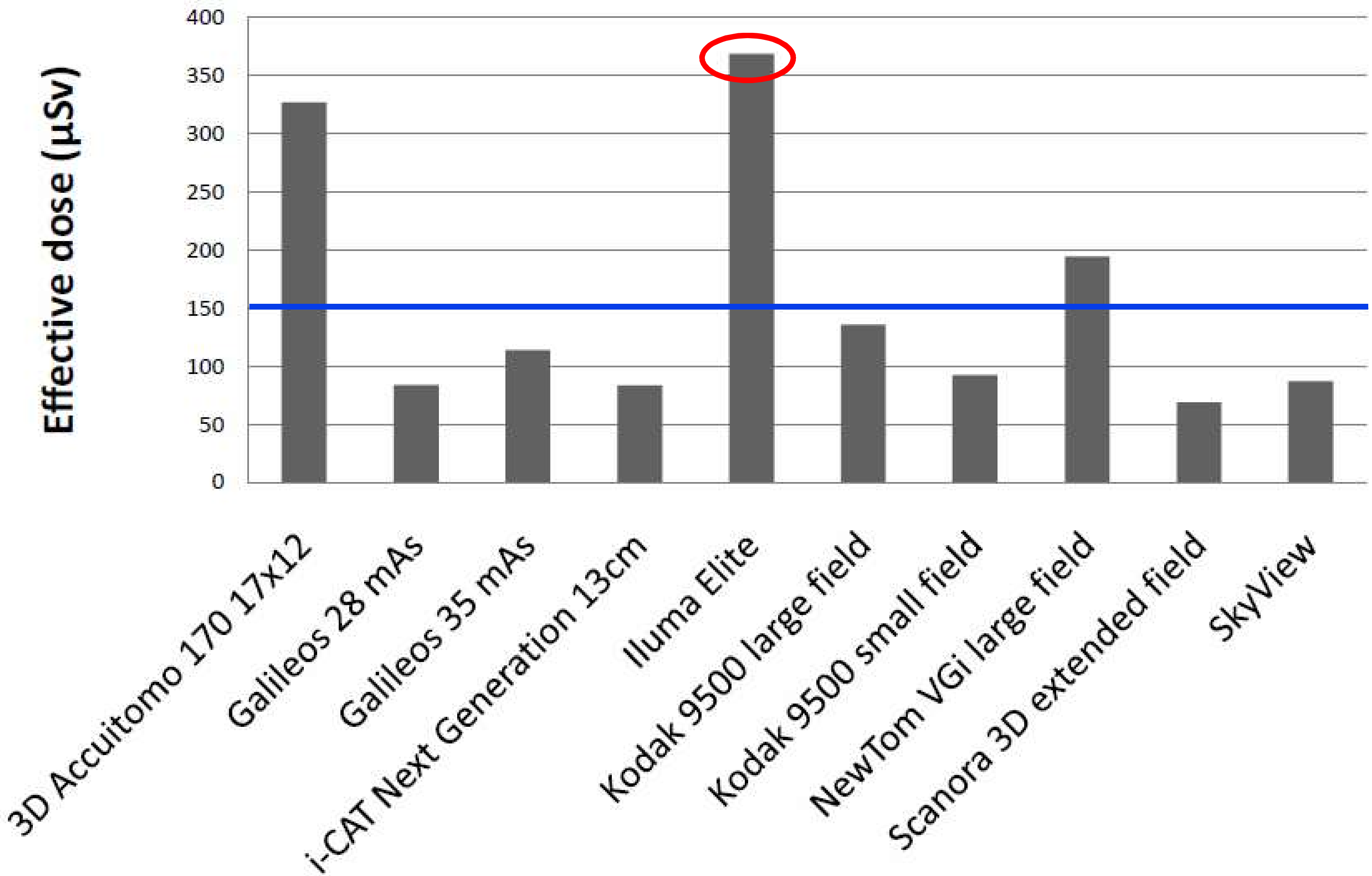
[a] *Oral Imaging Center, School of Dentistry, Oral Pathology and Maxillofacial Surgery, Faculty of Medicine, Catholic University of Leuven, Belgium*
[b] *Center for Periodontology and Implantology, Heverlee, Belgium*
[c] *North Western Medical Physics, The Christie NHS Foundation Trust, Manchester Academic 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)

SEDENTEXCT measured Effective Doses for common CBCT scanners and found they were in the range

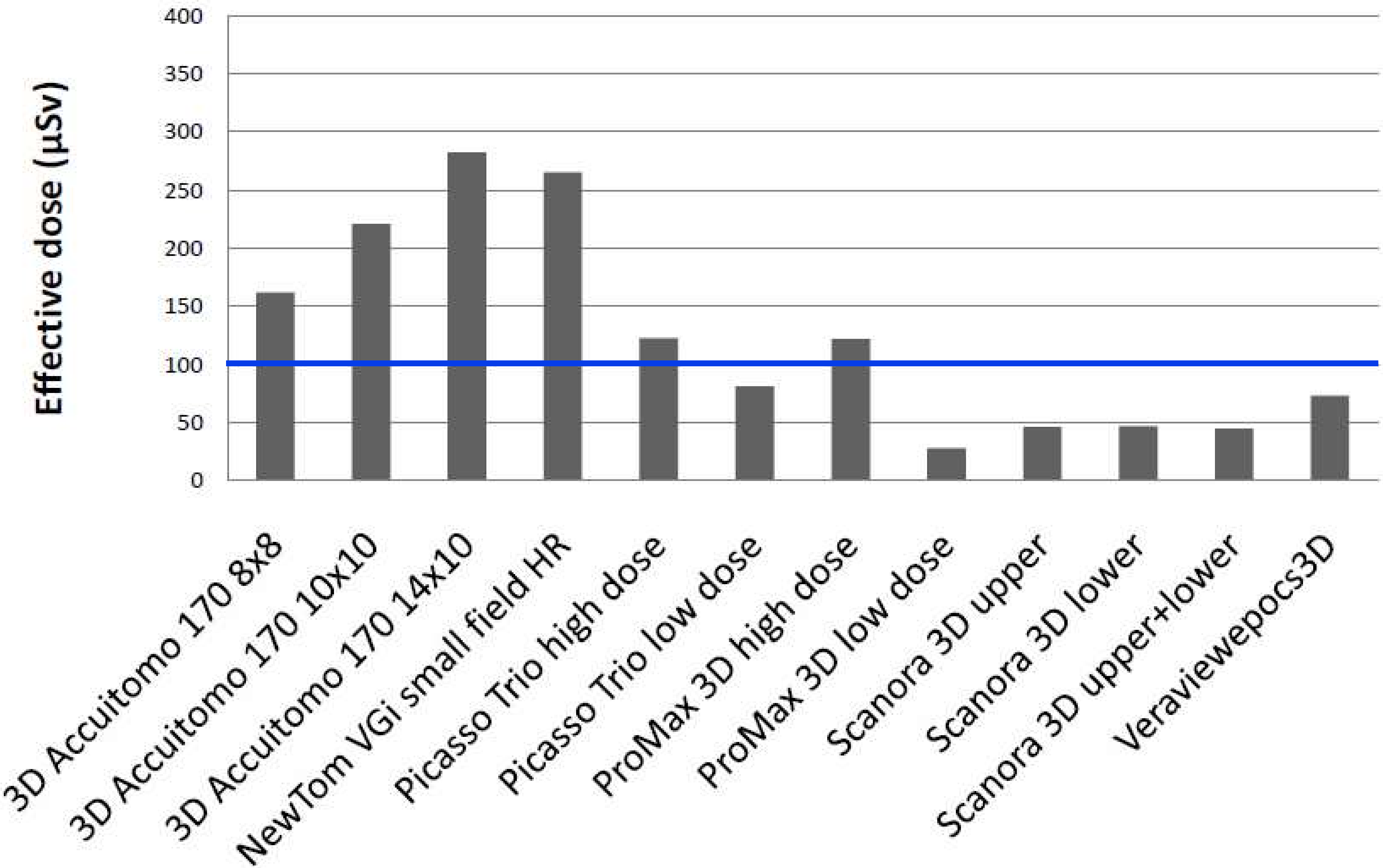
20 microSieverts to 370 microSieverts

Effective dose for large field CBCTs



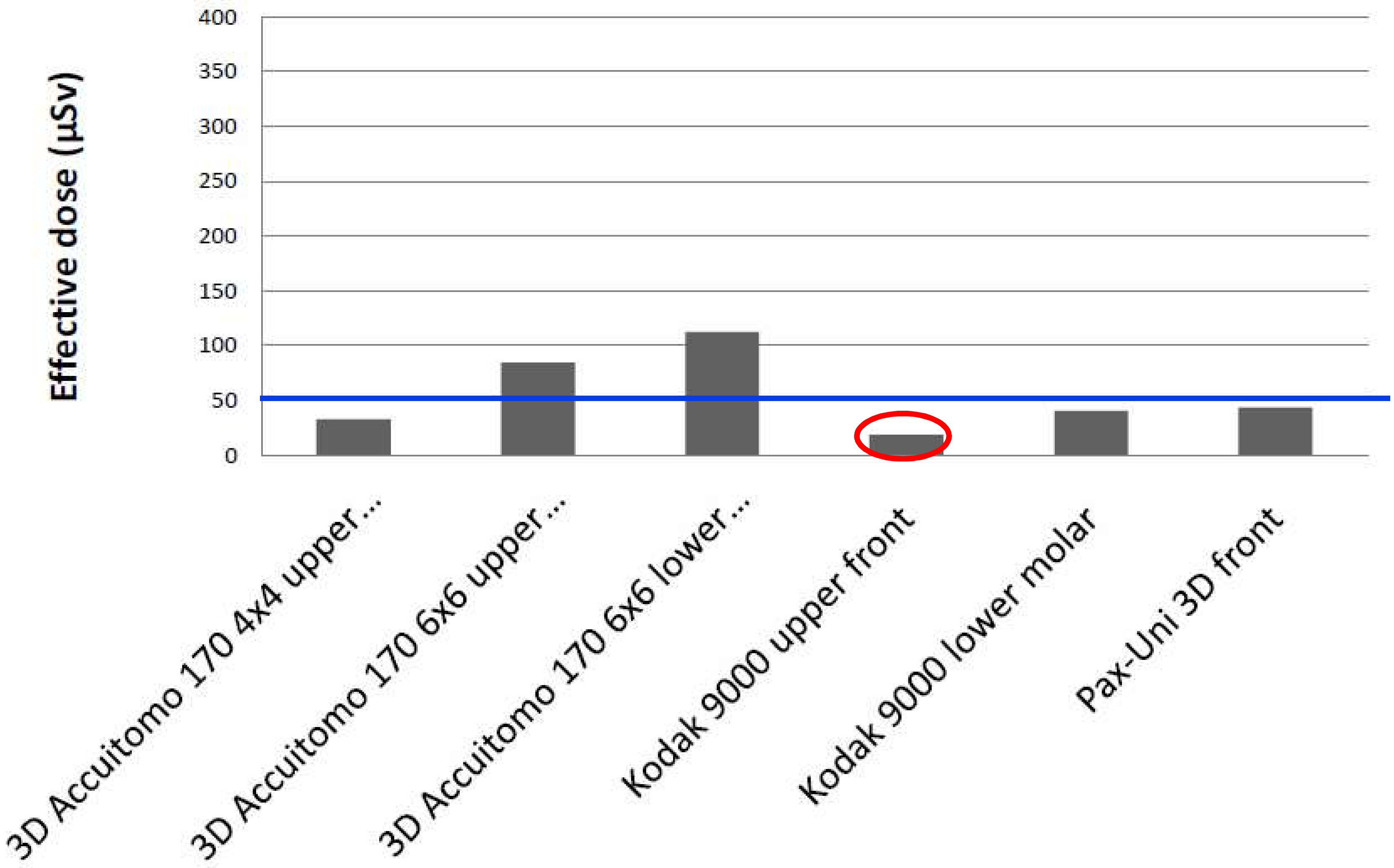
Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

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

Source of exposure	Dose
Dental x-ray	0.005 mSv
100g of Brazil nuts	0.01 mSv
Chest x-ray	0.014 mSv
Transatlantic flight	0.08 mSv
Nuclear power station worker average annual occupational exposure (2010)	0.18 mSv
UK annual average radon dose	1.3 mSv
CT scan of the head	1.4 mSv
UK average annual radiation dose	2.7 mSv
USA average annual radiation dose	6.2 mSv
CT scan of the chest	6.6 mSv
Average annual radon dose to people in Cornwall	7.8 mSv
CT scan of the whole spine	10 mSv
Annual exposure limit for nuclear industry employees	20 mSv
Level at which changes in blood cells can be readily observed	100 mSv
Acute radiation effects including nausea and a reduction in white blood cell count	1000 mSv
Dose of radiation which would kill about half of those receiving it in a month	5000 mSv

https://www.gov.uk/government/publications/ionising-radiation-dose-comparisons/ionising-radiation-dose-comparisons

Risk Bands

Negligible	< 1 in a million risk
Minimal	1 in 100,000 to 1 in a million risk
Very Low	1 in 10,000 to 1 in 100,000 risk
Low	1 in 1,000 to 1 in 10,000 risk

Department of Health (1995)

Dental x-rays are in the range "Negligible" to "Very Low"

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 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

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

BMJ VOLUME 313 28 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**
- **Effective Dose might be 100 microSieverts (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**

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

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% per Sievert at age 30

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

www.sedentexct.eu

Typical Risks from Dental X-Rays

	Effective Dose (µSv)	Risk
Intraoral (F speed, rect coll)	**1 to 2**	
Intraoral (E speed, round coll)	**3 to 6**	
Lateral Ceph	**5 to 10**	
Panoramic	**3 to 25**	
Cone Beam CT	**20 to 370**	
Medical CT (using dental protocol)	**150 to 1500**	

Typical Risks from Dental X-Rays

	Effective Dose (μSv)	Risk	
Intraoral (F speed, rect coll)	1 to 2	< 1 in 10 million	Negligible
Intraoral (E speed, round coll)	3 to 6	< 1 in 3.3 million	Negligible
Lateral Ceph	5 to 10	< 1 in 2 million	Negligible
Panoramic	3 to 25	1 in 6.7 million to 1 in 800 thousand	Negligible to Minimal
Cone Beam CT	20 to 370	1 in 1 million to 1 in 50 thousand	Mimimal to Very Low
Medical CT (using dental protocol)	150 to 1500	1 in 130 thousand to 1 in 13 thousand	Very Low

Risks from Dental x-rays

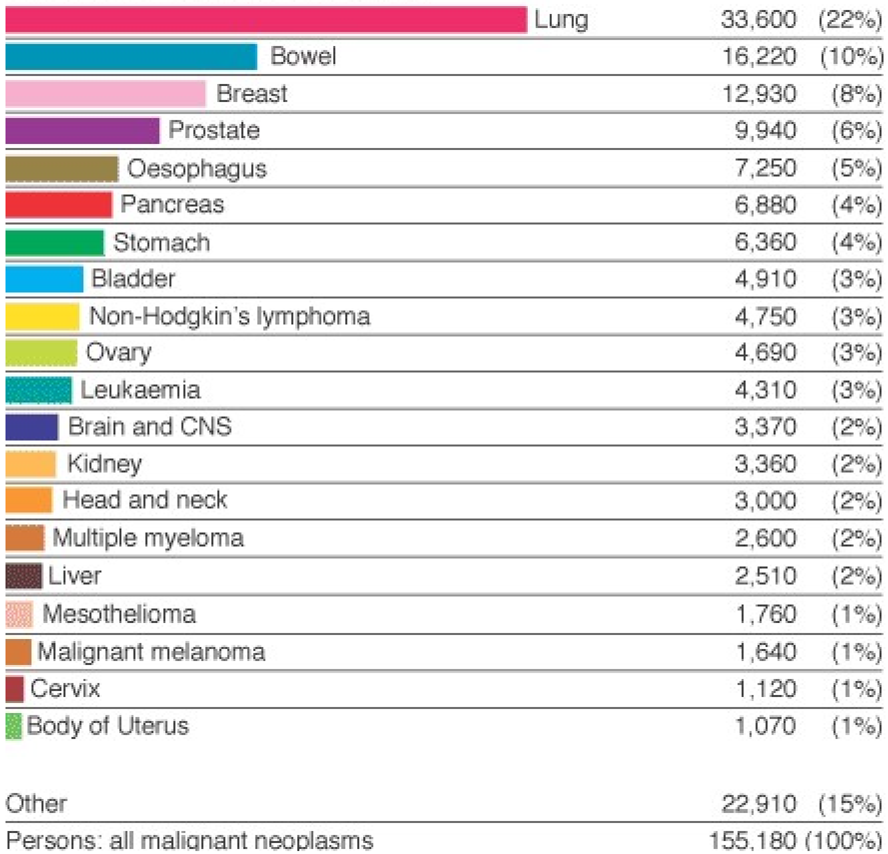
- **Zero risk of Deterministic Effects**
- **Negligible to Very Low risk of radiation induced cancers**
- **Negligible risk of serious hereditary disease in an individual's descendants**

If everyone in the UK had a dental CBCT scan every year ...

- ***There might be 160 extra cancer deaths per year***
  (if estimates are correct)

- ***Compared to 155,000 cancer deaths from other causes***

UK Mortality 2002: Cancers which contribute one per cent or more to total cancer mortality



http://www.cancerresearchuk.org/aboutcancer/statistics/mortality

Principles of Radiation Protection (for Patients)

- **Justification** (benefits must outweigh the risks)
- **Optimisation** (keep doses As Low As Reasonably Practicable)
  (consistent with the intended diagnostic purpose)
- **Limitation**
  ~~(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)

applies to staff
not patients

Justification

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

Implant Surgery Complications: Etiology and Treatment

Kelly Misch, DDS,* and Hom-Lay Wang, DDS, MSD, PhD†

ISSN 1056-6163/08/01702-159
Implant Dentistry
Volume 17 • Number 2

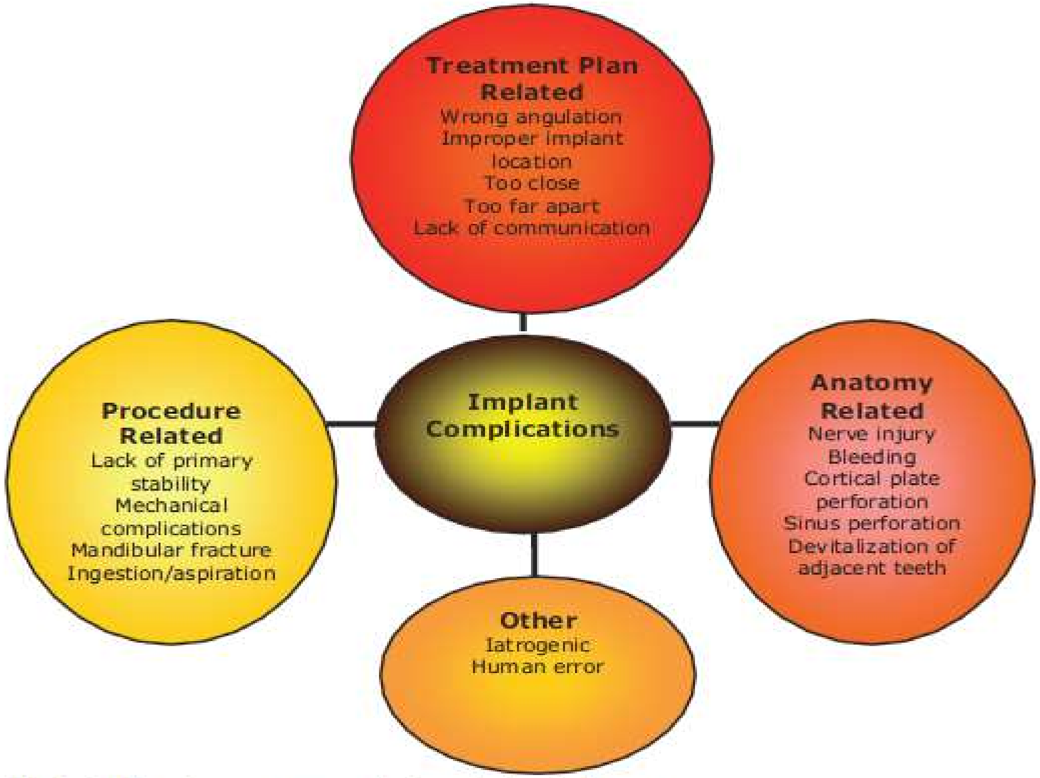
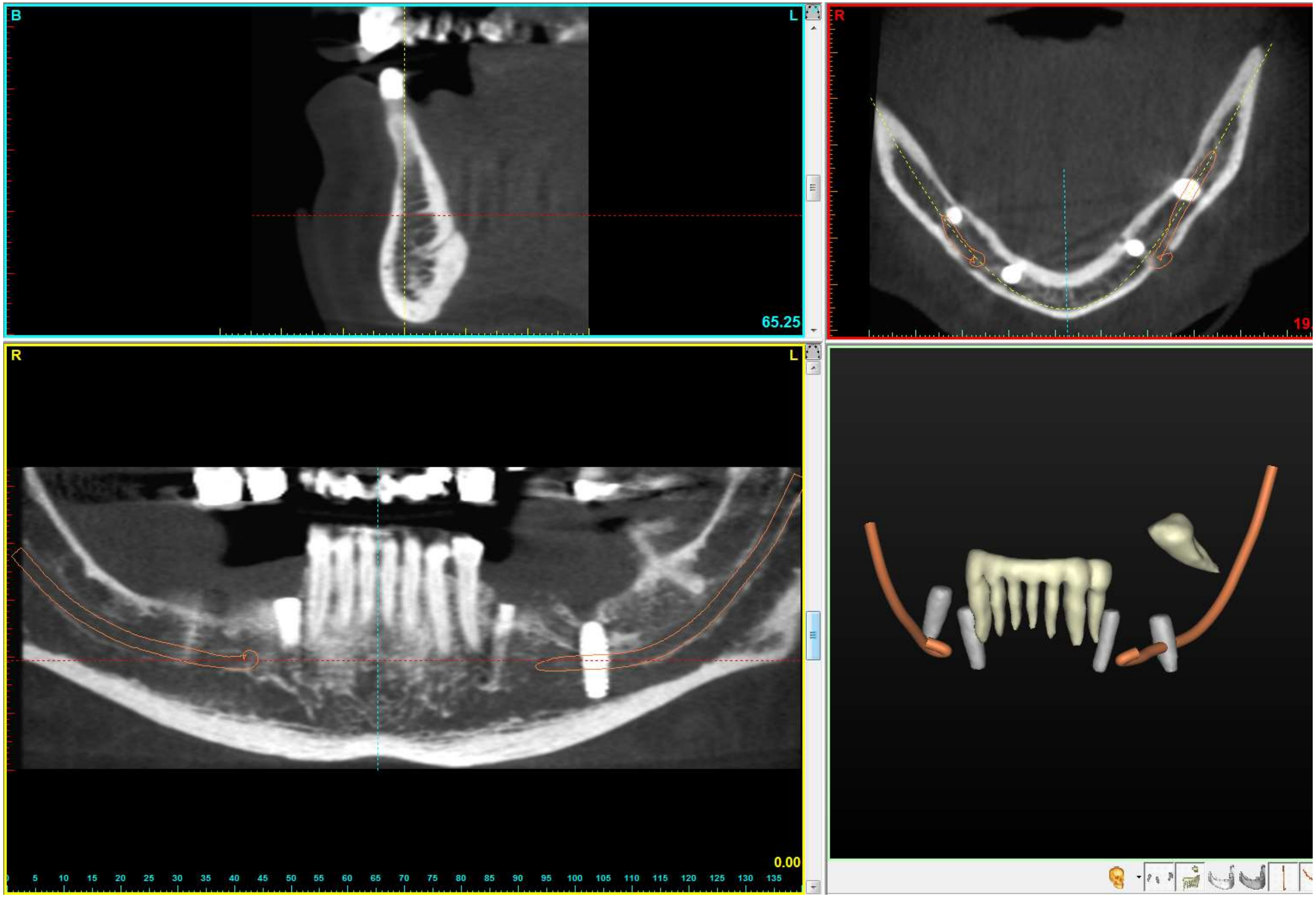


Fig. 1. Outline of common complications during implant surgery.

The Risk of Not Having a CBCT Scan



Take the CT Scan first, do the surgery second (not the other way around)!

Optimisation

Want to Optimise

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

* not to the dentist!

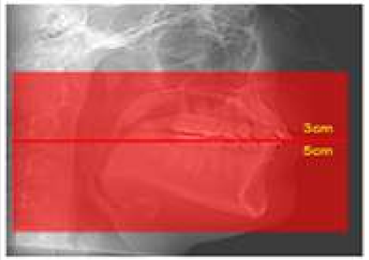
There is a legal requirement to reduce the risk
There is no legal requirement to increase the benefit, but it is good practice.

Practical ways to Reduce the ~~Dose~~ Risk

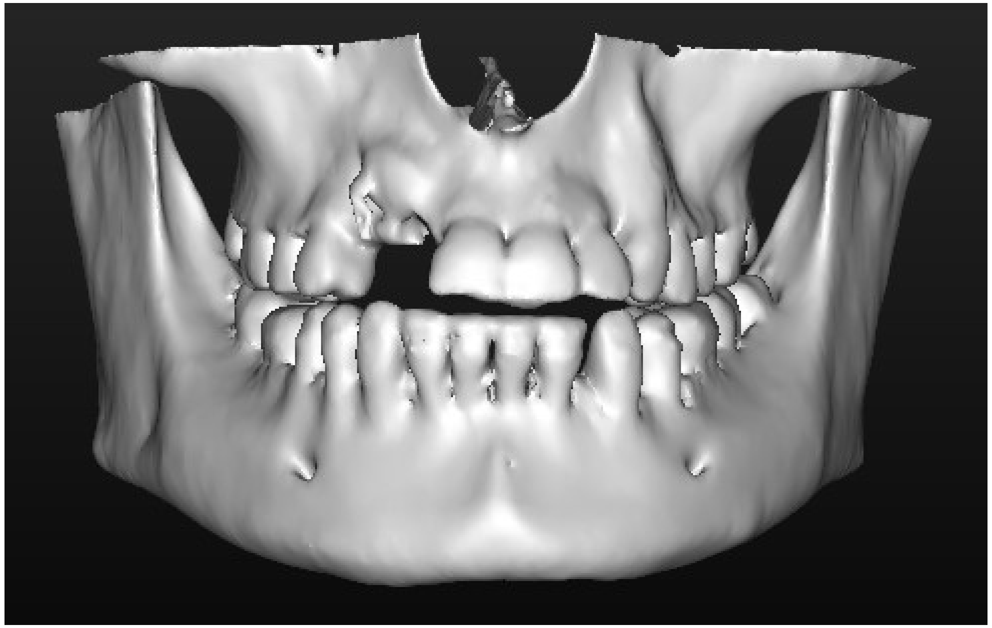
CBCT Scans:

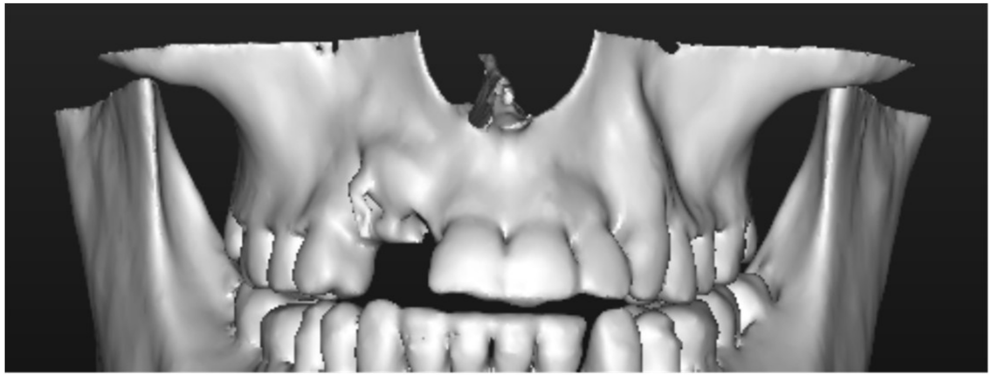
1. **Reduce the Height (vertical collimation)**

   Reduces the risk without loss of benefit in most cases.

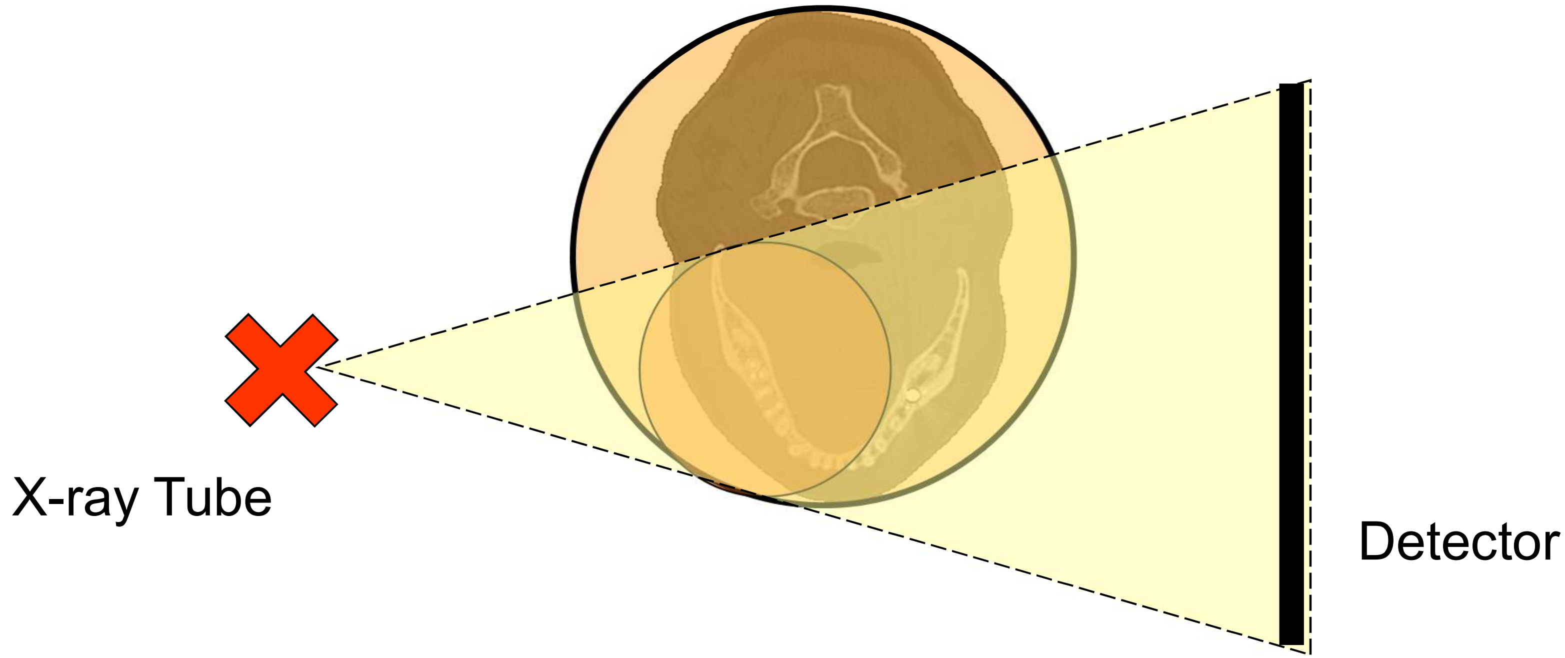
	Full face 13cm height x 16cm diameter 83 microSieverts
	Both arches 8cm height x 16cm diameter 56 microSieverts (interpolated)
	Mandible 6cm height x 16cm diameter 45 microSieverts

Absorbed Dose outside primary beam is effectively zero



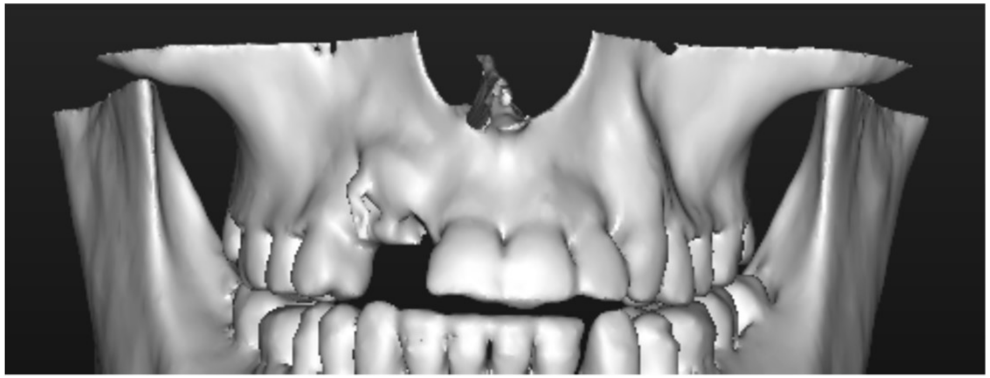


2. Reduce the Width (horizontal collimation)

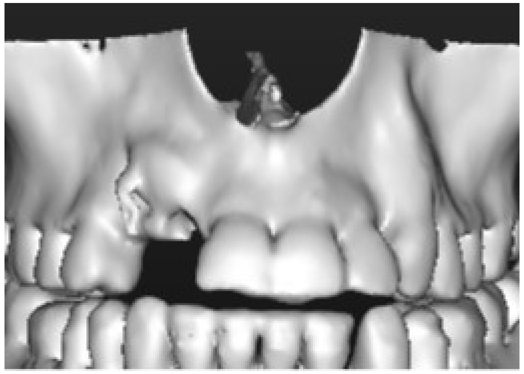


- **Absorbed Dose outside primary beam is not zero (about 50% from SEDENTEXCT measurements)**

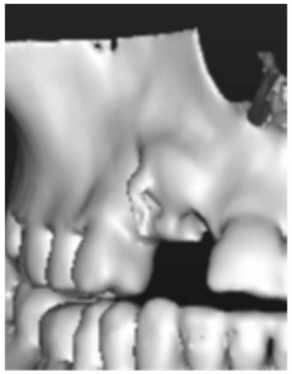
- **There may be some loss of benefit**



16cm diameter



8cm diameter



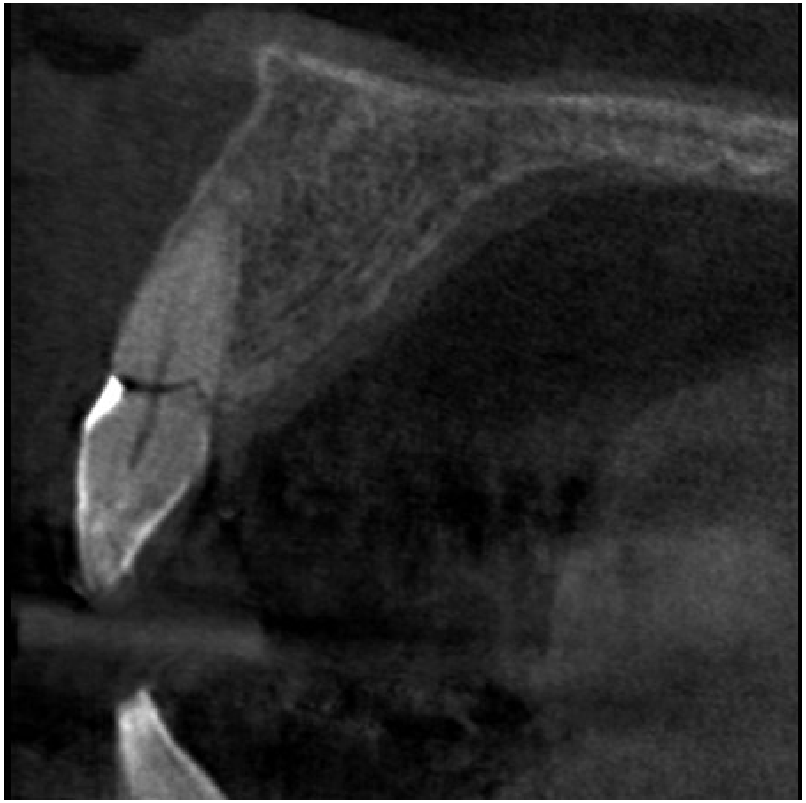
4cm diameter

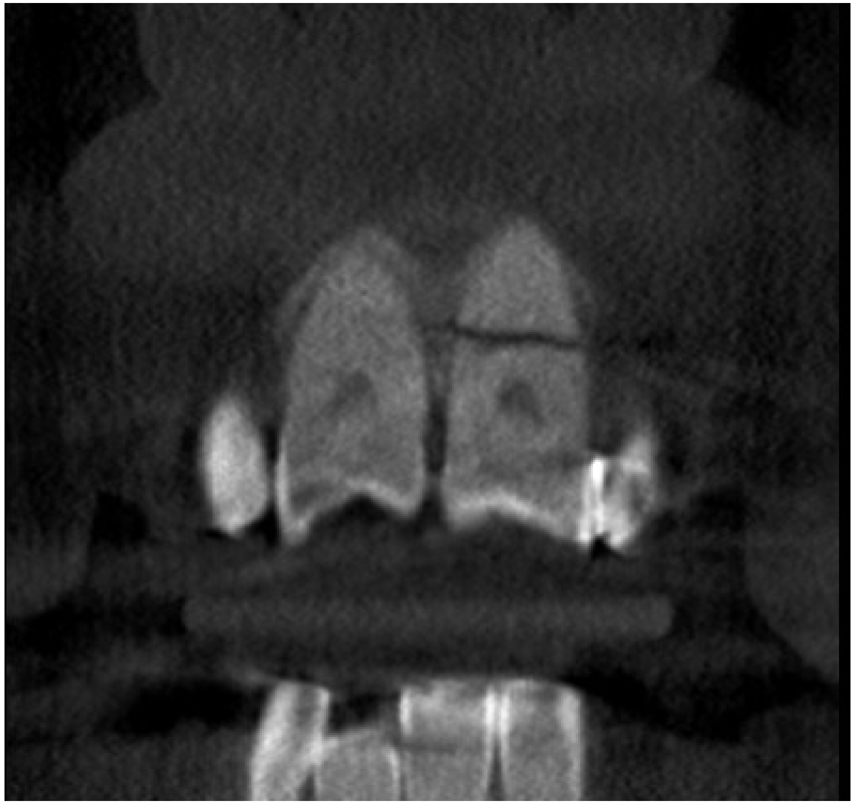
CBCT Scans

3. Reduce the mAs (tube current, scan time)

- **Reducing the mAs will have a negative impact on image quality**
  - **more noise**
  - **less angular samples**

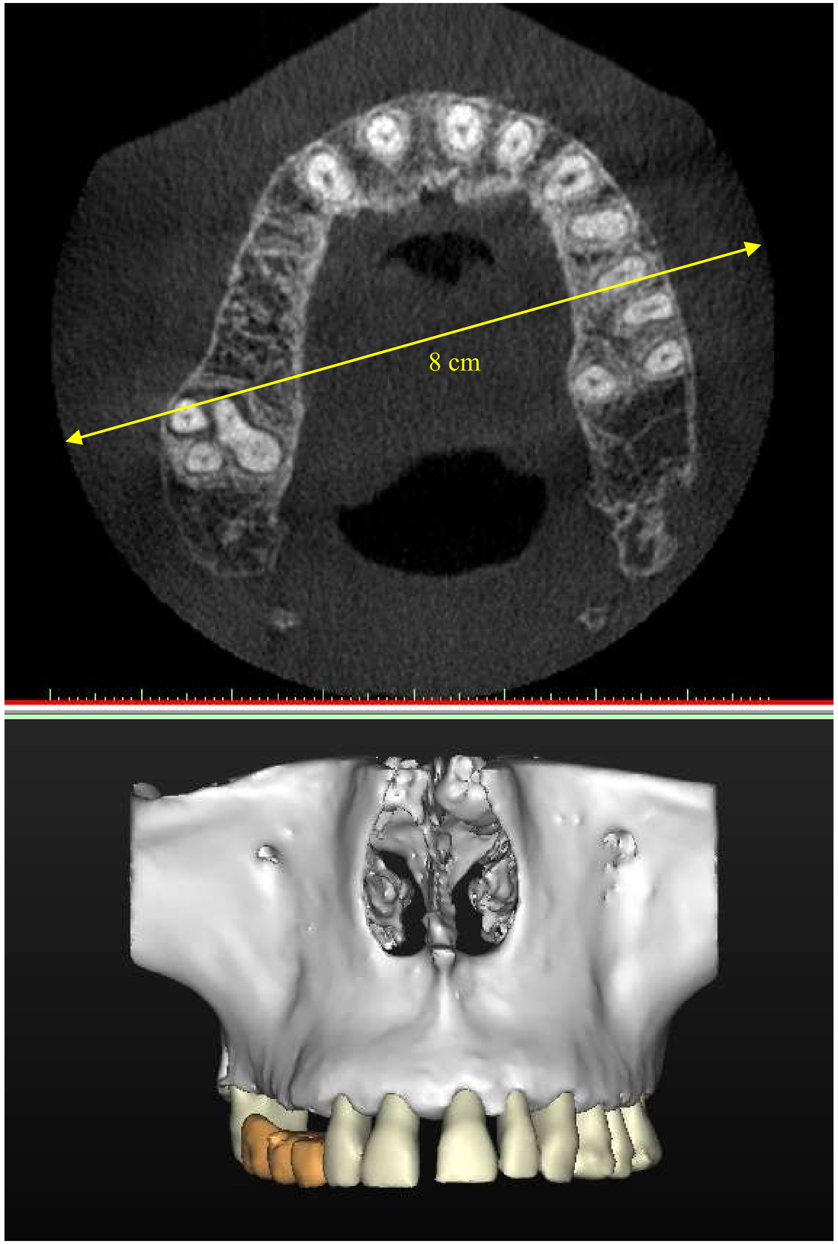
- **On some scanners, the voxel size is linked to the mAs**





5cm x 5cm DAP 113 mGy.cm2
Effective Dose 15 microSv approx.

Is this optimal patient positioning?



1. Reduce the height to avoid the orbits.

2. Centre the patient to get the maximum information for the same radiation dose.

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.

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 is 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**

Controlled and Supervised Areas

An area is *Controlled* or *Supervised* (depending on the level of risk) if special procedures ("Local Rules") are needed to prevent significant exposure.

Intra-orals:

- **Within the primary x-ray beam until sufficiently attenuated**
- **Within 1.5m of the x-ray tube and patient in any other direction (operator should be at least 2m from the patient).**

Dental CBCT:

- **Usually the entire room is a Controlled Area while the power is on.**
- **Two-stage warning lights are recommended**
- **Cleaners etc should not enter while the power is on.**

Radiation Protection Advisor (RPA)

- **Dental Practices must appoint a suitable RPA (in writing)**
- **Involved with Radiation Safety of staff and the public**
- **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**

Where can I find a Radiation Protection Advisor (RPA)?

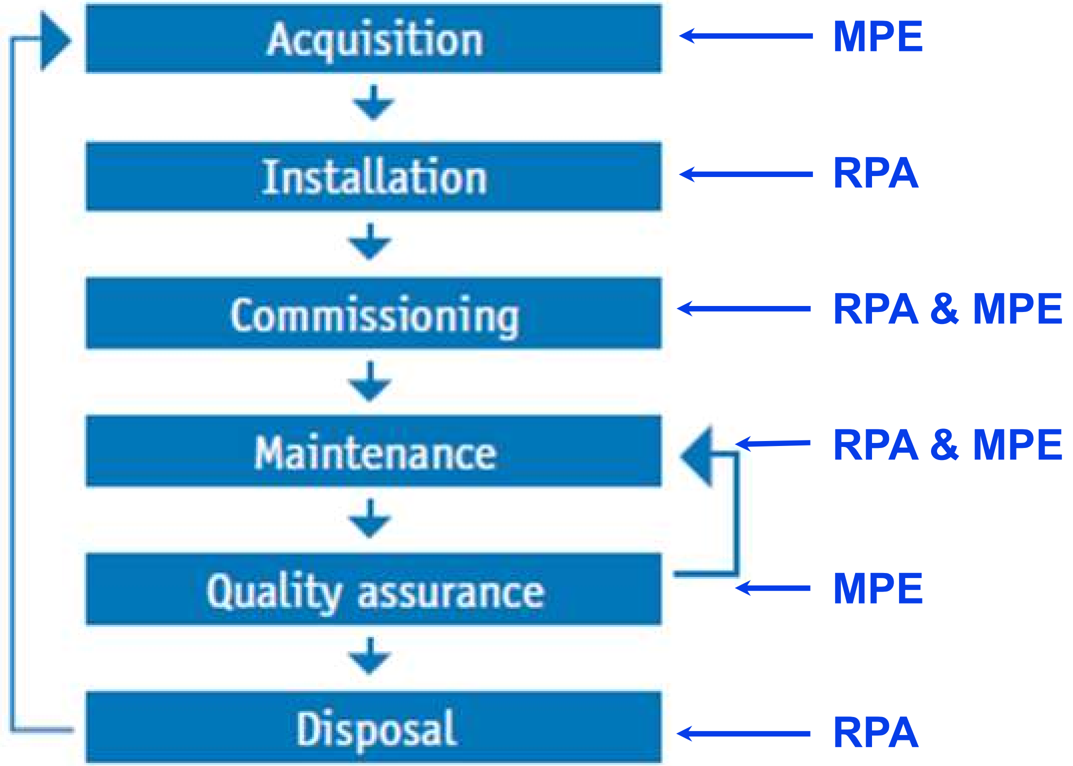
- **An RPA is generally a physicist with certification from an HSE-approved Assessing Body**
- **Usually an outside consultant**
- **Should make themselves available for consultation (otherwise, get a different one)**
- **A list of RPAs is available at www.rpa2000.org.uk**

Medical Physics Expert (MPE)

The BSSD defines Medical Physics Expert as:

- "An individual …having the knowledge, training and experience to act or give advice on matters relating to radiation physics applied to medical exposure, whose competence in this respect is recognised by the competent authority"
- RPAs are concerned with Radiation Safety for Workers and the Public
- MPEs are concerned with Radiation Safety for Patients, getting involved with Equipment Purchases, Quality Assurance and Optimisation
- MPEs are certified by the Department of Health & Social Care
- In many cases, the RPA and the MPE will be one and the same person.

Equipment Life Cycle



Frequently Asked Questions

What are the current Radiation Safety laws in the UK?

- **Radiation Safety for Workers and the Public**
  - **IRR 2017**

- **Radiation Safety for Patients**
  - **IR(ME)R 2017 (as amended in 2018)**

- **IRR99 and IR(ME)R 2000 have been revoked.**

Are Film Badges required for Dental Practice staff?

- Personal monitoring (using electronic dosimeters, or film badges) is recommended where a risk assessment indicates that staff are liable to receive doses in excess of 1 mSv per year.

- In practice, this would be for staff whose workload exceeds 100 intraoral or 50 extraoral per week (or some pro-rata combination).

- Most staff in dental practices will not reach this limit.

What about Lead Aprons?

- **There is no justification for the routine use of lead aprons for patients in dental radiography.**

- **There is no requirement to provide a lead apron to a pregnant patient.**

- **However, lead aprons should be available for any person (comforters, carers or staff) who provides assistance by supporting a patient during a radiographic procedure.**

What about Thyroid Collars?

- **Thyroid collars should be used in the few examinations where the thyroid may be in the main primary beam and the collar will not interfere with the image (e.g. cephalometric radiography but not panoramic radiography or CBCT).**

- **In practice, it is usually better to collimate so that the thyroid is outside the primary beam.**

- **The use of thyroid collars should also be considered when intraoral radiographs are taken with circular collimators on younger patients.**

- **The use of shielding which comes in contact with the patient is generally discouraged.**

What about Pregnant Patients?

There are special regulations relating to exposure of patients who are or may be pregnant.

- **European Guidance indicates that special precautions are not indicated for low dose procedures or where the uterus is not in the primary beam (e.g. in dental radiography).**
- **There is a requirement to ask a female of childbearing age if she is pregnant, and record her reply.**
- **There is no requirement to use lead aprons for pregnant patients.**
- **Vertex occlusion projections (which might irradiate the foetus) are generally prohibited.**

Who Can Refer a Patient for a CBCT Exam?

- *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.

Practitioner

- Usually a dentist in the practice that owns the CBCT Scanner
- 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).

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.**

Can my nurse take the CBCT scan?

An "Operator" is anyone who is entitled by the Employer to carry out practical aspects of an exposure.

The rules are the same for

- **Intraoral radiographs**
- **Dental Panoramic Tomography (DPT)**
- **Cephalometric radiographs**
- **CBCT scans**
- **Any other type of dental X-ray**

If your nurse is entitled to take intraorals or DPTs then he/she can be entitled to take CBCT scans as well

Entitlement should be based on adequate training as spelled out in Schedule 3 of the IR(ME)R legislation.

Who can be a Referrer?

A Referrer must be a Registered Health Care Professional.

Referrers can only refer patients for specific procedures in accordance with the Employer's referral criteria.

There is no formal requirement for Referrers to have received additional training, but it is good practice.

Who can be a Practitioner?

A Practitioner must be a Registered Health Care Professional.

Practitioners are entitled to take responsibility for an individual exposure.

Practitioners must have received adequate training as spelled out in Schedule 3 of the IR(ME)R legislation.

So who can press the button?

- The Practitioner can either perform the procedure, or delegate it to a person who has received adequate training.

- Dental nurses, dental hygienists, etc may perform x-ray procedures provided that:

  1. they have completed appropriate training in radiation safety
  2. they have received practical training on operating the machine
  3. the procedure has been authorised by a Practitioner.

- The Practitioner retains clinical responsibility for the exposure, even though the practical aspects have been delegated.

What About 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.

Dentomaxillofacial Radiology (2014) 43, 20130291

http://dmfr.birjournals.org

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 Brown[1], R Jacobs[2], E Levring Jäghagen[3], C Lindh[4], G Baksi[5], D Schulze[6] and R Schulze[7]

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

Royal College of Surgeons
ADVANCING SURGICAL CARE

https://www.rcseng.ac.uk/education-and-exams/courses/search/dental-cbct-level-1/

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, and aims to help participants fulfill 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.

Royal College of Surgeons
ADVANCING SURGICAL CARE

https://www.rcseng.ac.uk/education-and-exams/courses/search/dentoalveolar-cbct-interpretation-level-2/

Patient Care | Careers in Surgery | Education & Exams | Library & Publications | Standards & Research | Dental Faculties | News & Events

Exams | Courses | For Regional and International Centres | Work with our Team | Our Surgical Training Facilities

Basics of Dento-alveolar 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

https://www.kcl.ac.uk/study/postgraduate/taught-courses/
dental-cone-beam-ct-radiological-interpretation-pg-cert.aspx

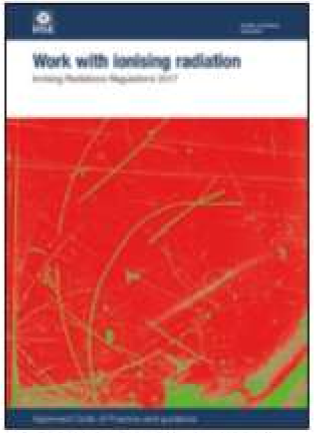
Guidance Documents (UK)

- **New Approved Code of Practice L121 costs £27 or download for free**
  www.hse.gov.uk/pubns/priced/l121.pdf

- **Medical and Dental Guidance Notes (IPEM) (IPEM) to be published.**

- **Guidance Notes for Dental Practitioners on the Safe Use of X-Ray Equipment (PHE) updates planned.**

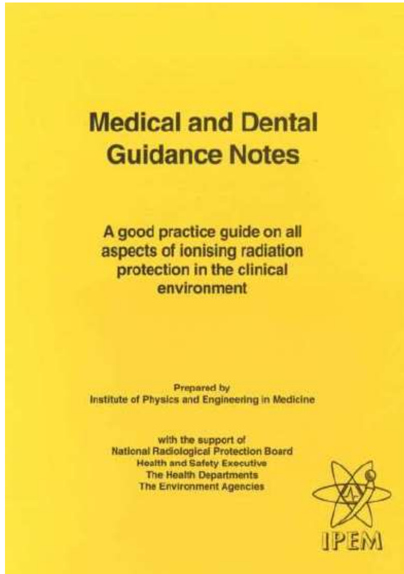
- **IR(ME)R 2017 legislation is available here:**
  www.legislation.gov.uk/uksi/2017/1322/pdfs/uksi_20171322_en.pdf



L121 (Second edition)
Published 2018

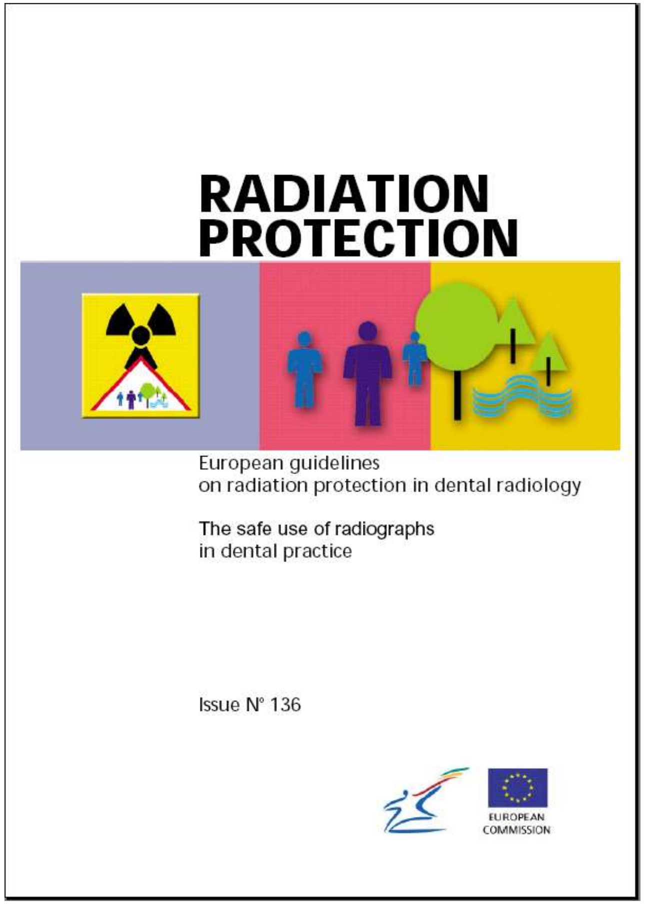
Medical and Dental Guidance Notes

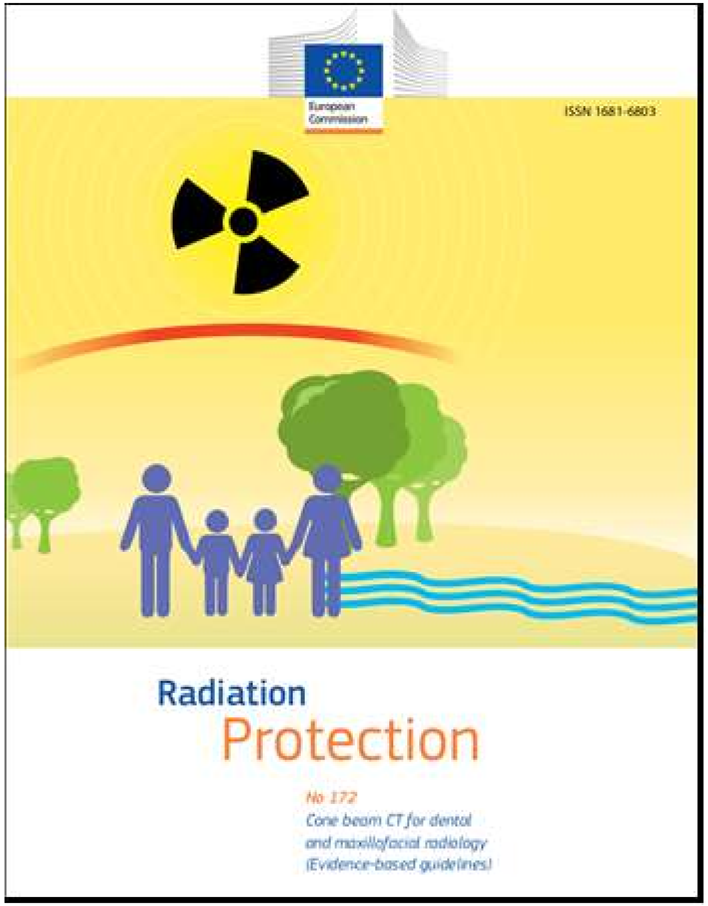
- Provides general guidance on good practice
- Not an attempt to interpret legal requirements
- Following the guidance is not compulsory but should be sufficient to comply with the law
- Covers IRR2017, IR(ME)R 2017
- Equipment, shielding, patient protection, etc



IPEM 2022
Costs £20

Guidance Documents (Europe)





**https://ec.europa.eu/energy/en/topics/nuclear-energy/radiation-protection/
scientific-seminars-and-publications/radiation-protection-publications**

The End

Thank you for listening.