making the most

IDT

of your image™

Image Diagnostic Technology Ltd

5th Floor, Hyde Park Hayes 3, 11 Millington Road, Hayes UB3 4AZ

Tel: +44 20 8982 3588 www.simplantscans.com email: info@ctscan.co.uk

The Science and Physics of CT and CBCT

Anthony Reynolds BA MSc PhD
Registered Clinical Scientist CS03469

Image Diagnostic Technology Ltd.

Who or what is IDT?

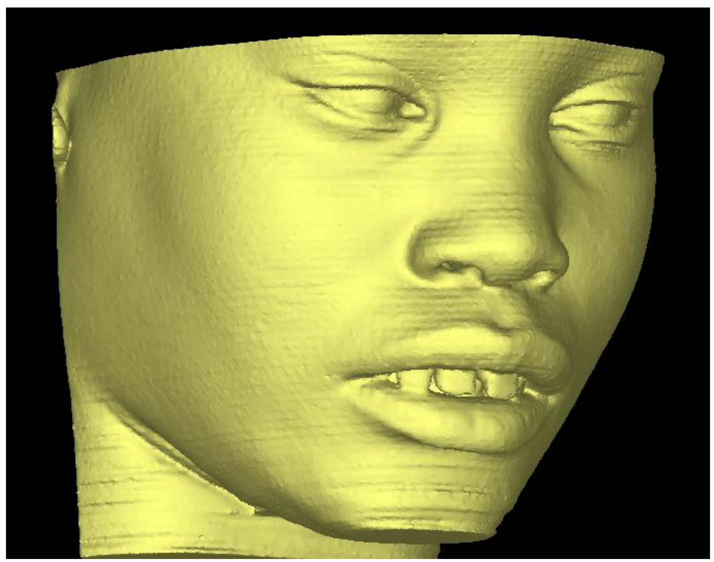
Three Companies in the IDT Group:

Image Diagnostic Technology Ltd

based in UK

specialises in arranging CT scans and 3D processing

since 1991



IDT Ireland based in Ireland

IDT Dental Products Ltd

based in UK

distributes

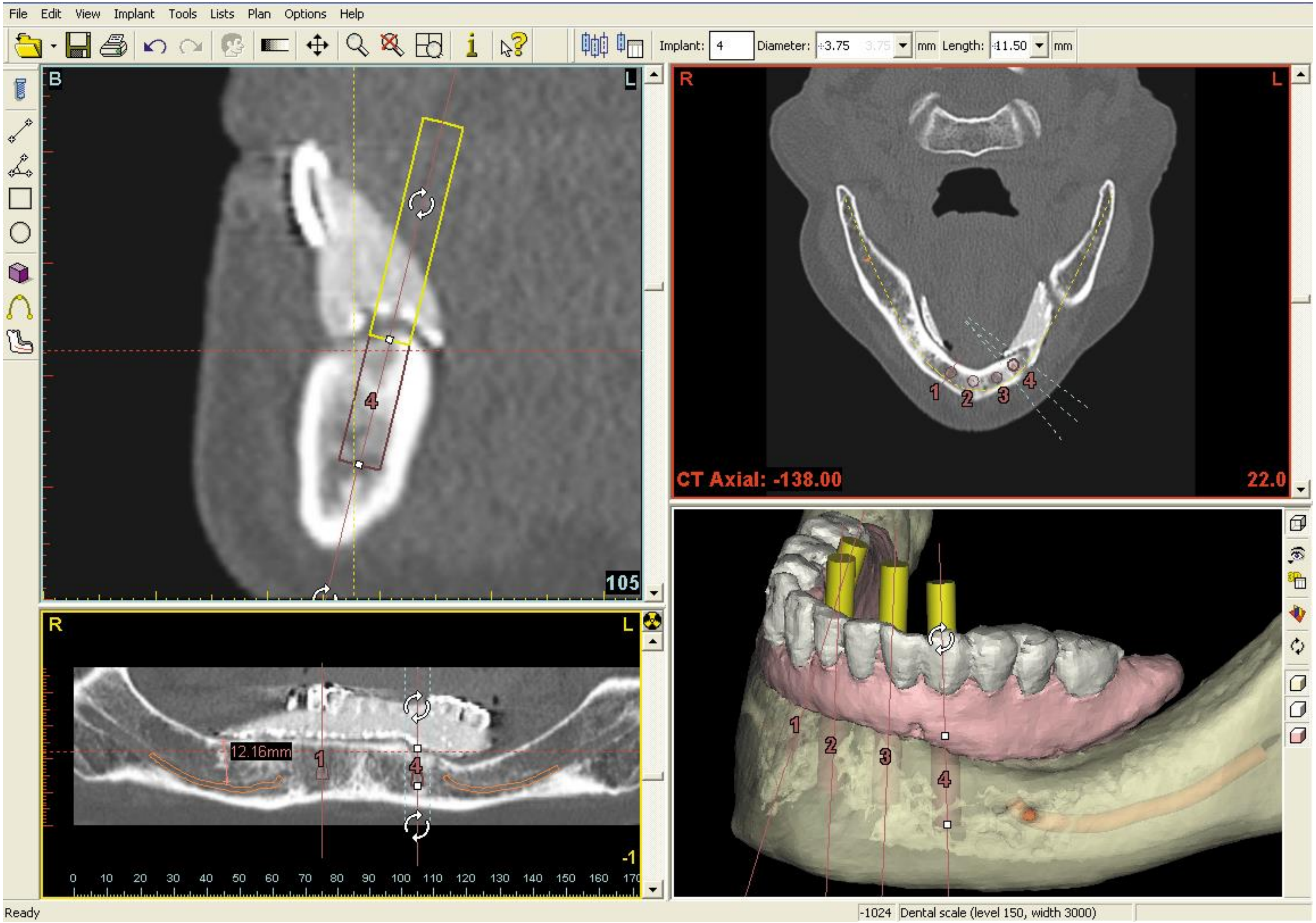
SimPlant® Computer Guided Implantology

SurgiGuide Computer Guided Implantology

i-CAT

GENDEX Imaging Excellence Since 1893

SimPlant Computer Guided Implantology *interactive implant planning software*

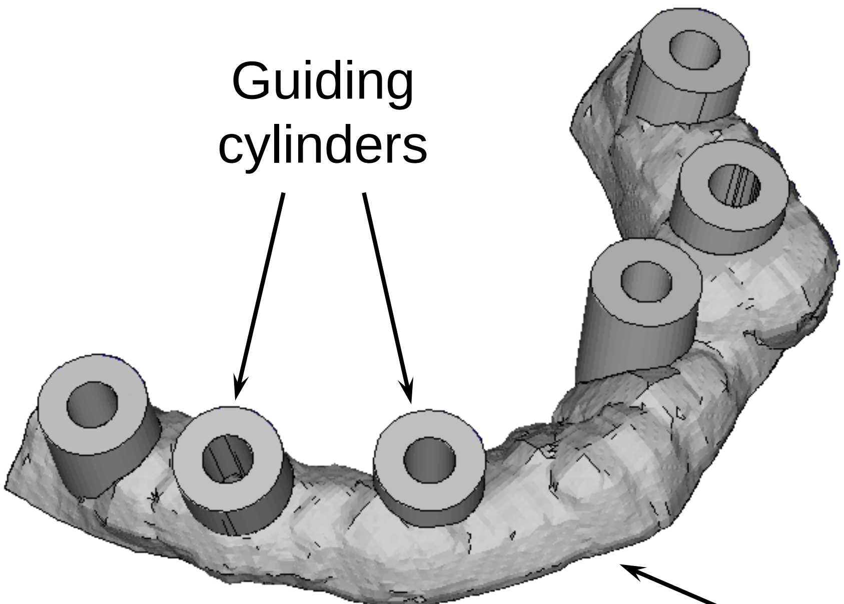


SIMPLANT™ is a trademark of DENTSPLY Implants

SurgiGuide Computer Guided Implantology

SIMPLANT drill guide

Guiding cylinders



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

Guide resting on:
- Bone
- Mucosa
- Teeth

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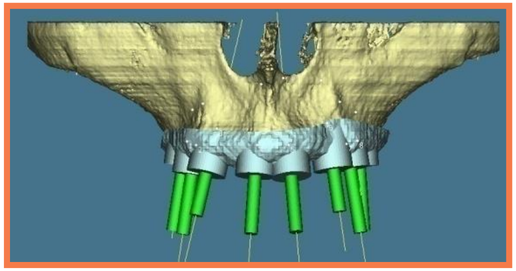
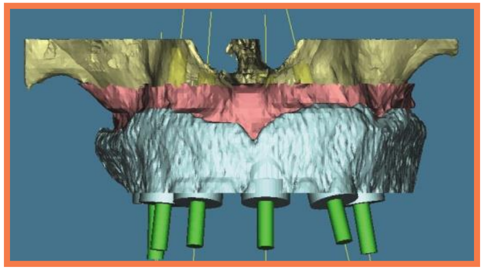
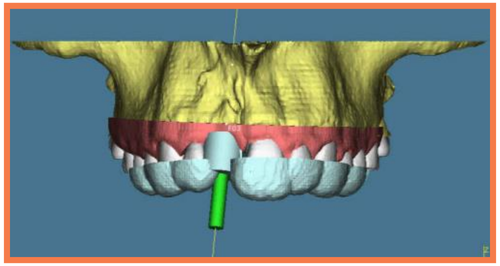
Drill Guides can be supported on



Bone



Mucosa



Teeth

Bone Supported Guides:

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

Mucosa Supported Guides:

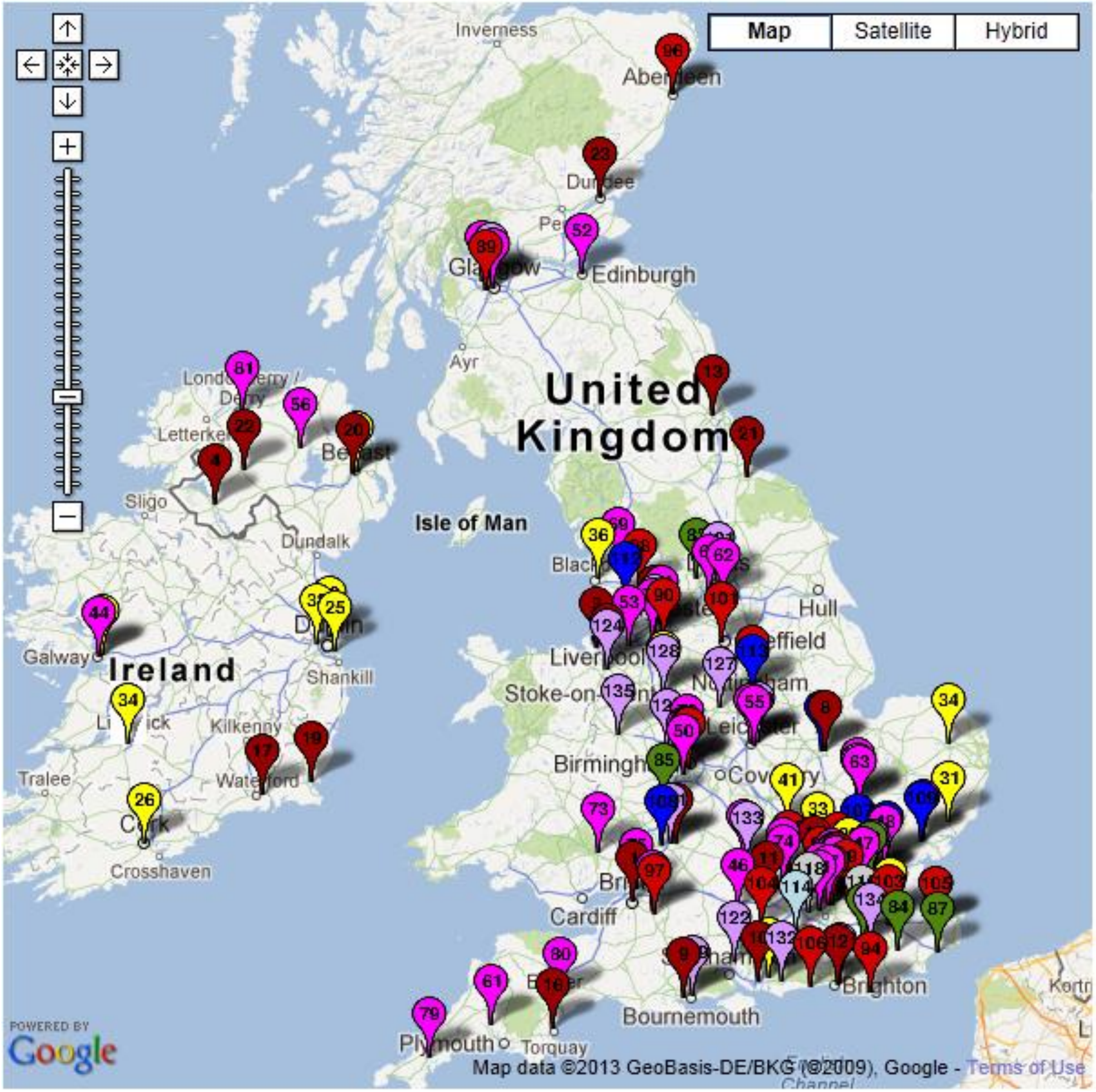
- Patient must be scanned with a radio-opaque scanning stent in place

Tooth Supported Guides:

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

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

www.simplantscans.com



www.simplantscans.com

View all scanning sites

Back

or choose your preferred location:

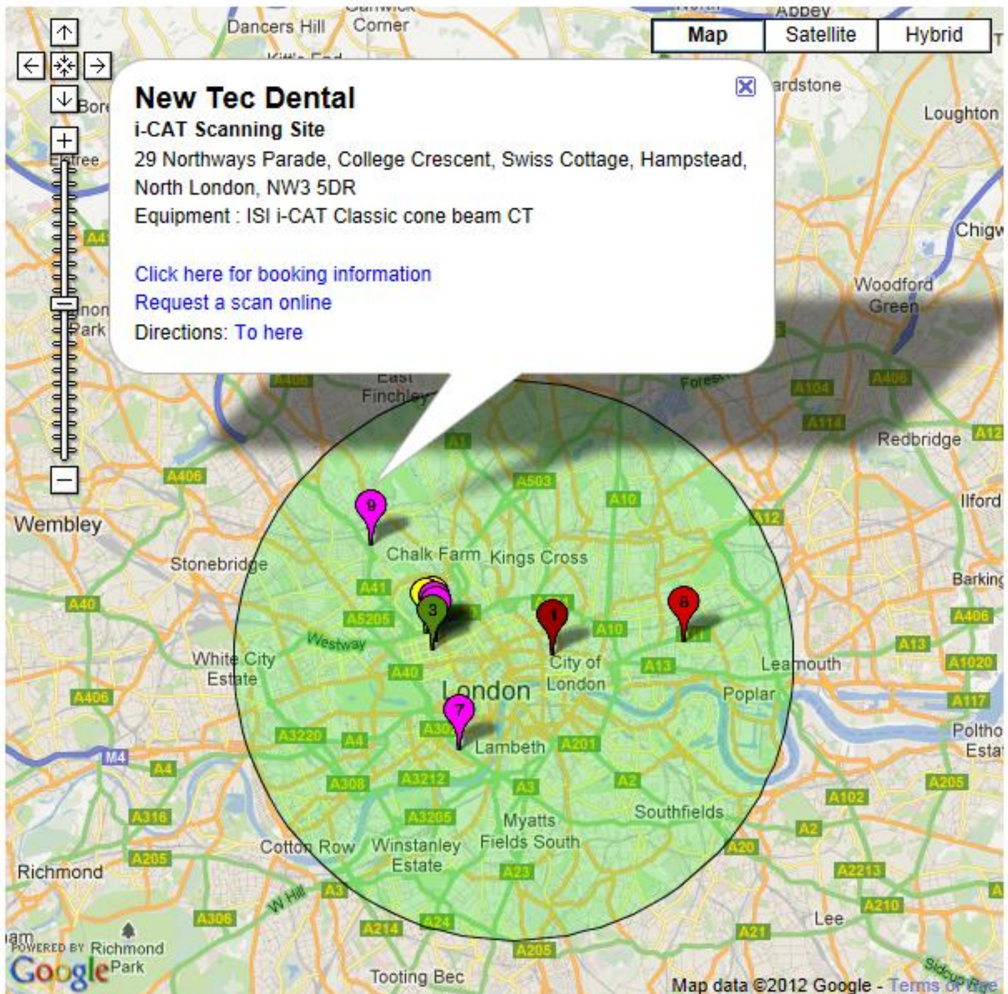
England, Scotland, Wales and Northern Ireland

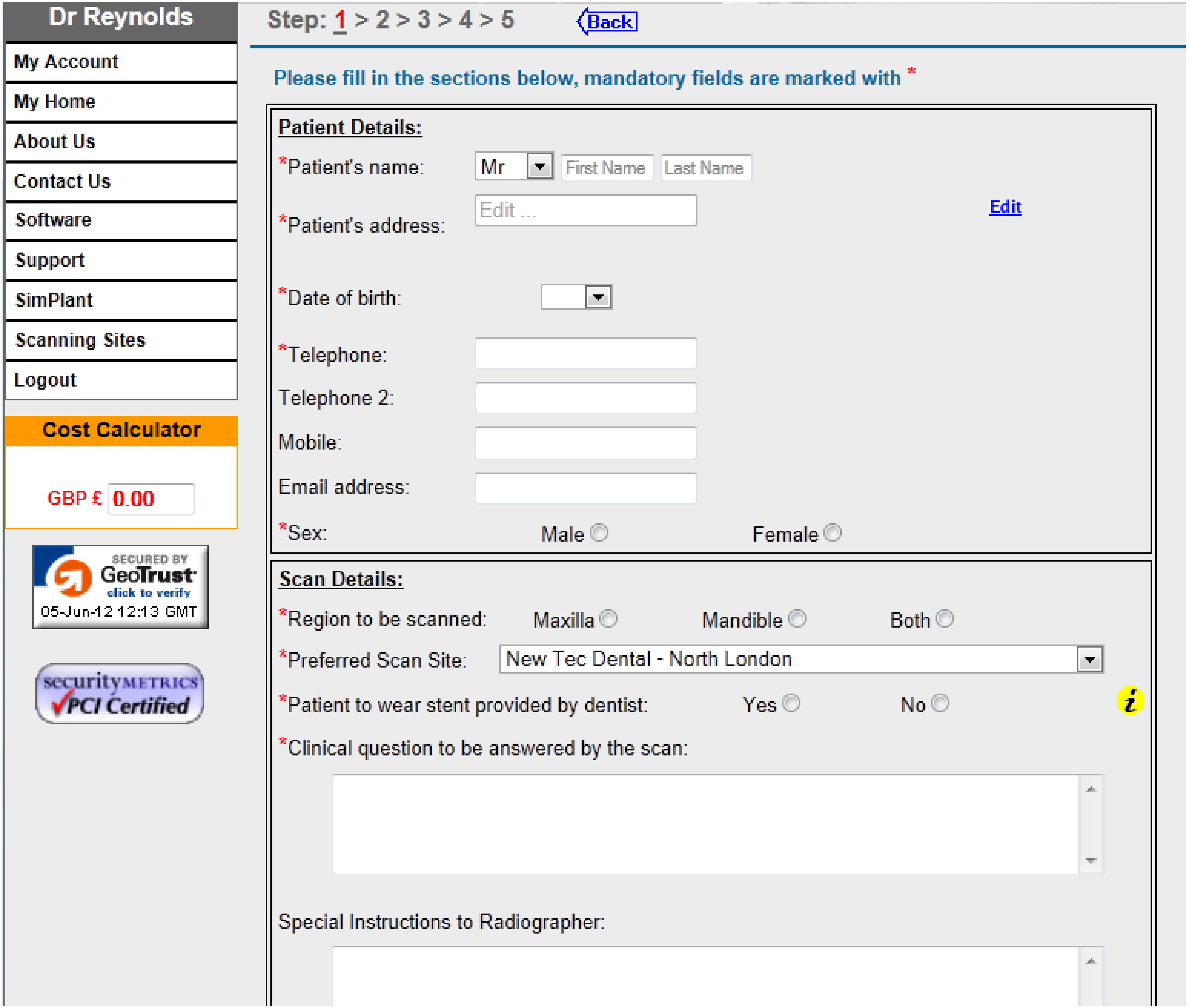
Postcode WC2A 3PE within 5 miles

Find Sites

Key to scanning sites

- i-CAT Scanning Site
- Public Hospitals
- Alliance Medical Sites
- Private Imaging Centres
- BMI Hospitals
- Lifescan Centres
- Nuffield Hospitals
- Ramsay Health Care
- UME Diagnostic Centres




Dr Reynolds
My Account
My Home
About Us
Contact Us
Software
Support
SimPlant
Scanning Sites
Logout
Cost Calculator
GBP £ 0.00
SECURED BY GeoTrust click to verify
05-Jun-12 12:13 GMT
securityMETRICS PCI Certified
Step: 1 > 2 > 3 > 4 > 5
Back
Please fill in the sections below, mandatory fields are marked with *
Patient Details:
*Patient's name: Mr First Name Last Name
*Patient's address: Edit ...
Edit
*Date of birth:
*Telephone:
Telephone 2:
Mobile:
Email address:
*Sex: Male Female
Scan Details:
*Region to be scanned: Maxilla Mandible Both
*Preferred Scan Site: New Tec Dental - North London
*Patient to wear stent provided by dentist: Yes No
*Clinical question to be answered by the scan:
Special Instructions to Radiographer:

Outline of Presentation

- ✔ Introduction / Disclosures
- Imaging for Dental Implants
  - Conventional Radiography
  - Cross-Sectional Imaging
- Radiation Dose and Risk
- Dose versus Image Quality

Imaging for Dental Implants

Need to be able to:

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

Restoration-Driven Implant Planning

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

- ***Radio-Opaque Scanning Stents***
- ***Treatment Planning Software***
- ***Surgical Drill Guides***

The Ultimate Goal

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

"The Immediate Smile" *– Materialise Dental*
"Teeth in an Hour" *- Nobel Biocare*
"Smart Implants" *- Dr Siew Lim*

The Ultimate Goal

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

- To do this you have to rely on your imaging!

Which Imaging Modalities are best?

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

✘ **Extra-oral radiography**
- **AP and Lateral cephs**

✘ **Conventional tomography**
- **Dental Panoramic Tomography (DPT)**
- **Linear / Complex Motion Tomography (CMT)**

✘ **Magnetic Resonance Imaging**

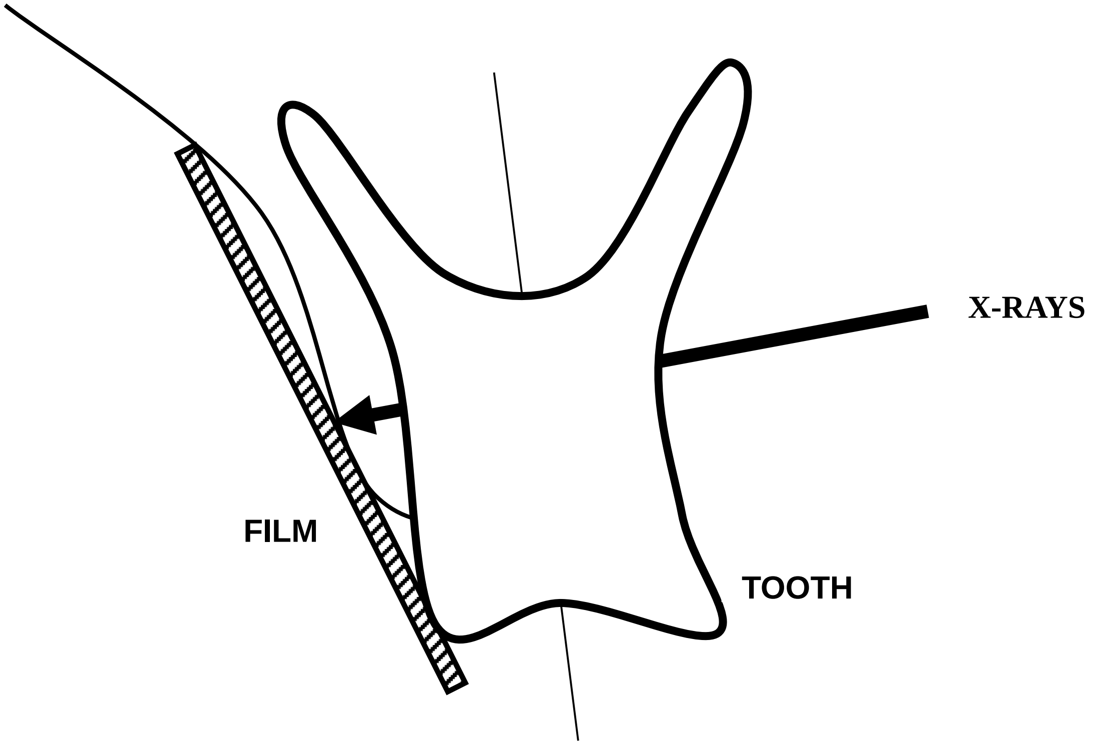
✔ **Medical computed tomography (CT)**

✔✔ **Cone Beam computed tomography (CBCT)**

Intra-oral Imaging

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

Distortion in intra-orals



Solutions:

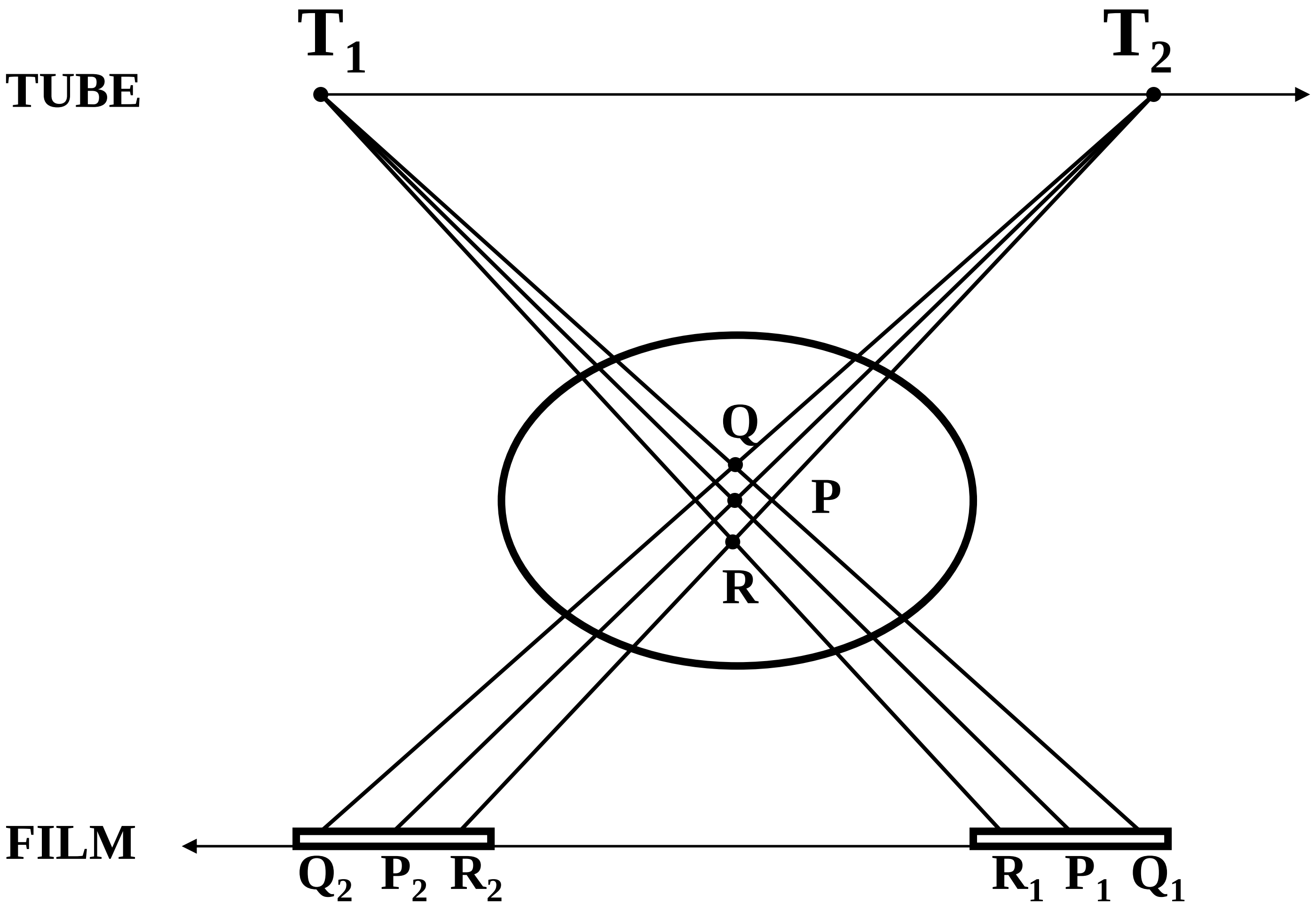
- bisecting angle ✗
- paralleling technique ✓

Extra-oral: Lateral Cephs

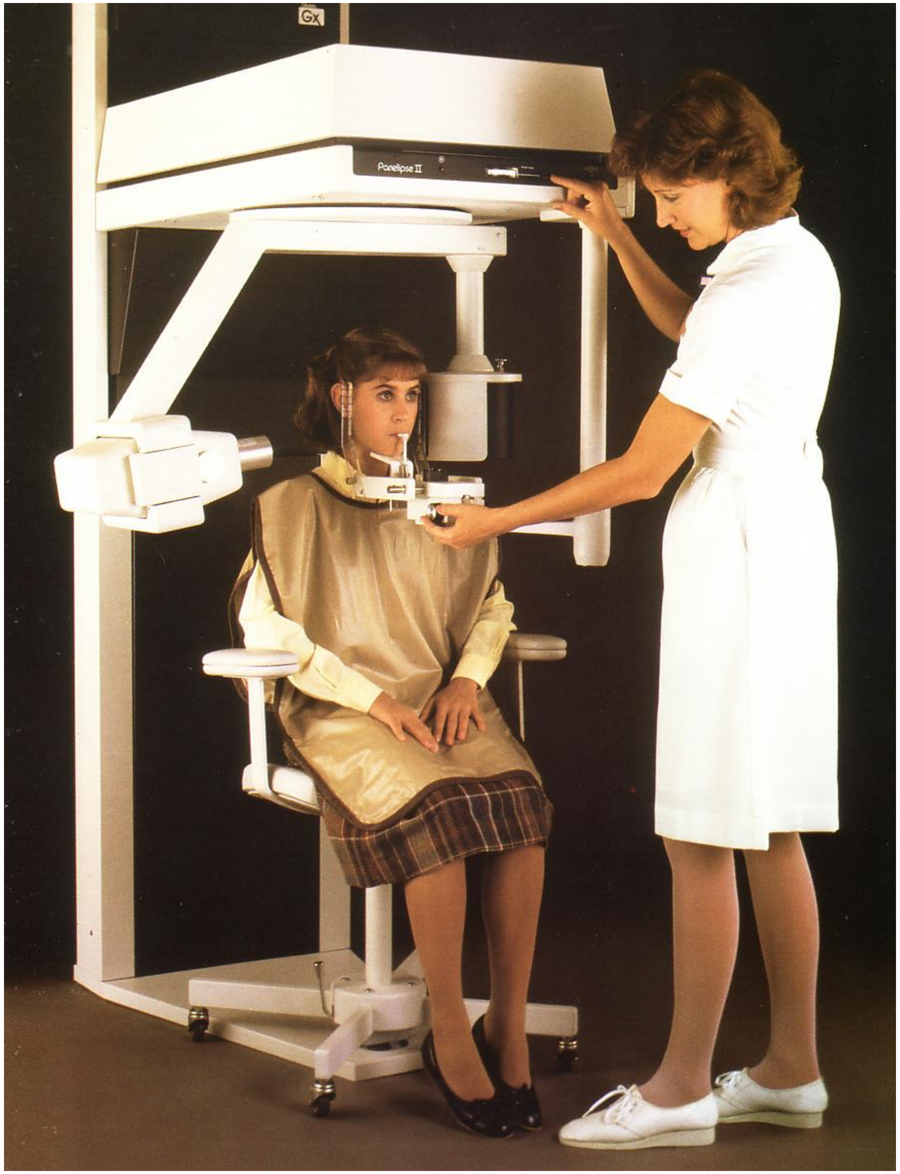
+ Good overview
– Width and height on midline only
– No (quantitative) bone quality

Conventional Tomography

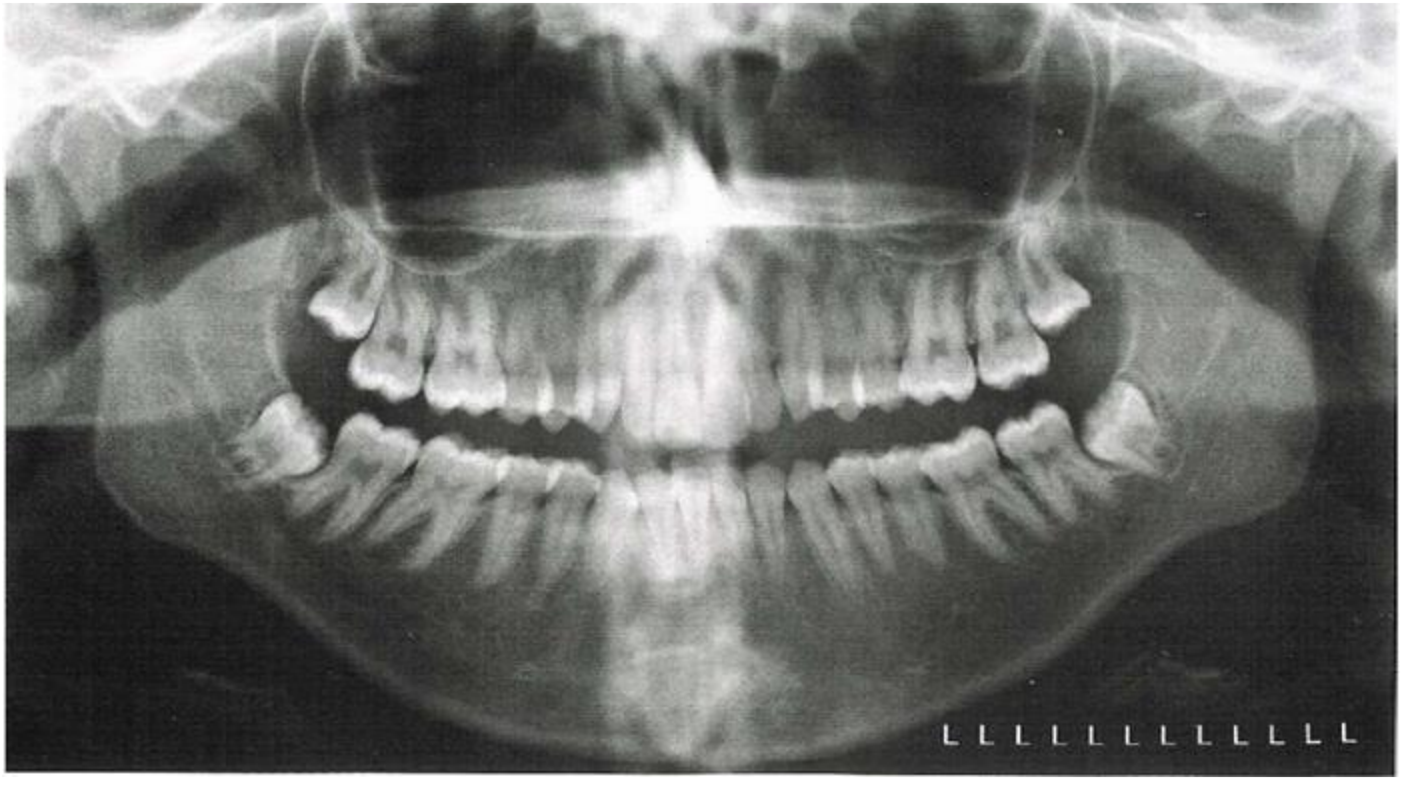
(tomography by blurring)



Dental Panoramic Tomography (DPT)



Dental Panoramic Tomography (DPT, OPG, OPT)



+ Very good overview
– No bone width
– No (quantitative) bone quality
– Variable magnification => distortion
– Patient positioning is crucial

DPTs are useful for:

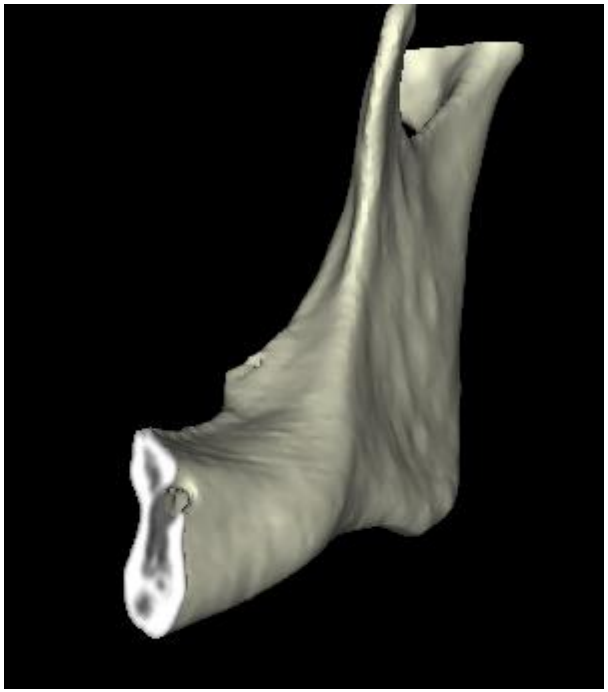
- Overall status of teeth and supporting bone
- Anatomical anomalies and pathological conditions
- Triage between:
  - Sites where placing implants will be straight-forward
  - Sites where grafting or distraction will be needed
  - Sites where implants are not advisable

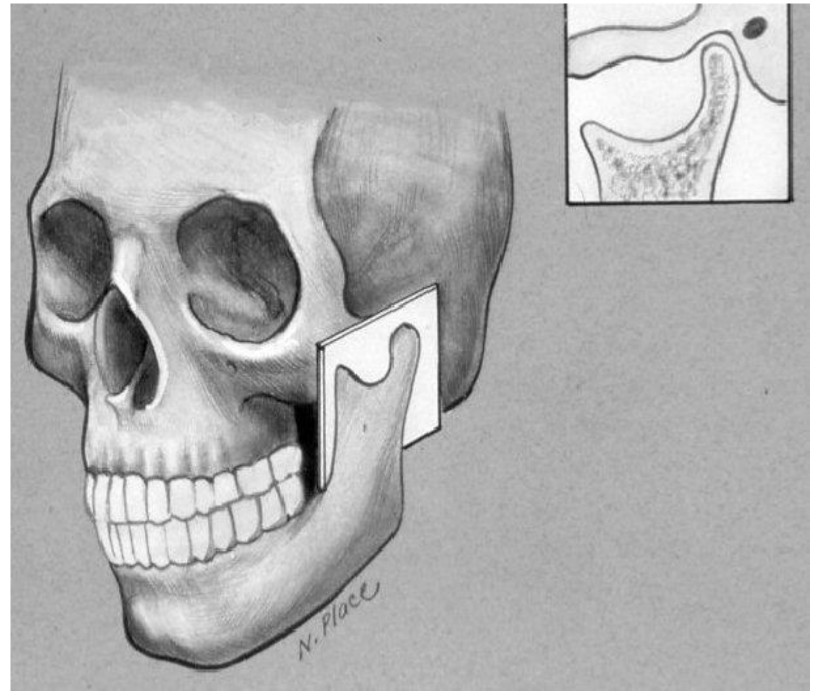
DPTs are not accurate:

Reddy et al. Clin Oral Implants Res. 1994 Dec; 5(4):229-238

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

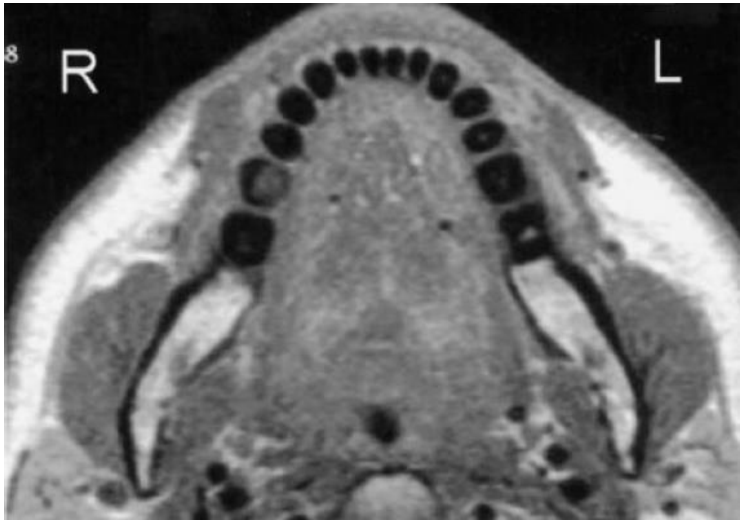
Cross-Sectional Imaging





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

Magnetic Resonance Imaging



+ no radiation dose
+ no metallic artefact
- large, expensive machine
- teeth generate no signal

Advanced imaging: Magnetic resonance imaging in implant dentistry

A review

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

Article first published online: 31 JAN 2003

DOI: 10.1034/j.1600-0501.2003.140103.x

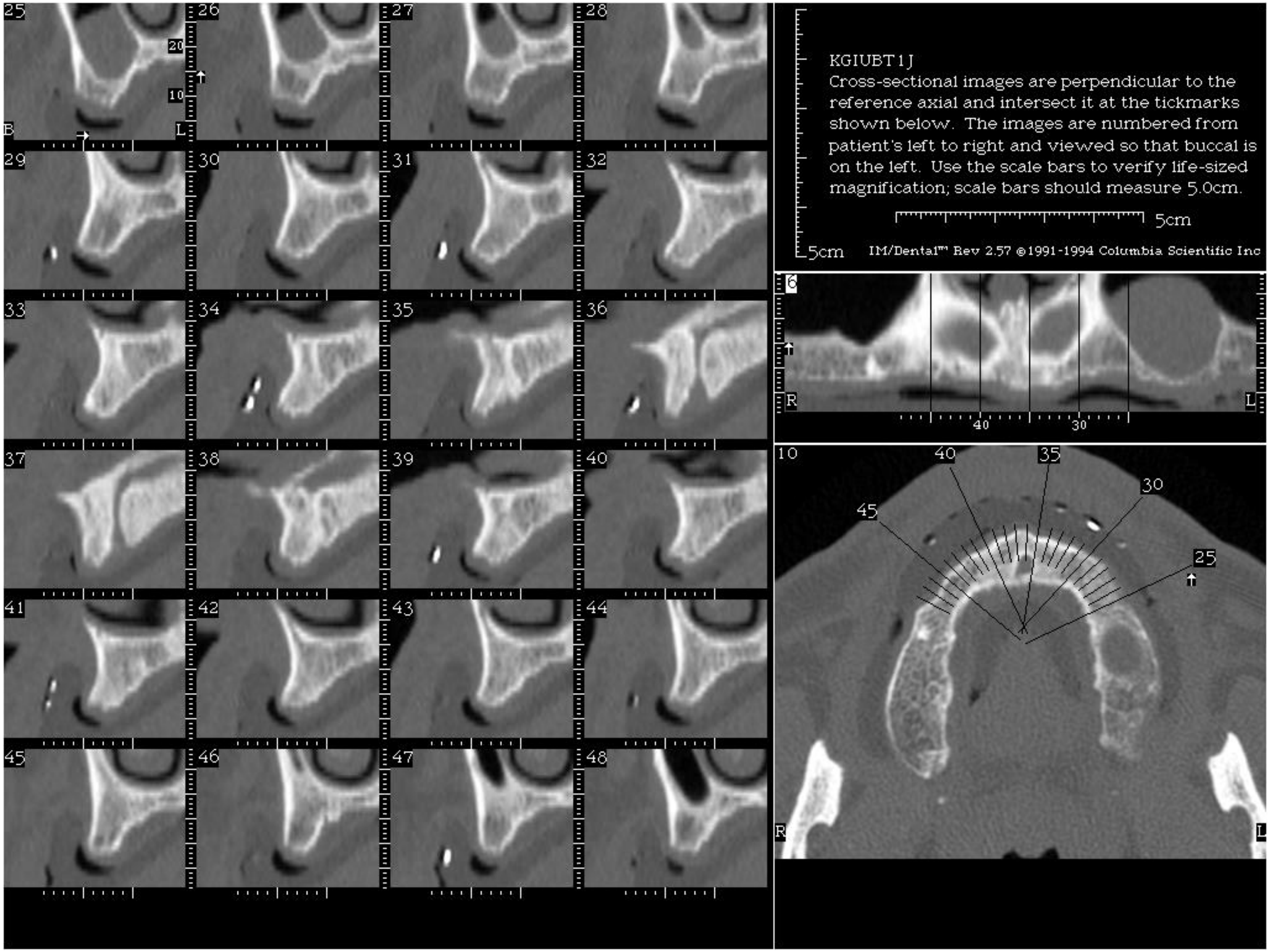
Issue

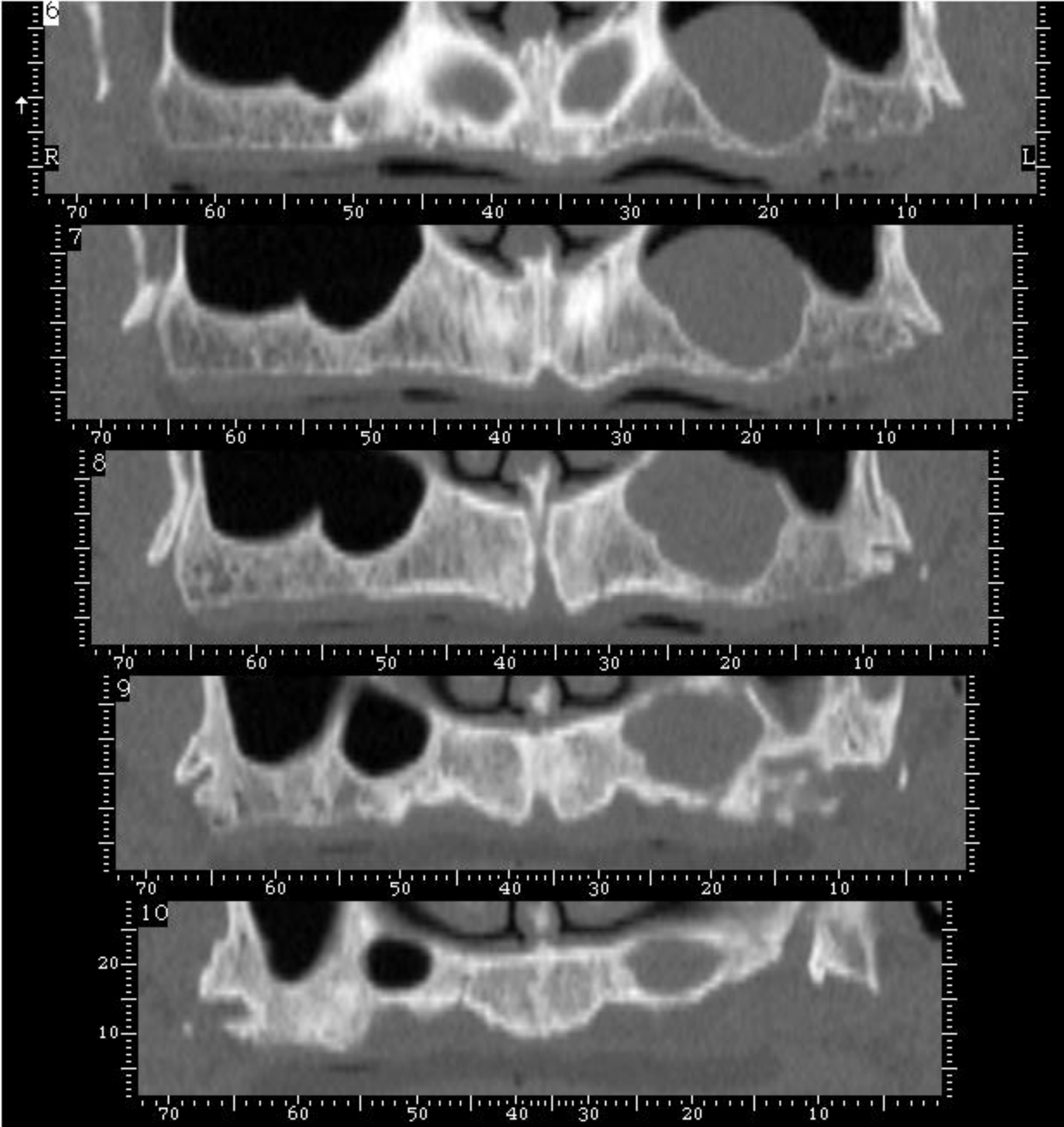
Clinical Oral Implants Research

Volume 14, Issue 1, pages 18–27, February 2003

Computed Tomography (CT)

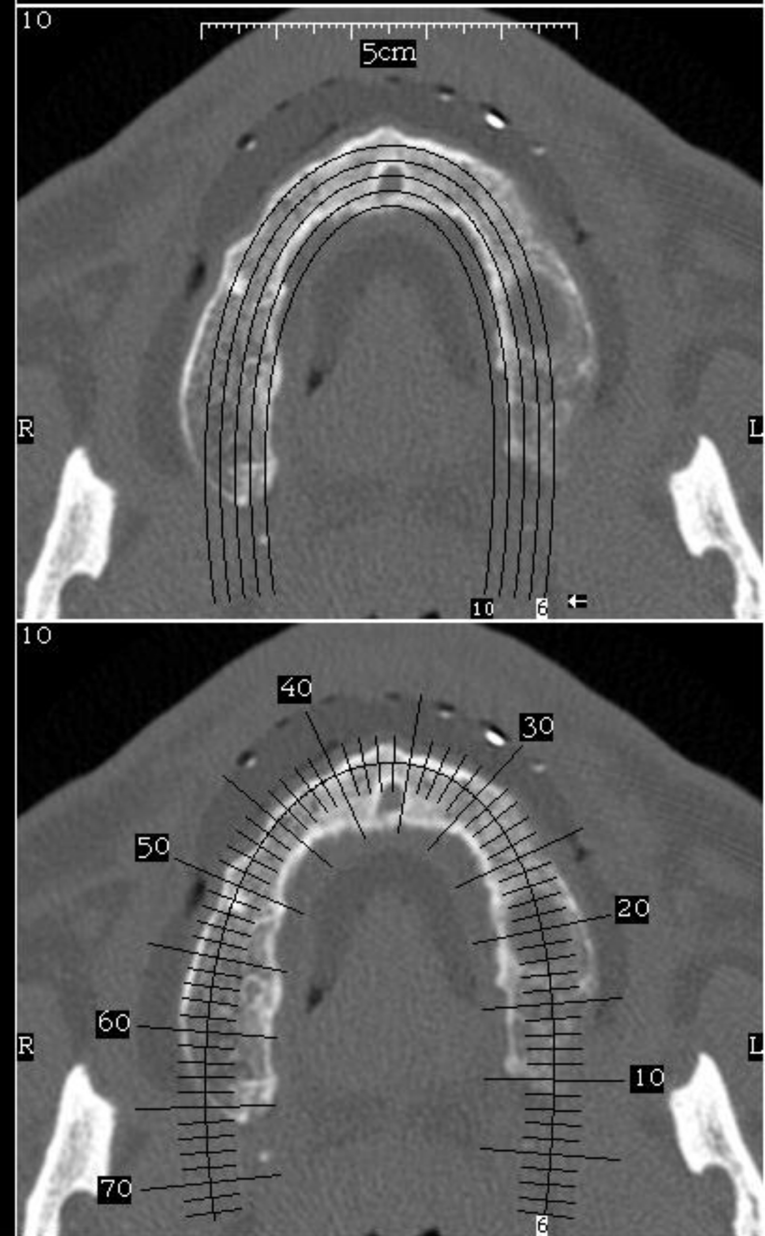
(tomography by computation)



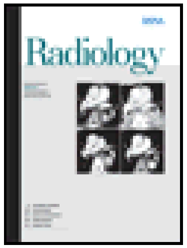


KGIUBT1J Panoramic images are perpendicular to the reference axial and intersect it at the curves shown below. Images are numbered from buccal to lingual and are viewed from buccal.

IM/Dental™ Rev 2.57 ©1991-1994 Columbia Scientific Inc



(First paper on dental reformatted CT)

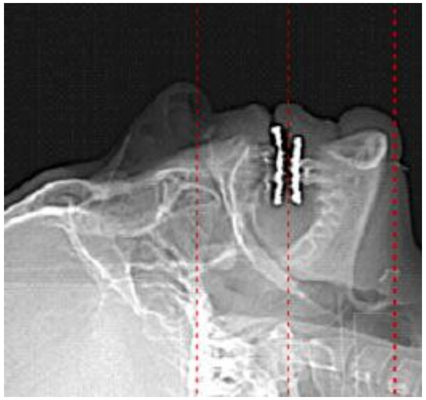


S L Rothman, N Chaftez, M L Rhodes, M S Schwarz and M S Schwartz

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

Radiology July 1988 168:171-175

Dental CT or CBCT Scans

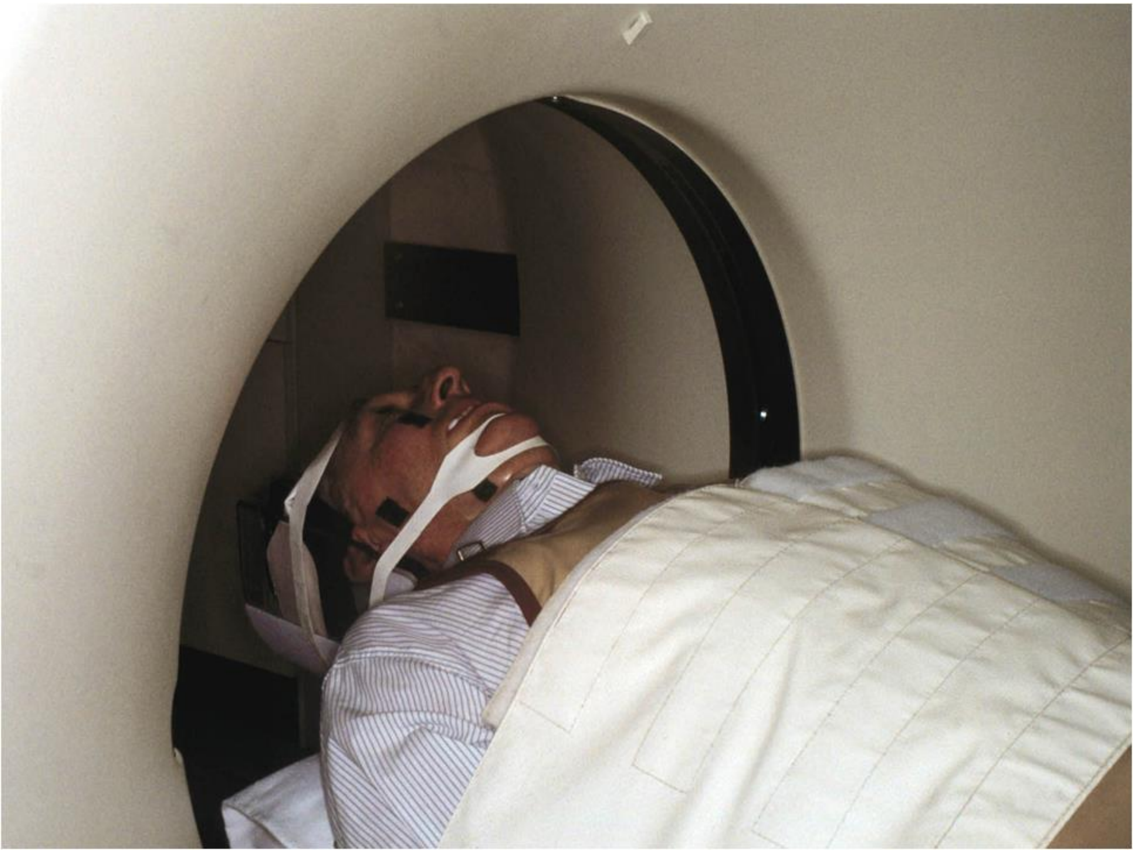


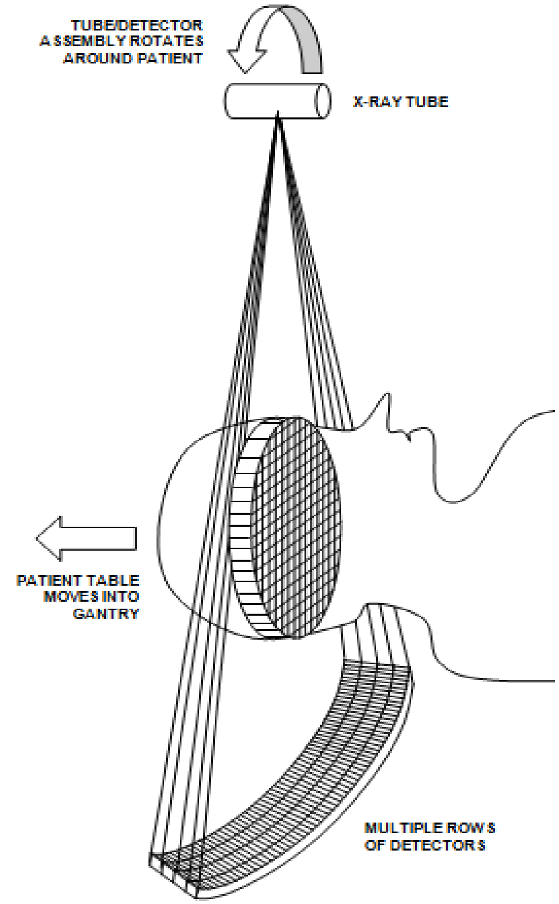
- Bony anatomy of Mandible, Maxilla or Both

- Useful for:
  - planning dental implants
  - maxillofacial surgery
  - TMJ and airway analysis
  - impacted and supernumerary teeth
  - root canals, root fractures etc

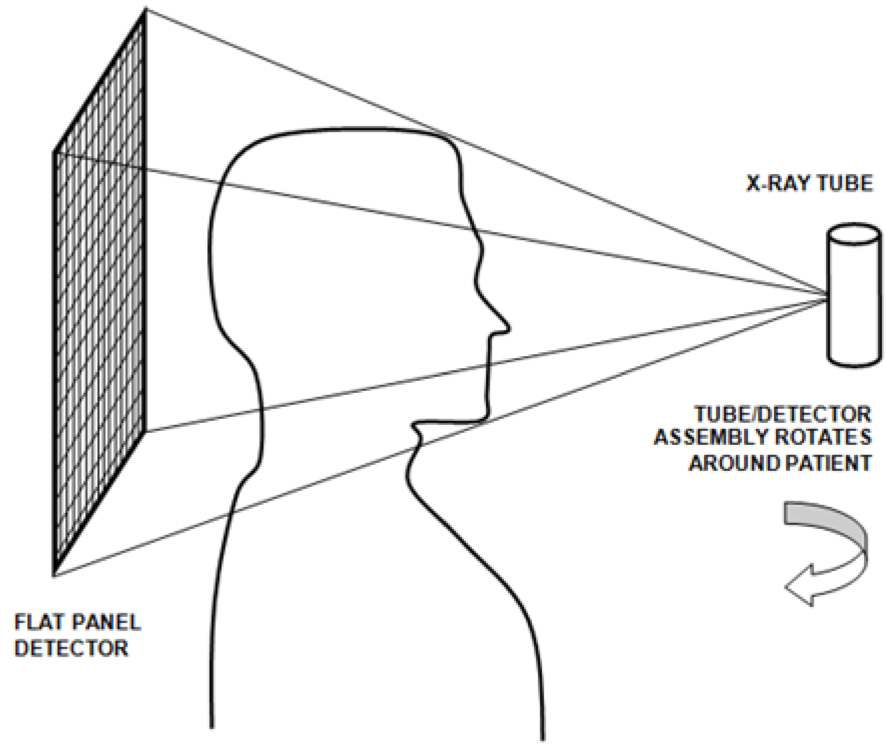
- High natural contrast
- High resolution
- Low dose

Medical CT Scanner




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

Cone Beam CT (CBCT) Scanner



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

(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]

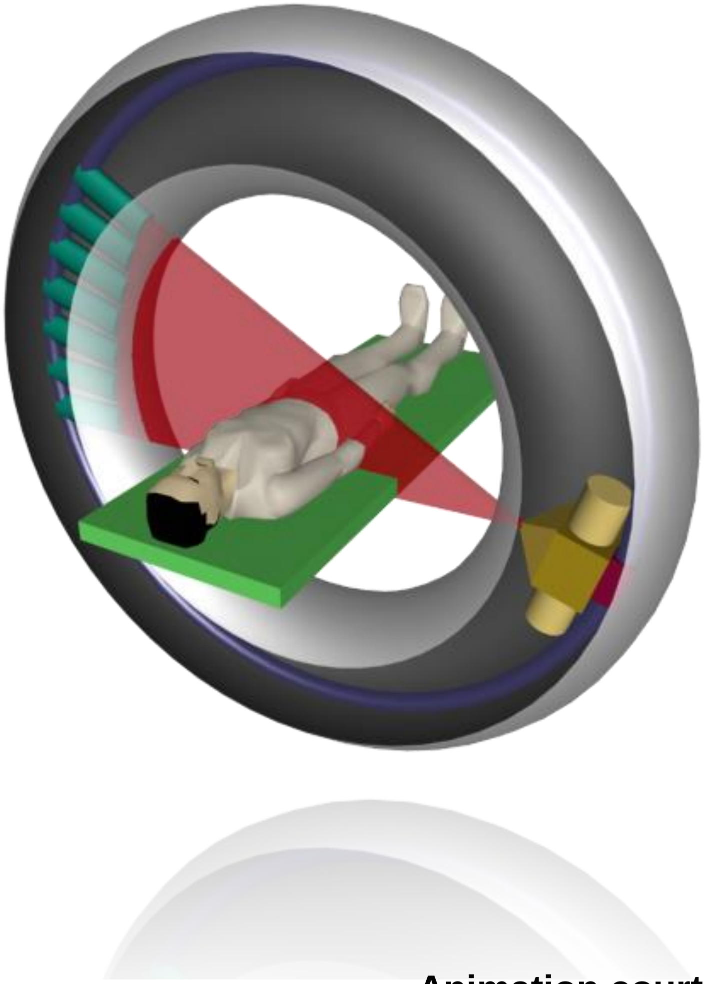
[1]Division of Maxillo-Facial Surgery, Department of Surgery, General Hospital St-Jan Bruges, Ruddershove 10, 8000 Bruges, Belgium; [2]Department of Radiology and Medical Imaging, General Hospital St-Jan Bruges, Ruddershove 10, 8000 Bruges, Belgium; [3]3-D Facial Imaging Research Group, (3-D FIRG), GH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

how CT works…

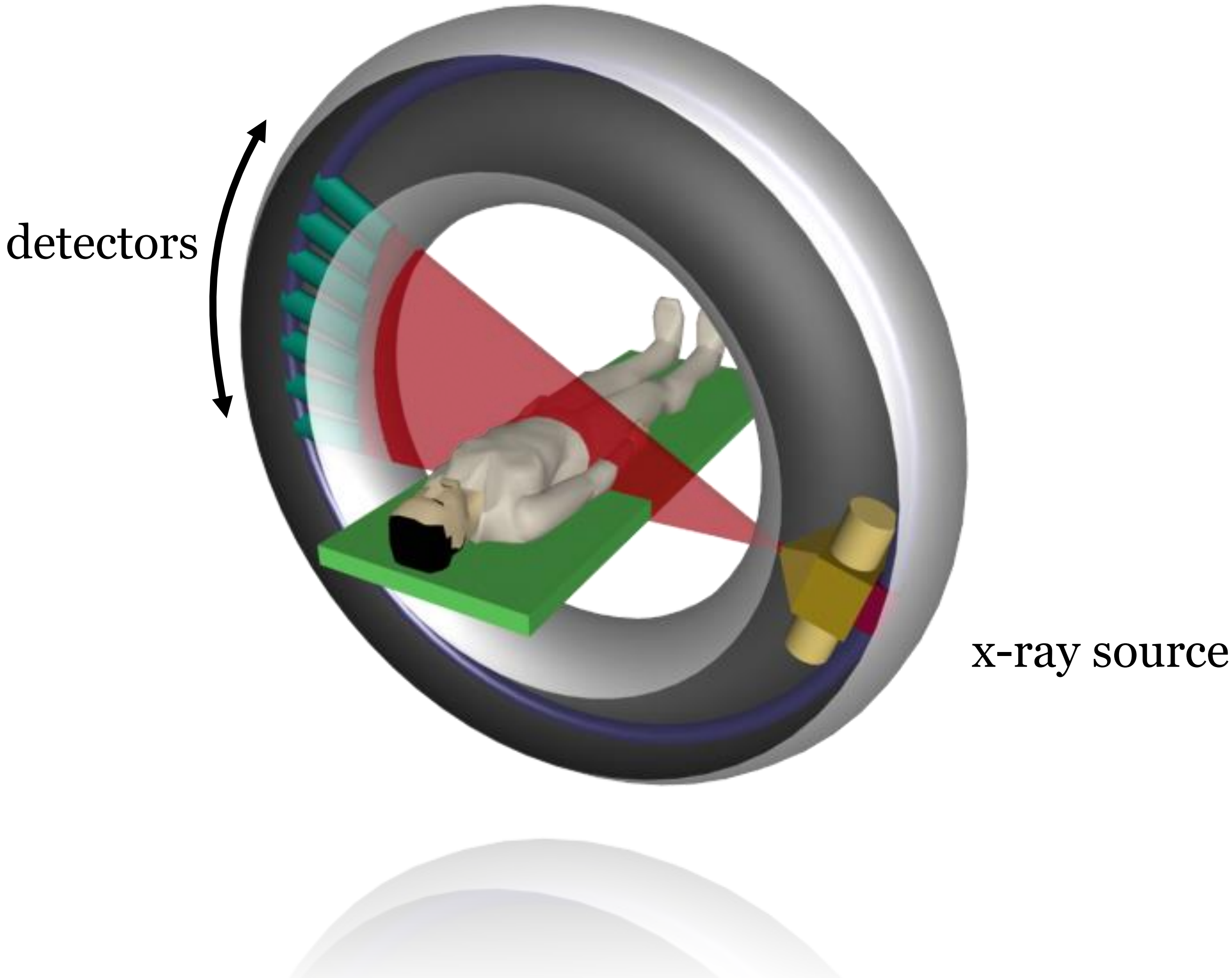
Godfrey Hounsfield

Allan Cormack

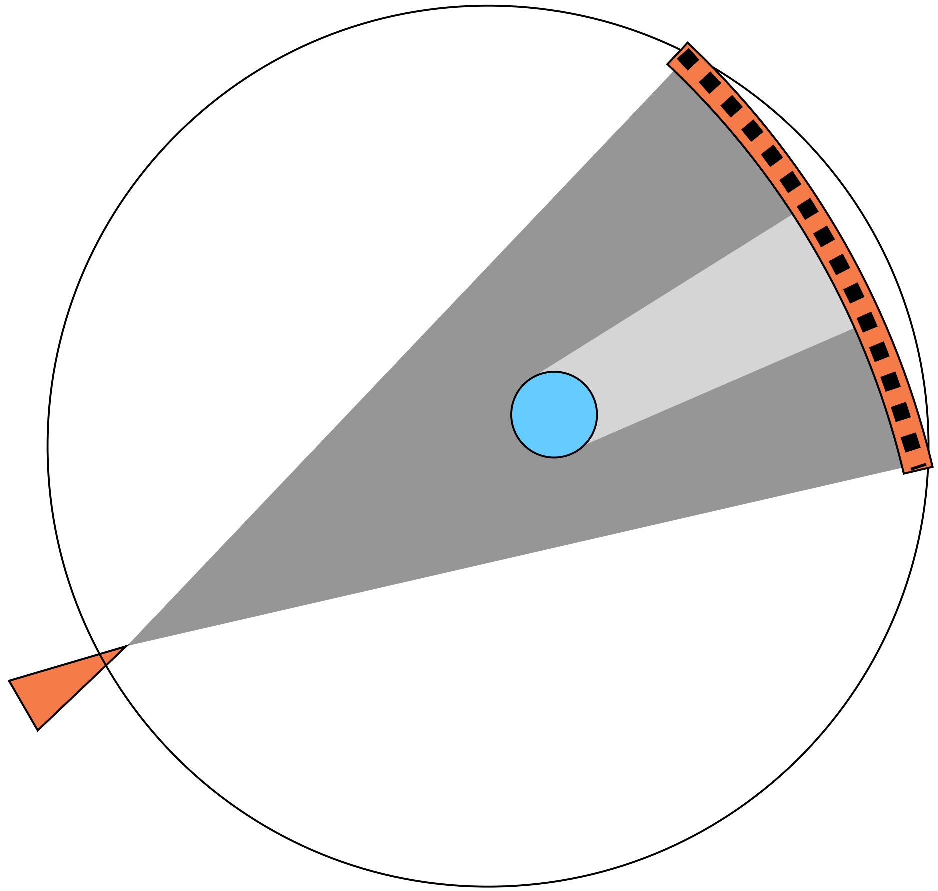
Nobel prize in Medicine, 1979



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

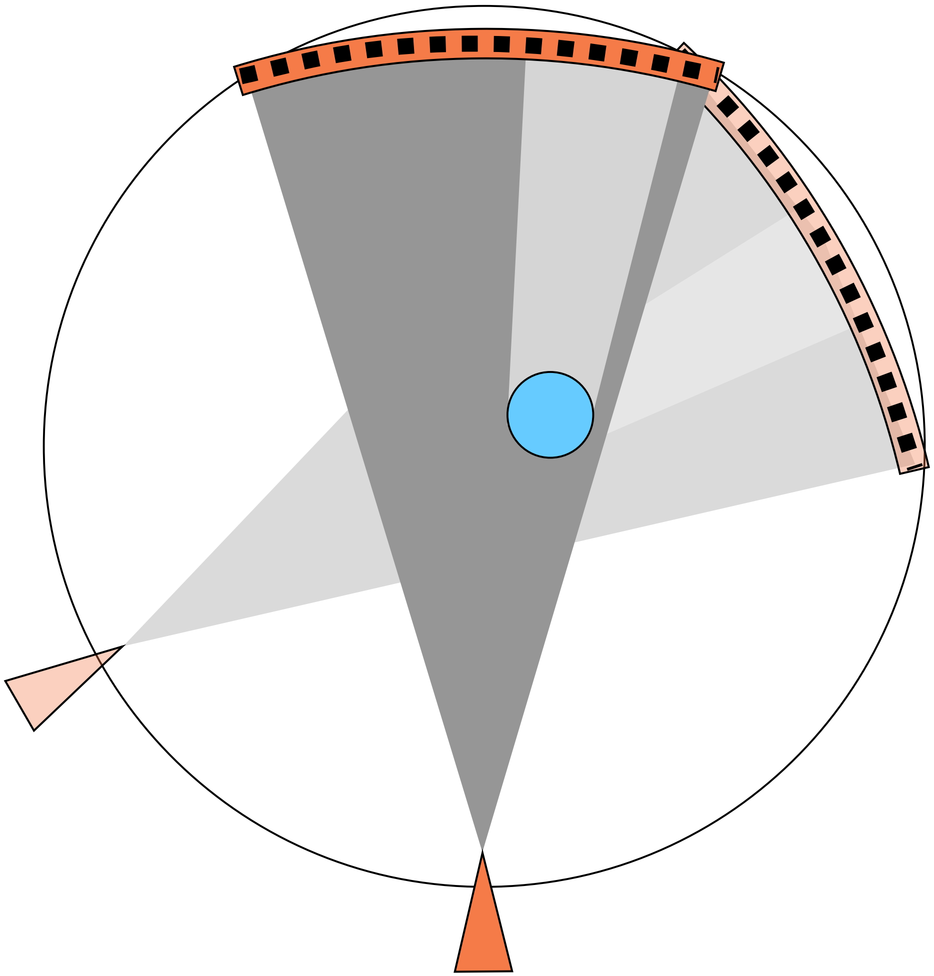

detectors
x-ray source

acquisition



Animation courtesy of
Demetrios J. Halazonetis

acquisition



Animation courtesy of
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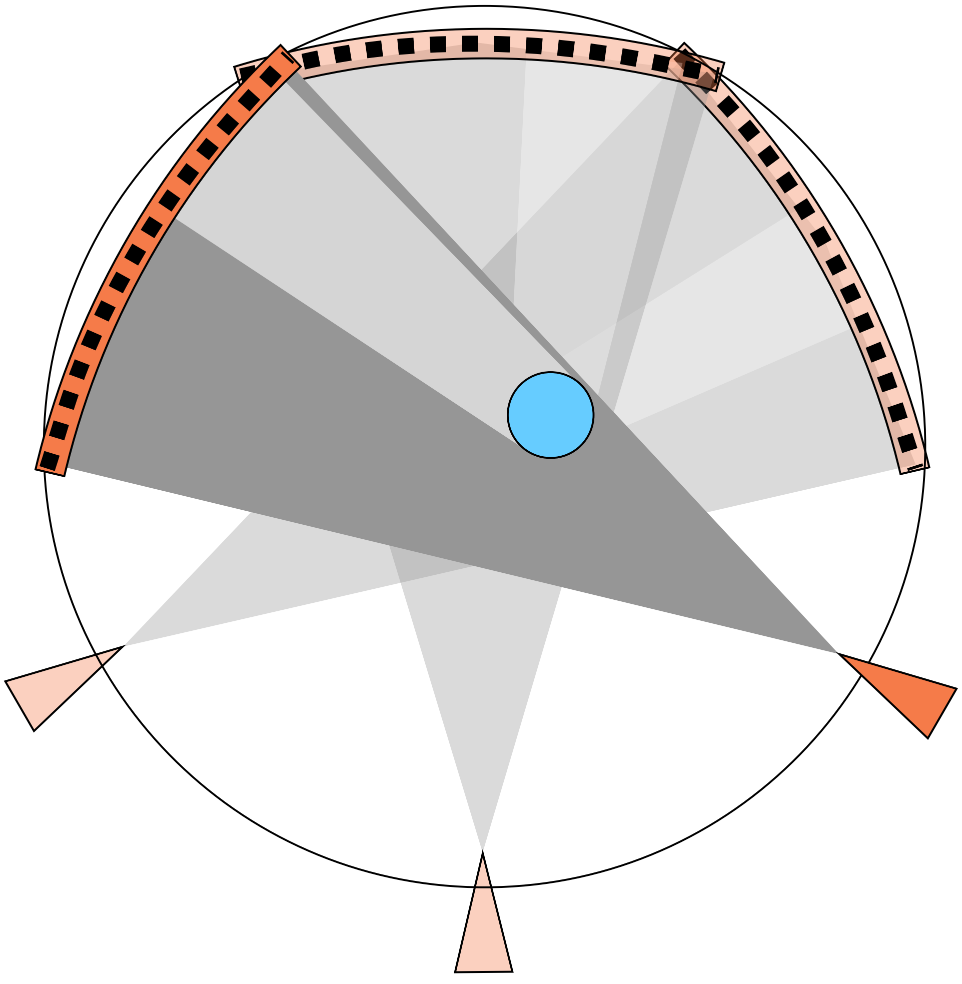
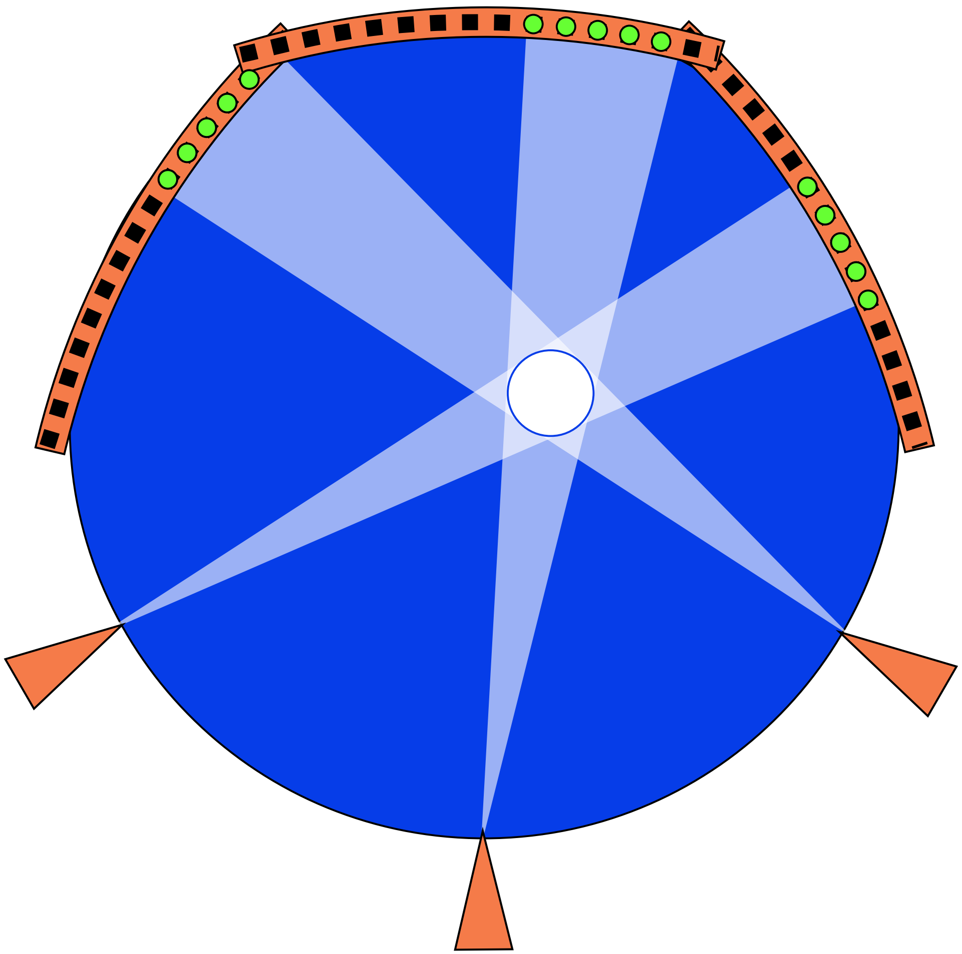
acquisition



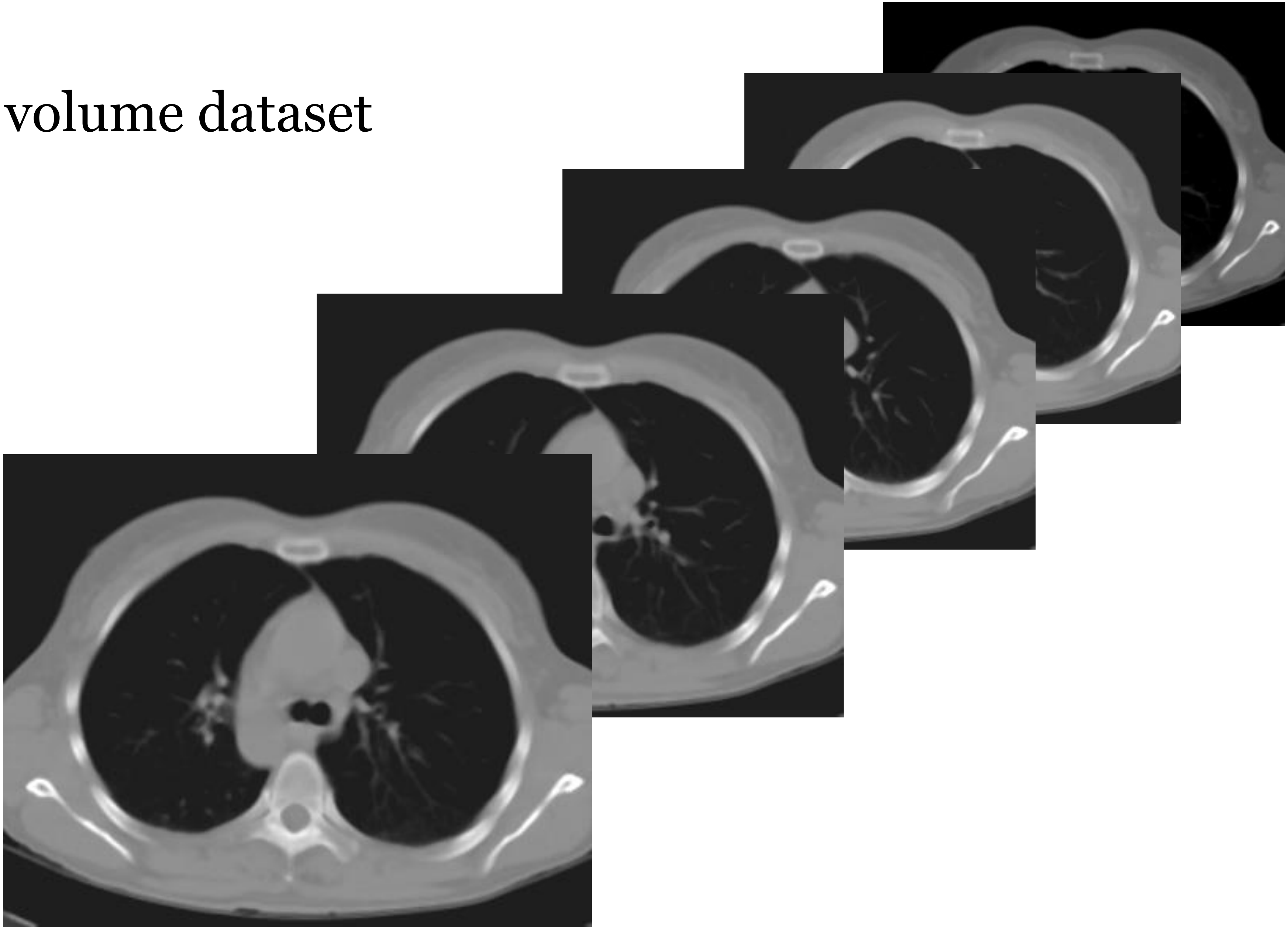
Animation courtesy of
Demetrios J. Halazonetis

reconstruction

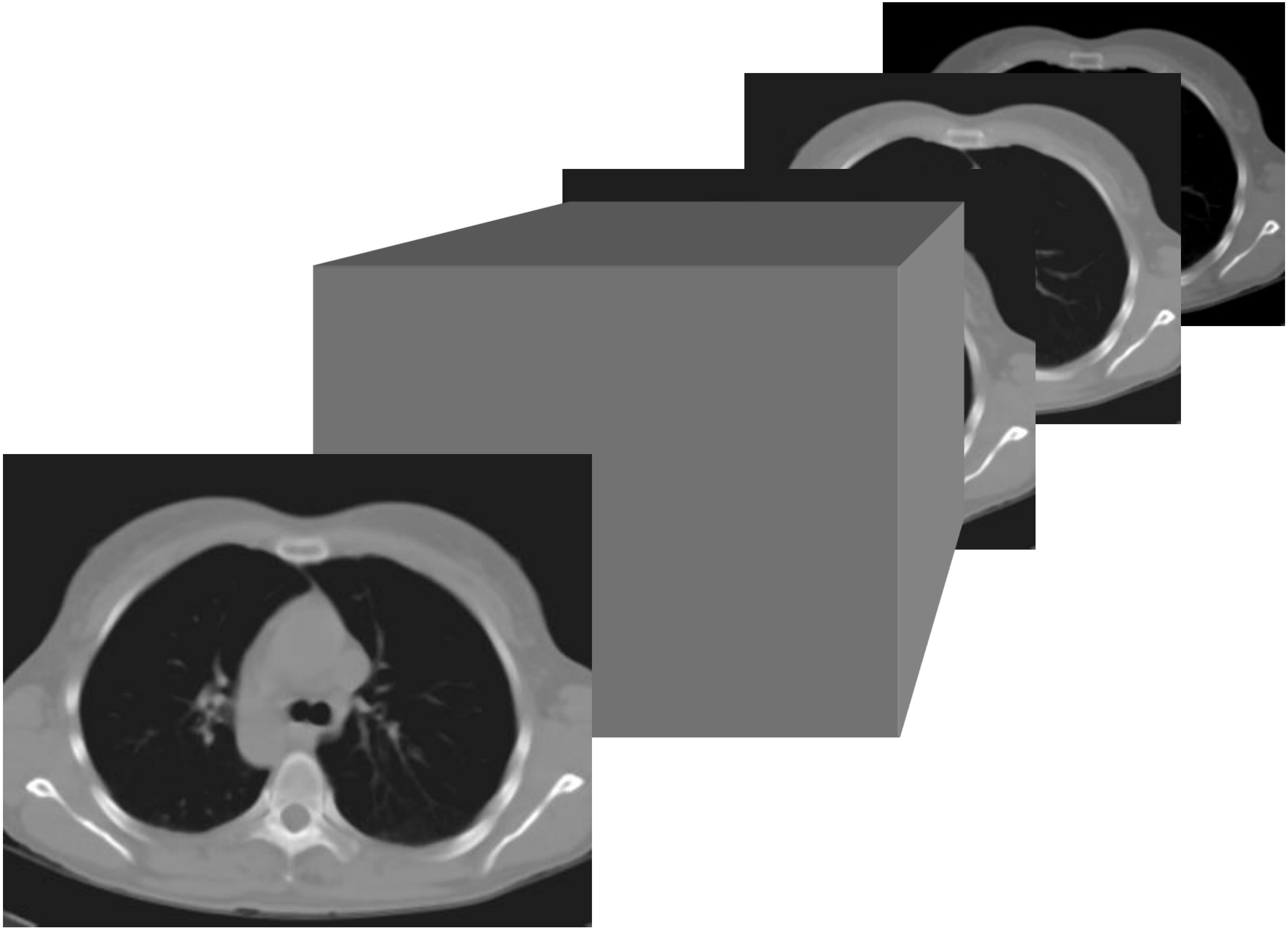


Animation courtesy of
Demetrios J. Halazonetis

volume dataset



Animation courtesy of Demetrios J. Halazonetis



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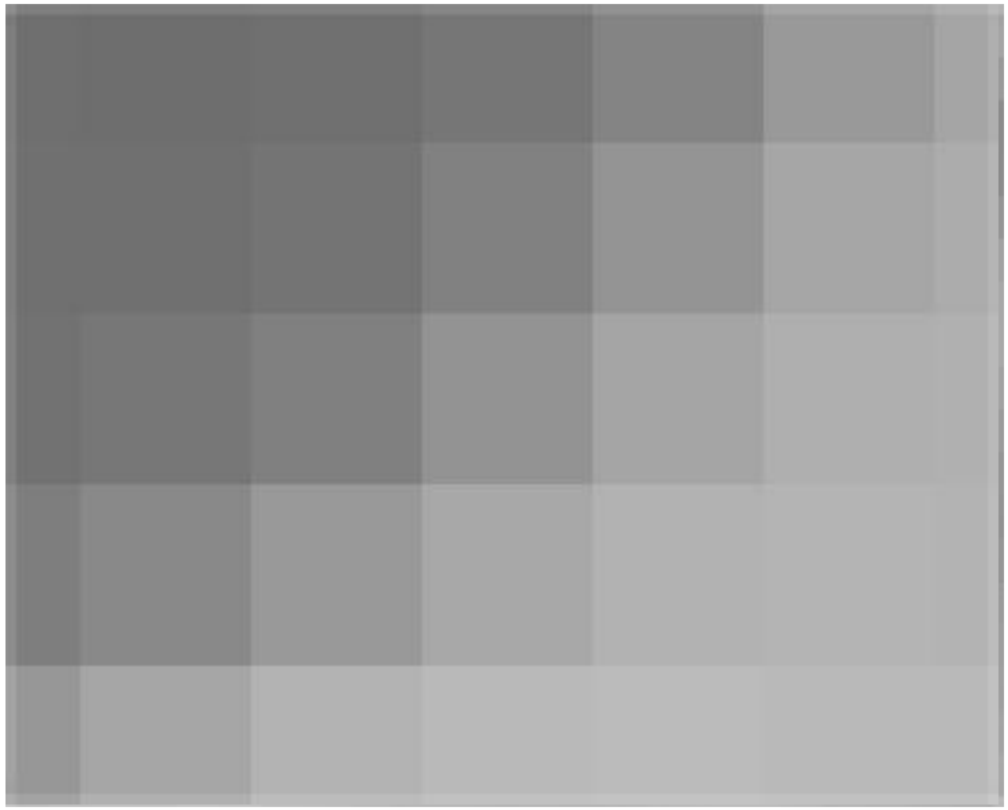
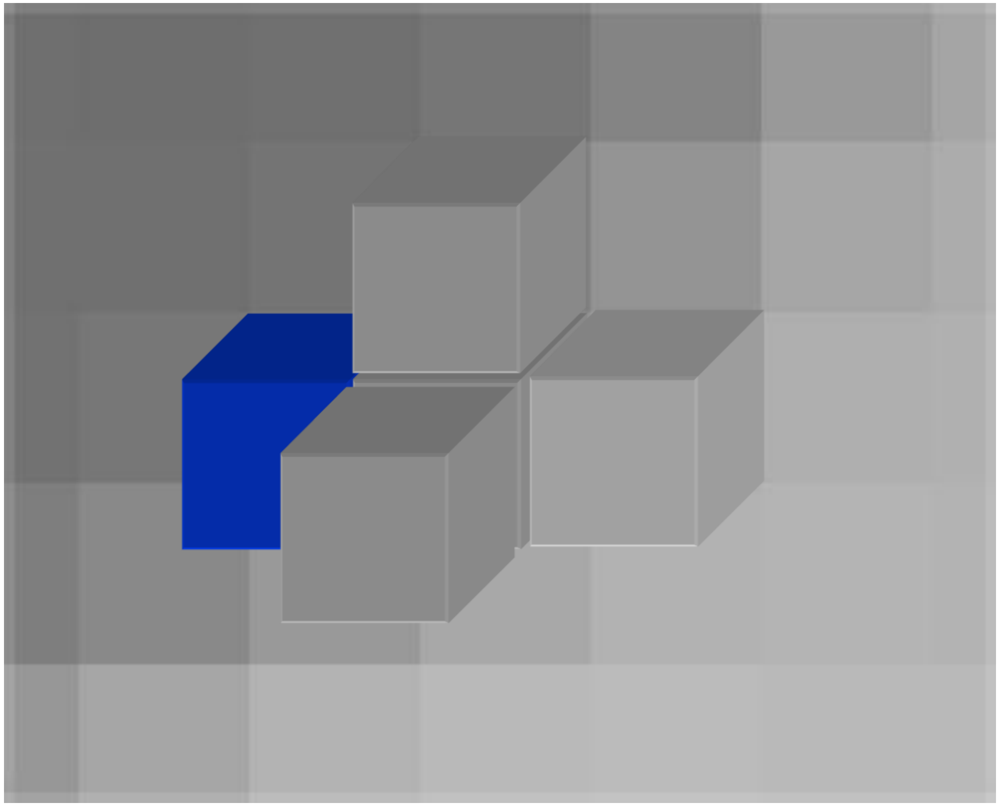
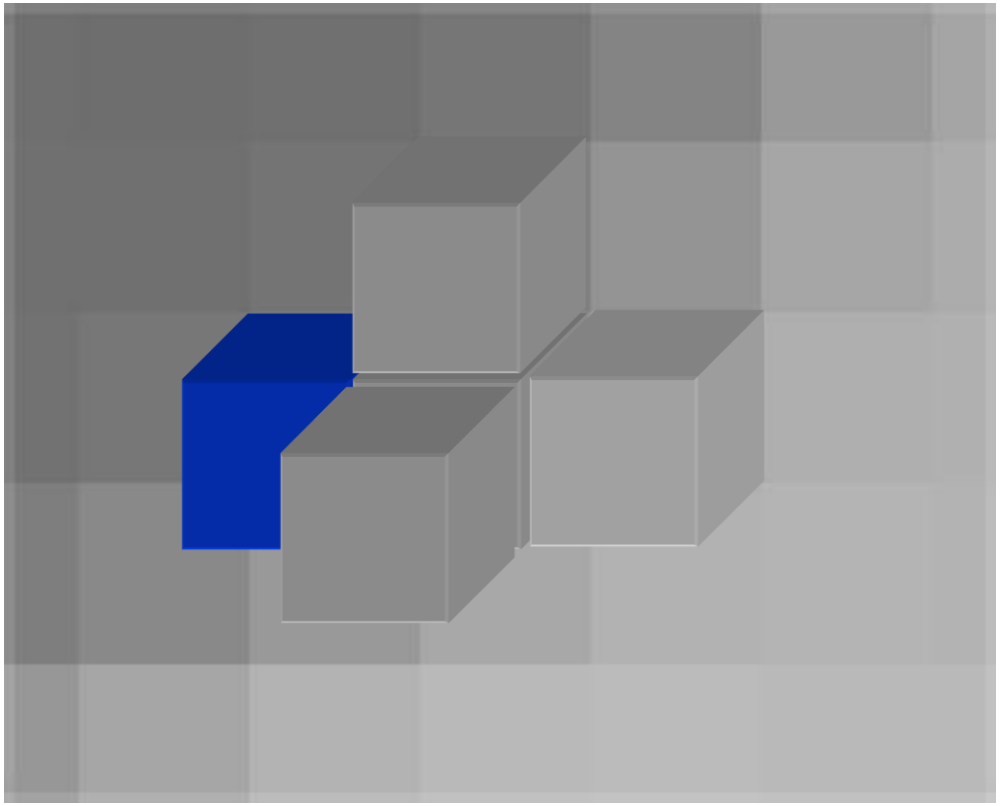


Animation courtesy of Demetrios J. Halazonetis



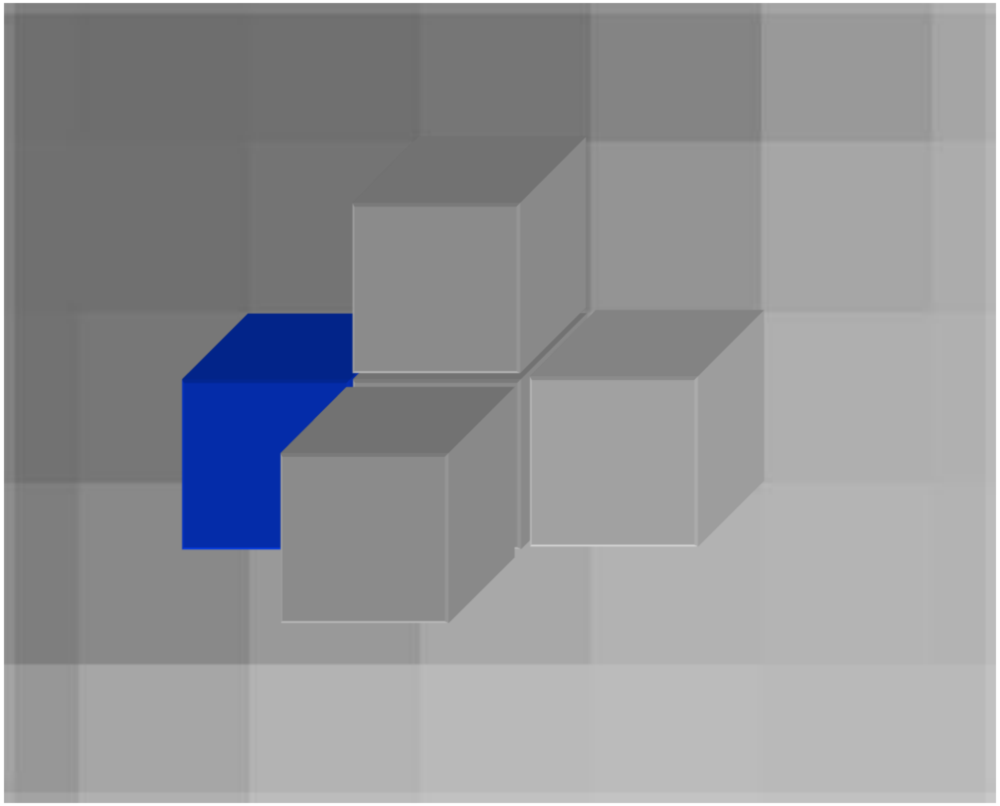
Animation courtesy of
Demetrios J. Halazonetis

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



Animation courtesy of
Demetrios J. Halazonetis

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

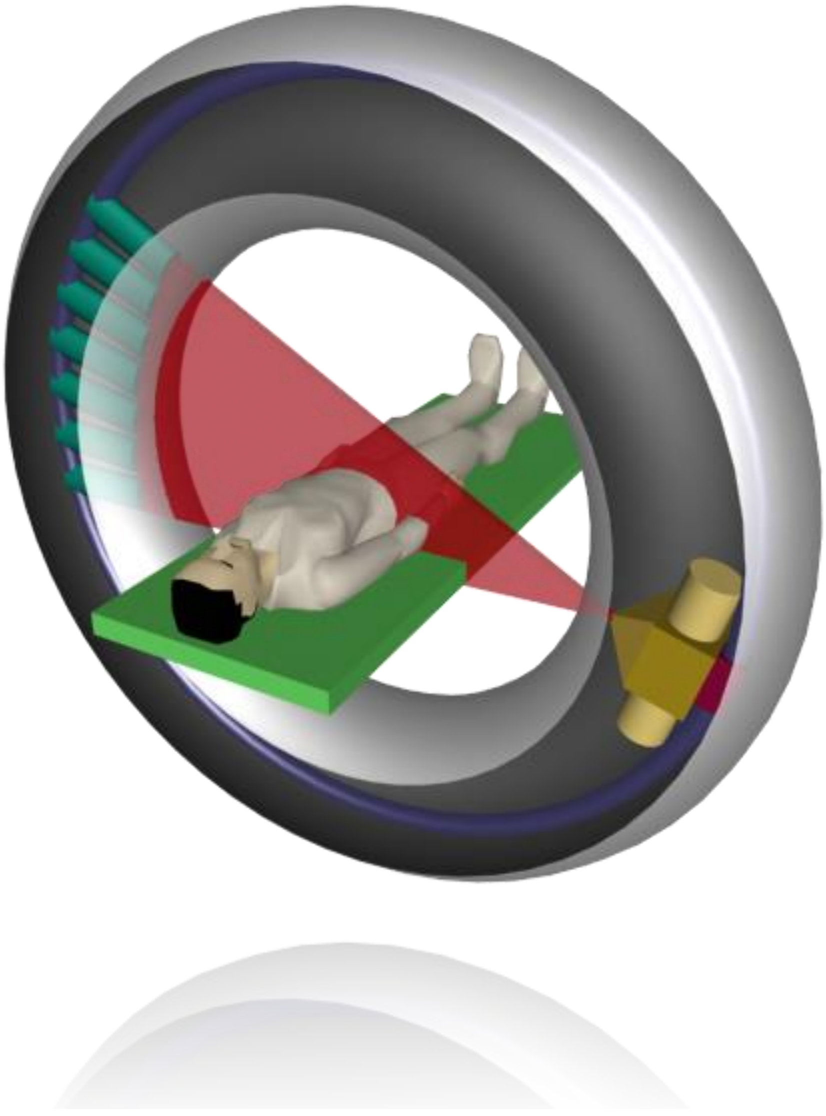


density:
0 - 4095

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

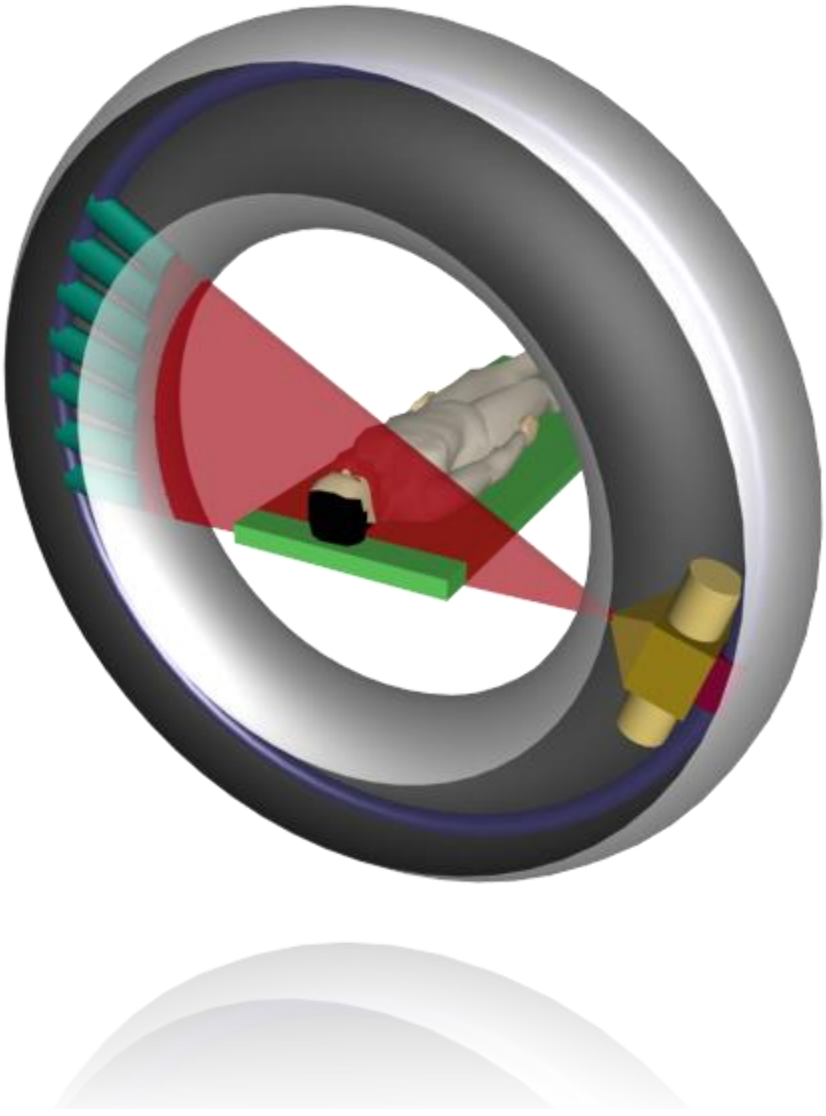
Animation courtesy of Demetrios J. Halazonetis

cone-beam CT (CBCT)



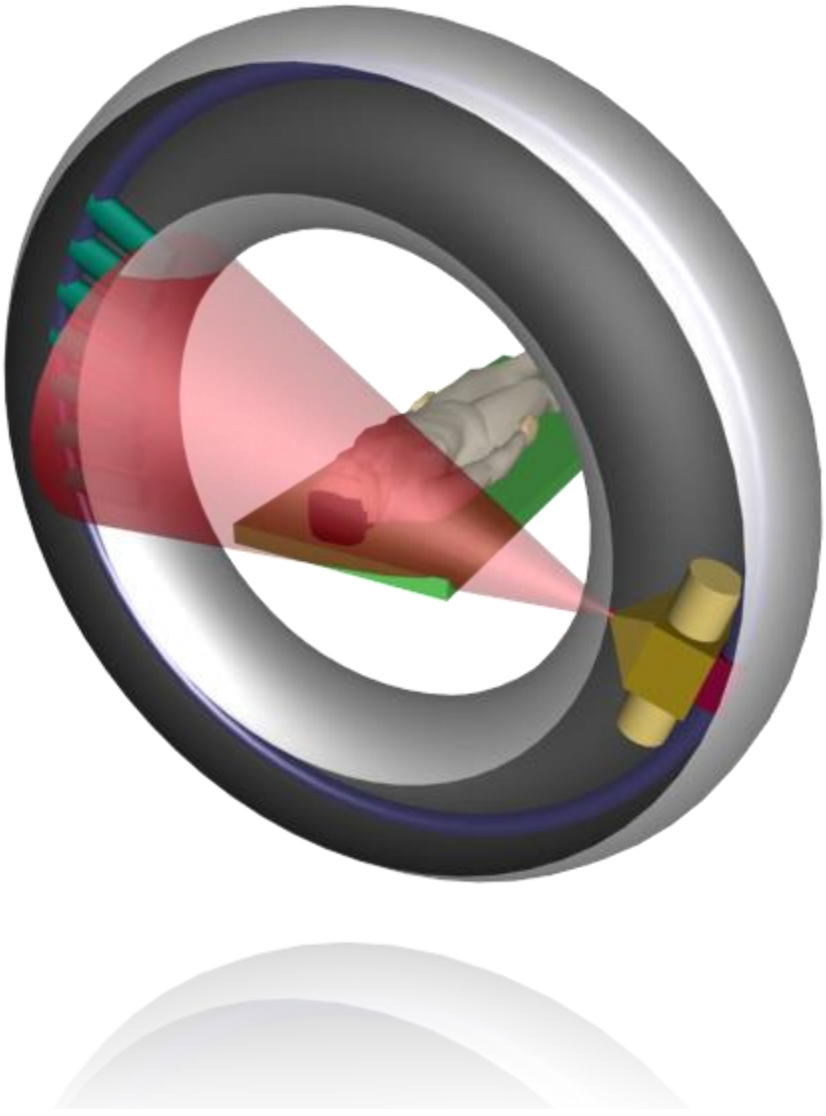
Animation courtesy of Demetrios J. Halazonetis

cone-beam CT (CBCT)



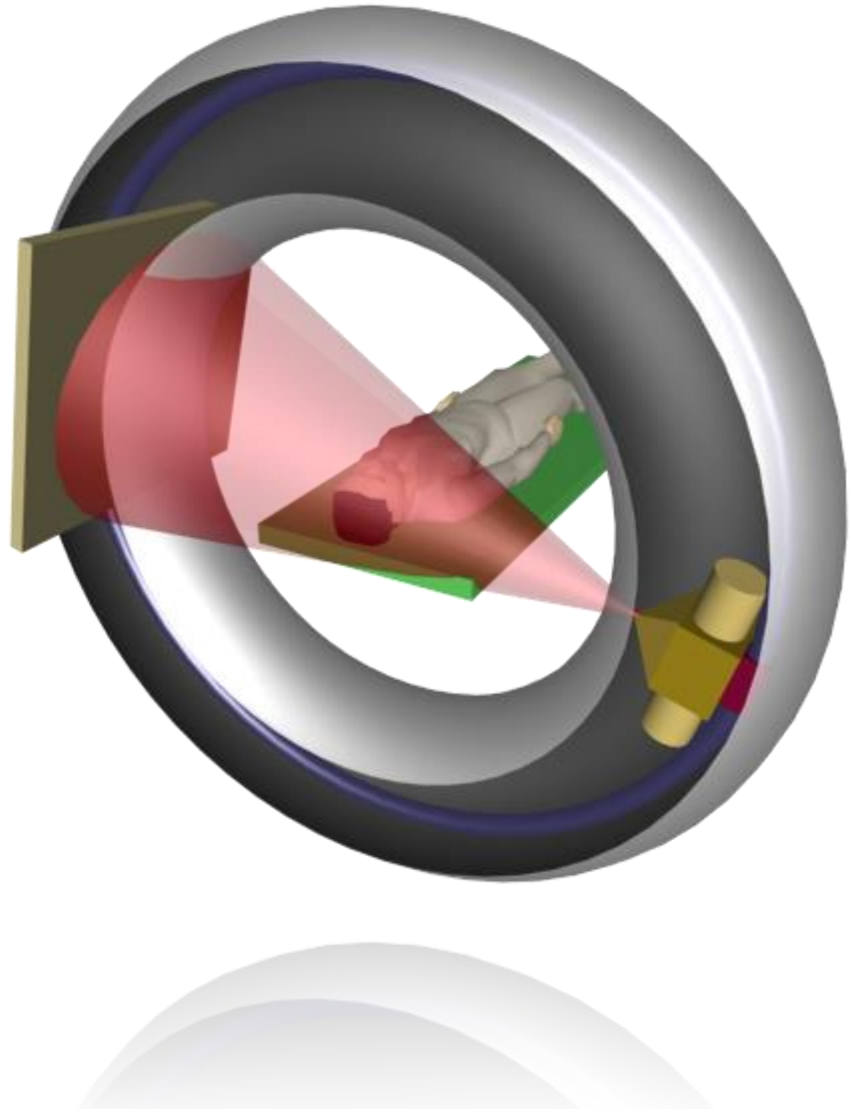
Animation courtesy of
Demetrios J. Halazonetis

cone-beam CT
(CBCT)



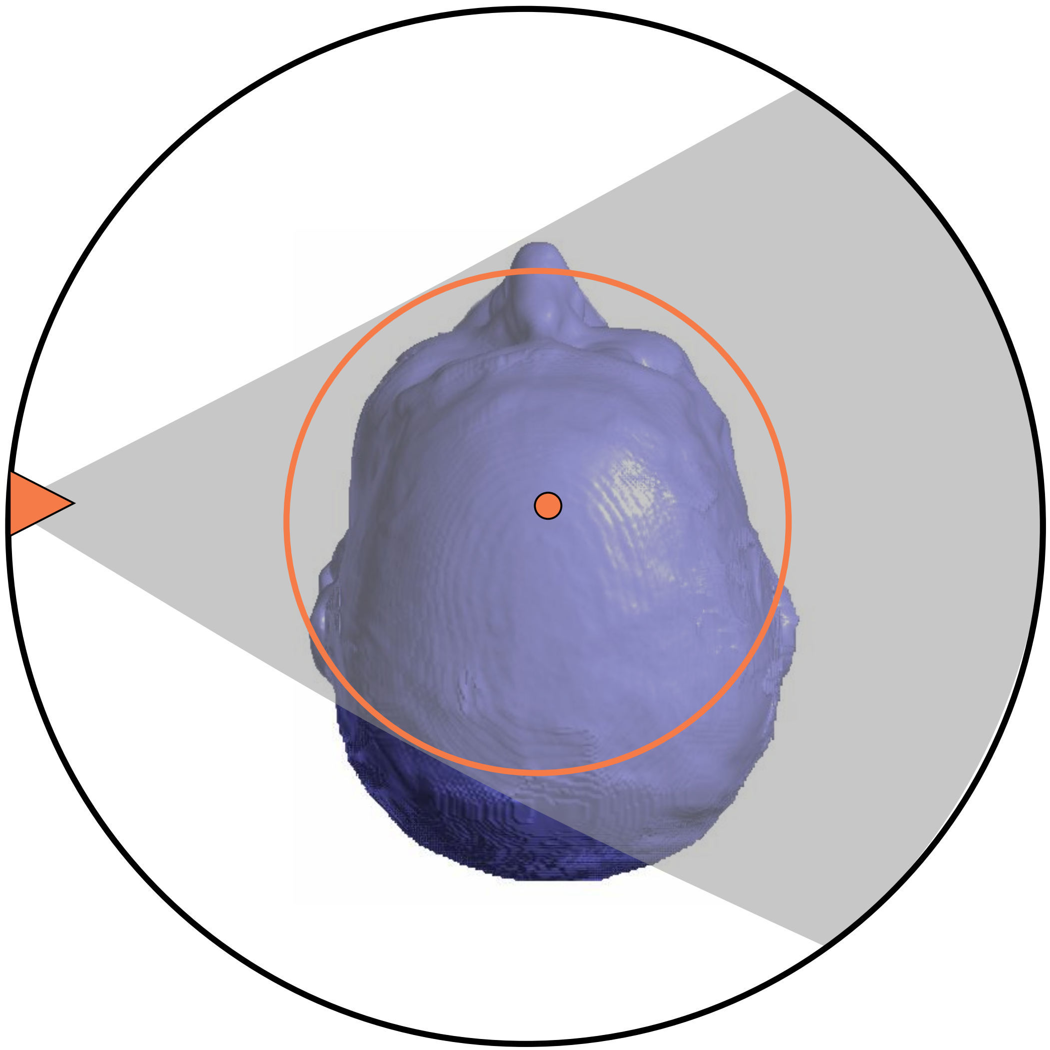
Animation courtesy of
Demetrios J. Halazonetis

cone-beam CT
(CBCT)



Animation courtesy of
Demetrios J. Halazonetis

cone-beam CT (CBCT)



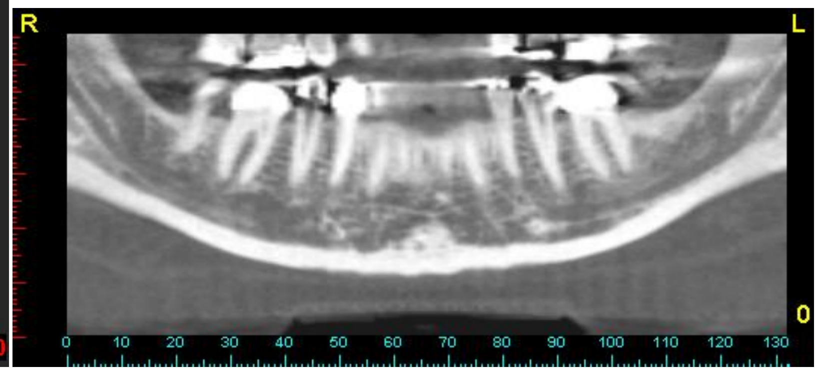
Animation courtesy of
Demetrios J. Halazonetis

i-CAT Cone Beam CT Scanner

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

Basic CT images

Axials

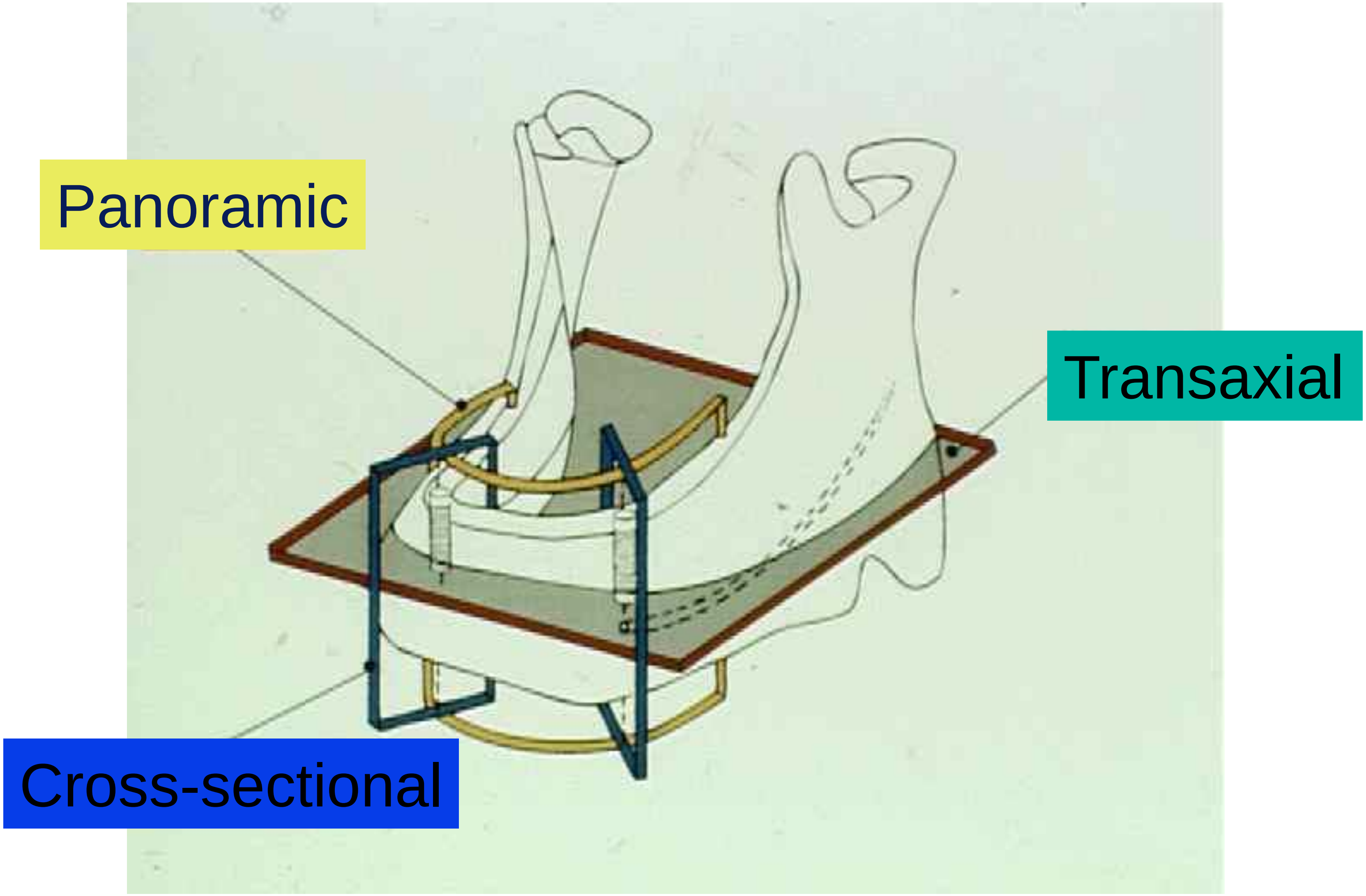


Panoramics

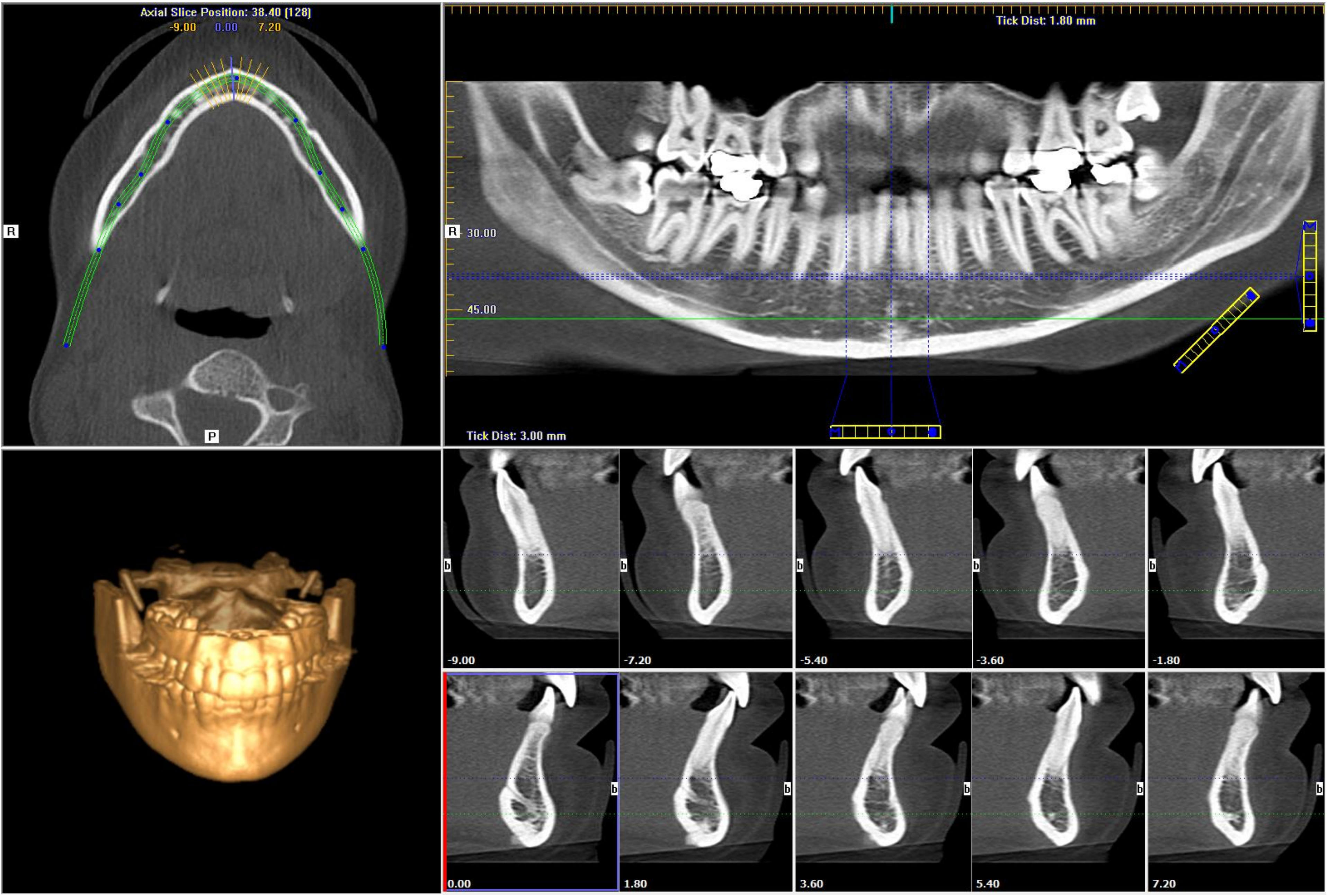
Cross Sections

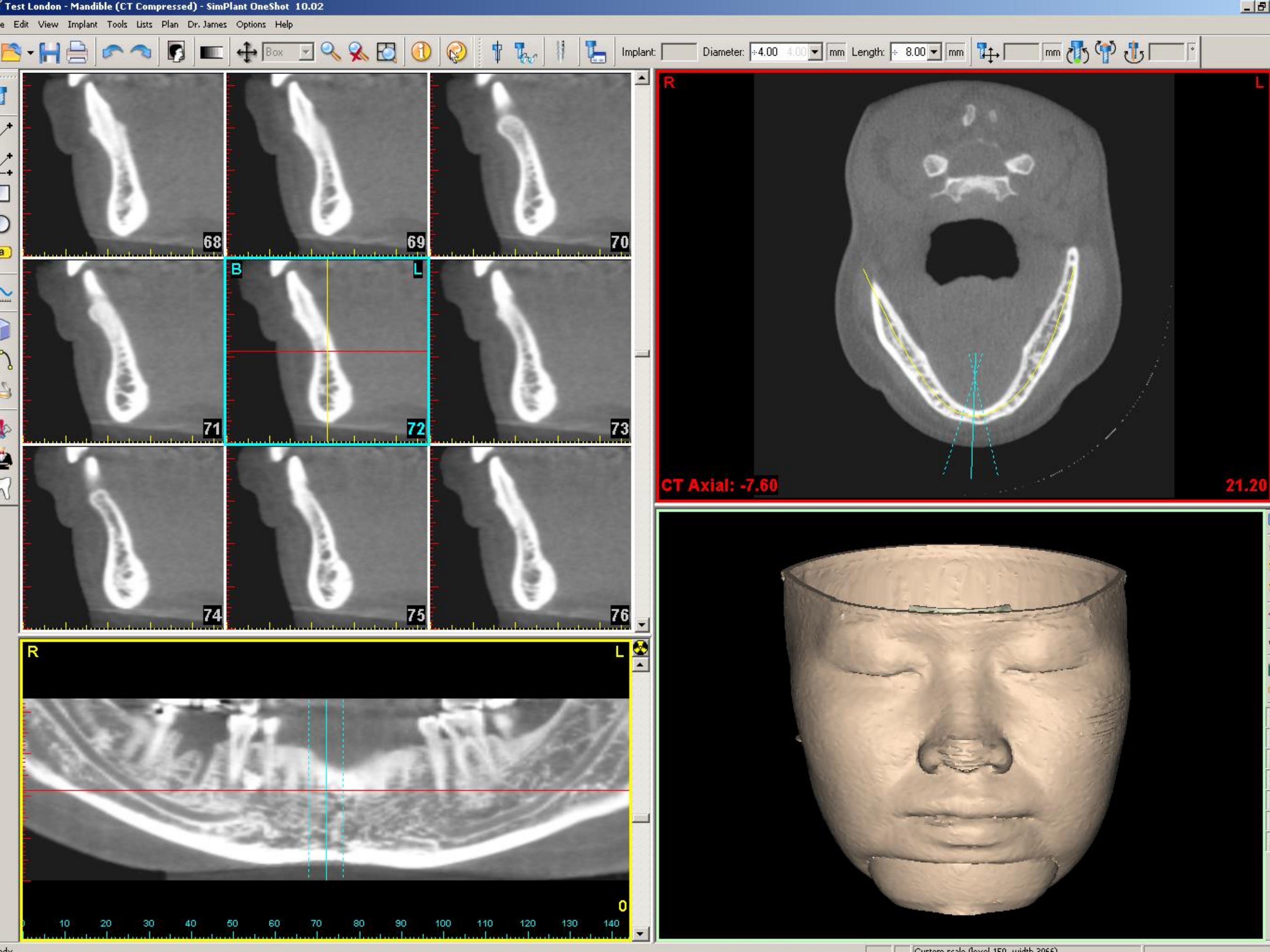
Sagittal

Coronal

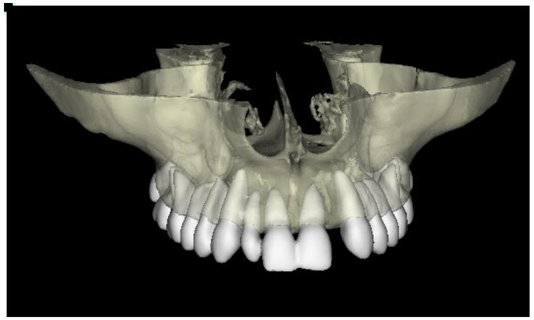

Panoramic
Transaxial
Cross-sectional

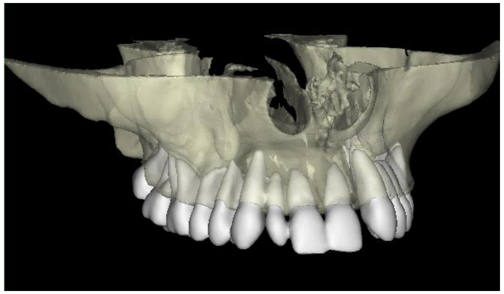
i-CATVision™

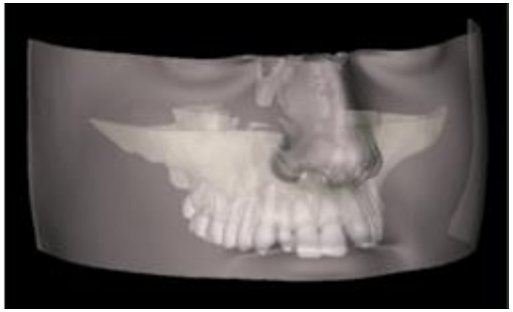

Axial Slice Position: 38.40 (128)
-9.00
0.00
7.20
R
P
Tick Dist: 1.80 mm
R
30.00
45.00
Tick Dist: 3.00 mm
b
-9.00
-7.20
-5.40
-3.60
-1.80
0.00
1.80
3.60
5.40
7.20

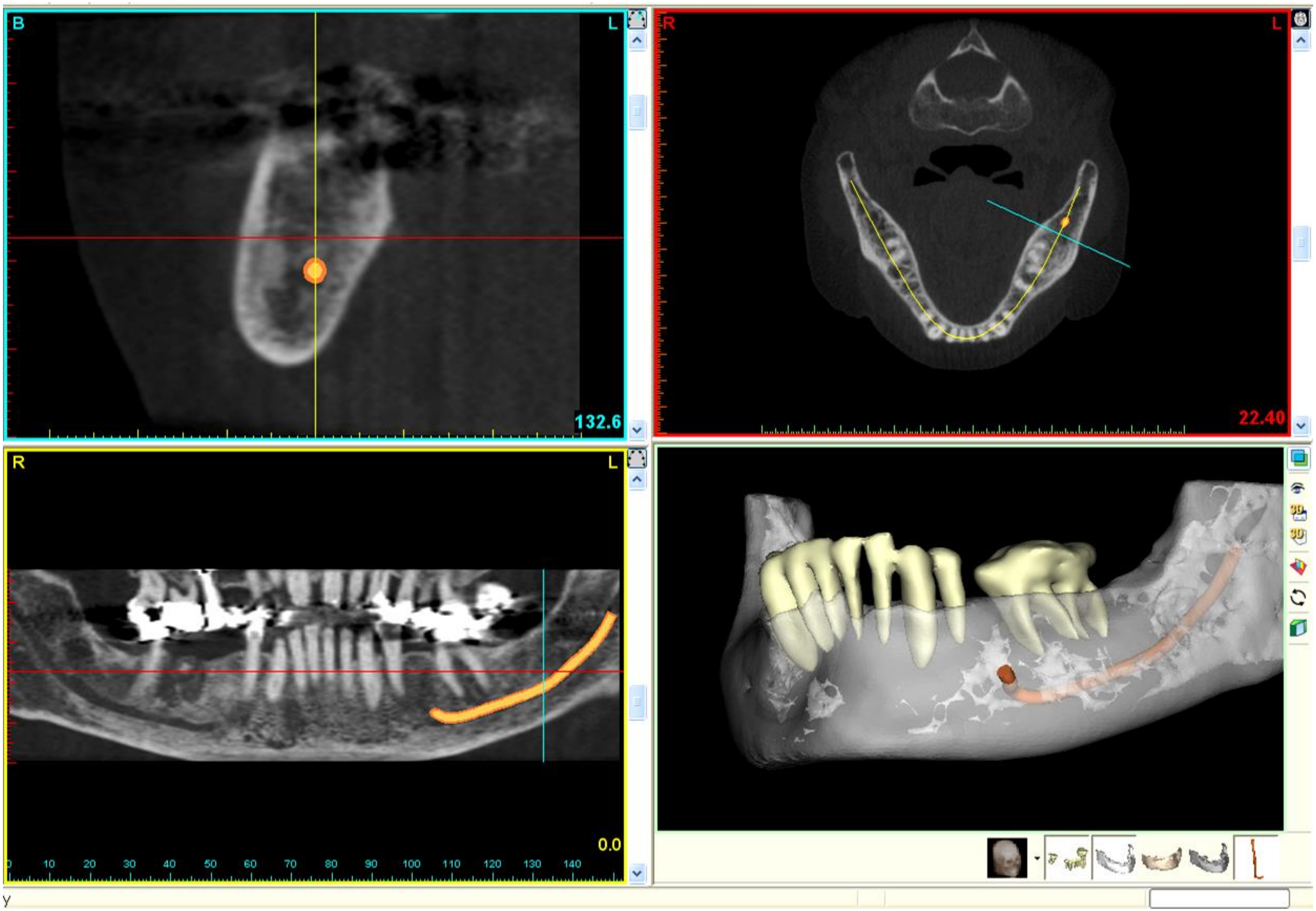

Test London - Mandible (CT Compressed) - SimPlant OneShot 10.02
Edit View Implant Tools Lists Plan Dr. James Options Help
Box
Implant:
Diameter: 4.00 mm
Length: 8.00 mm
mm
68
69
70
B
L
71
72
73
74
75
76
R
L
CT Axial: -7.60
21.20
R
L
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140

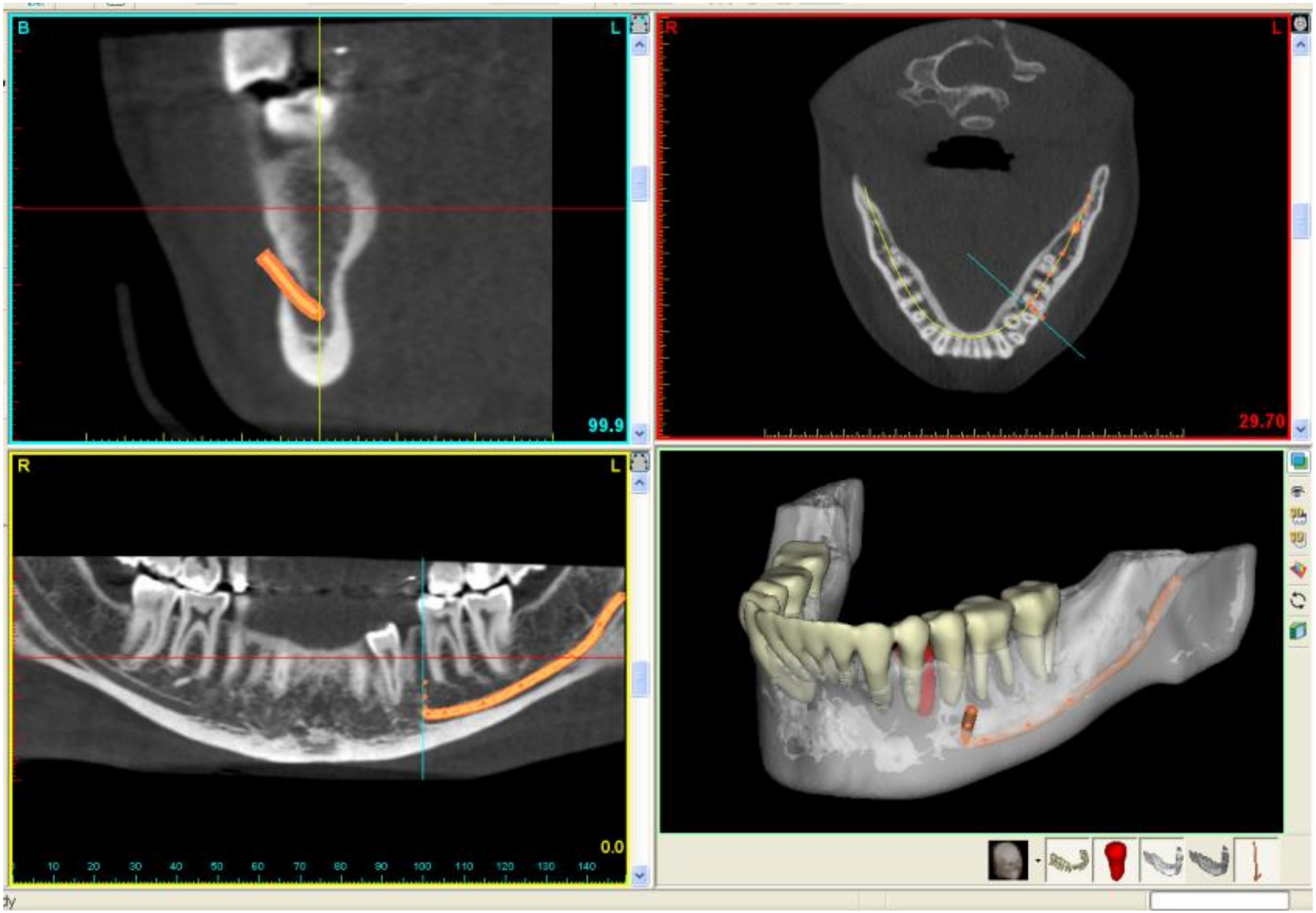
Segmentation



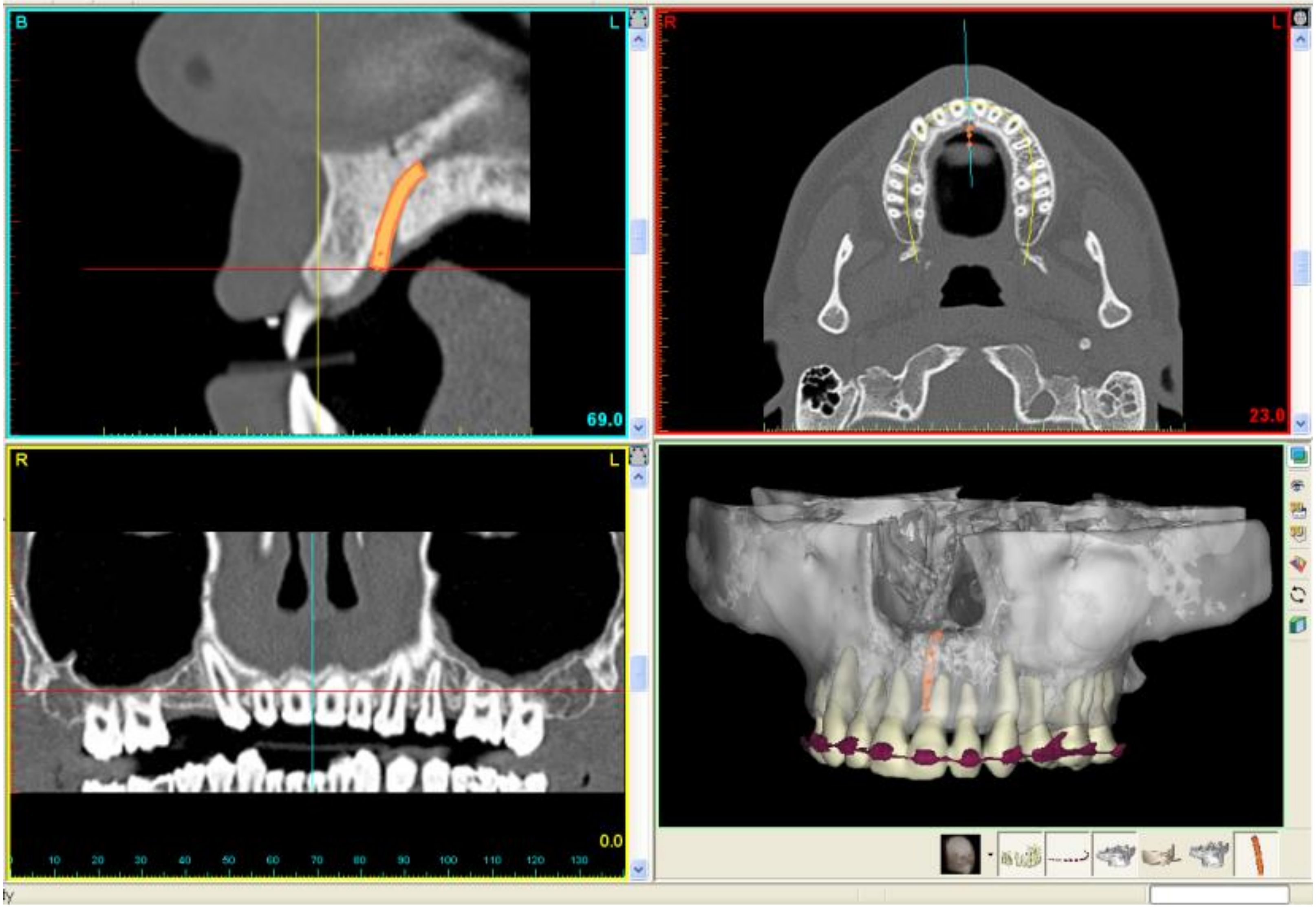




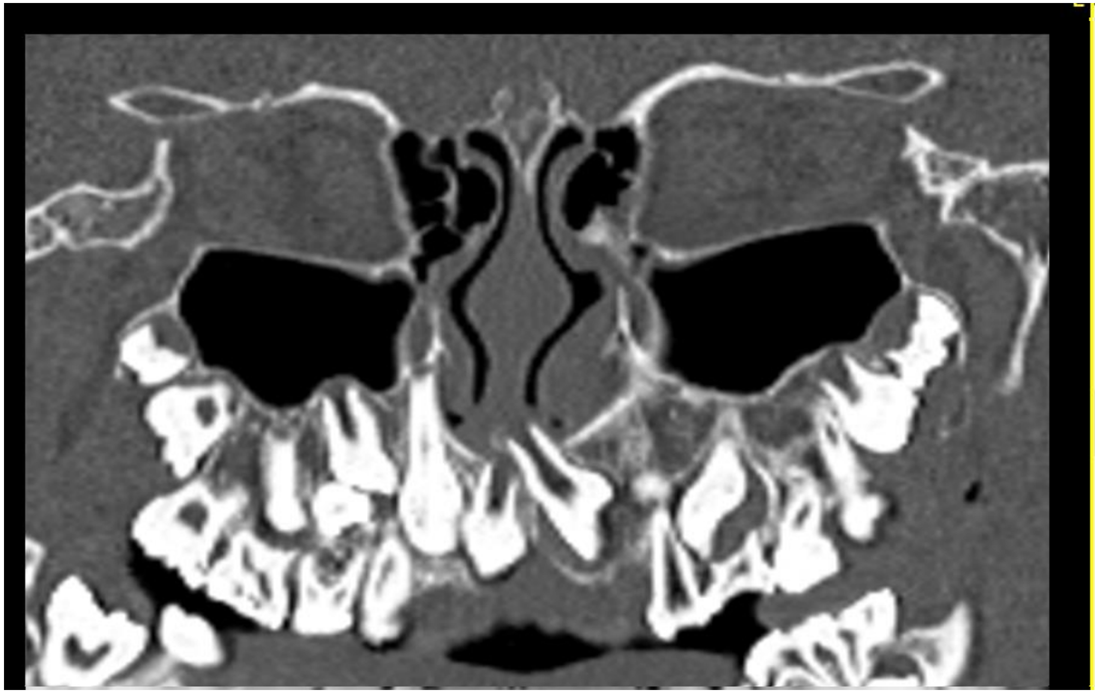

B
L
132.6
R
L
22.40
R
L
0.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140



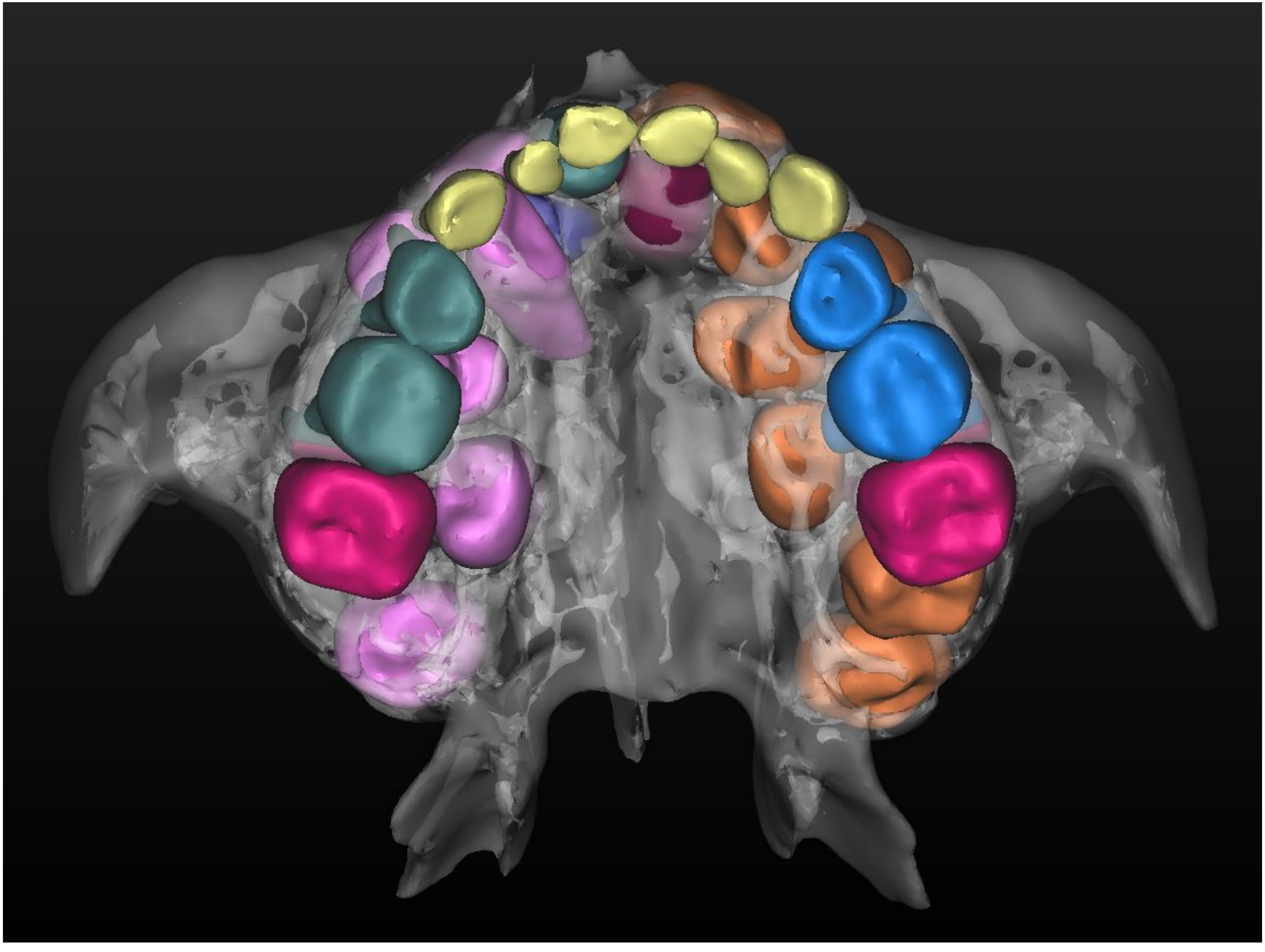
B
L
99.9
R
L
29.70
R
L
0.0
10
20
30
40
50
60
70
80
90
100
110
120
130
140


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

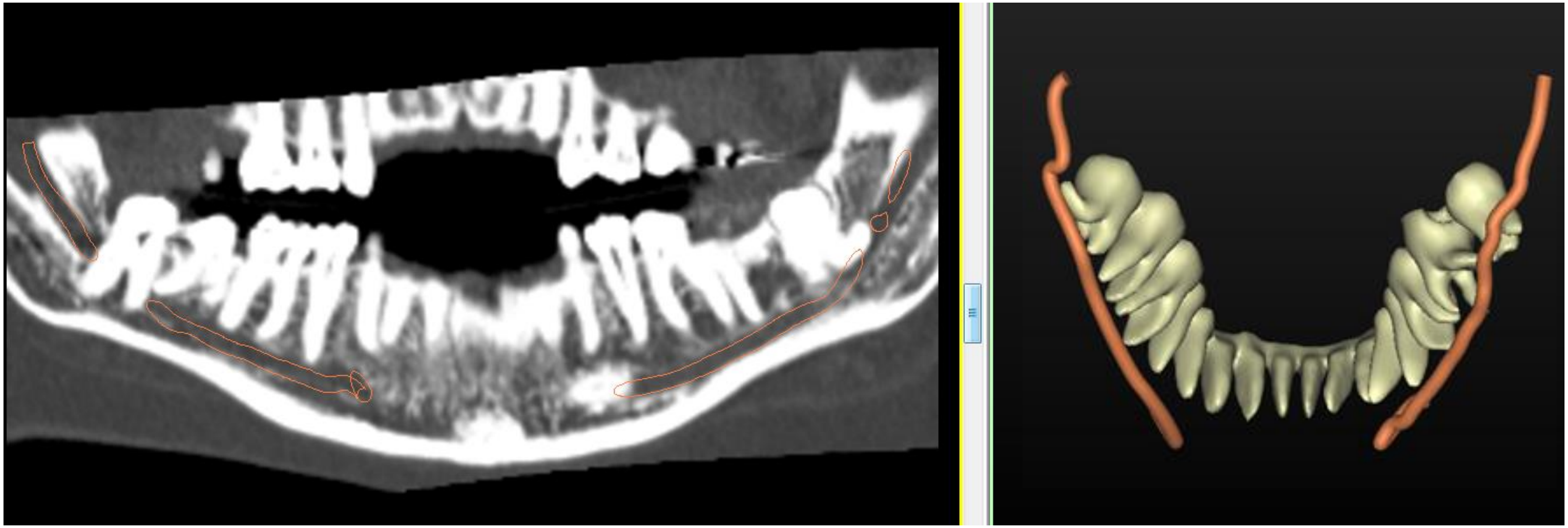
Hyperdontia



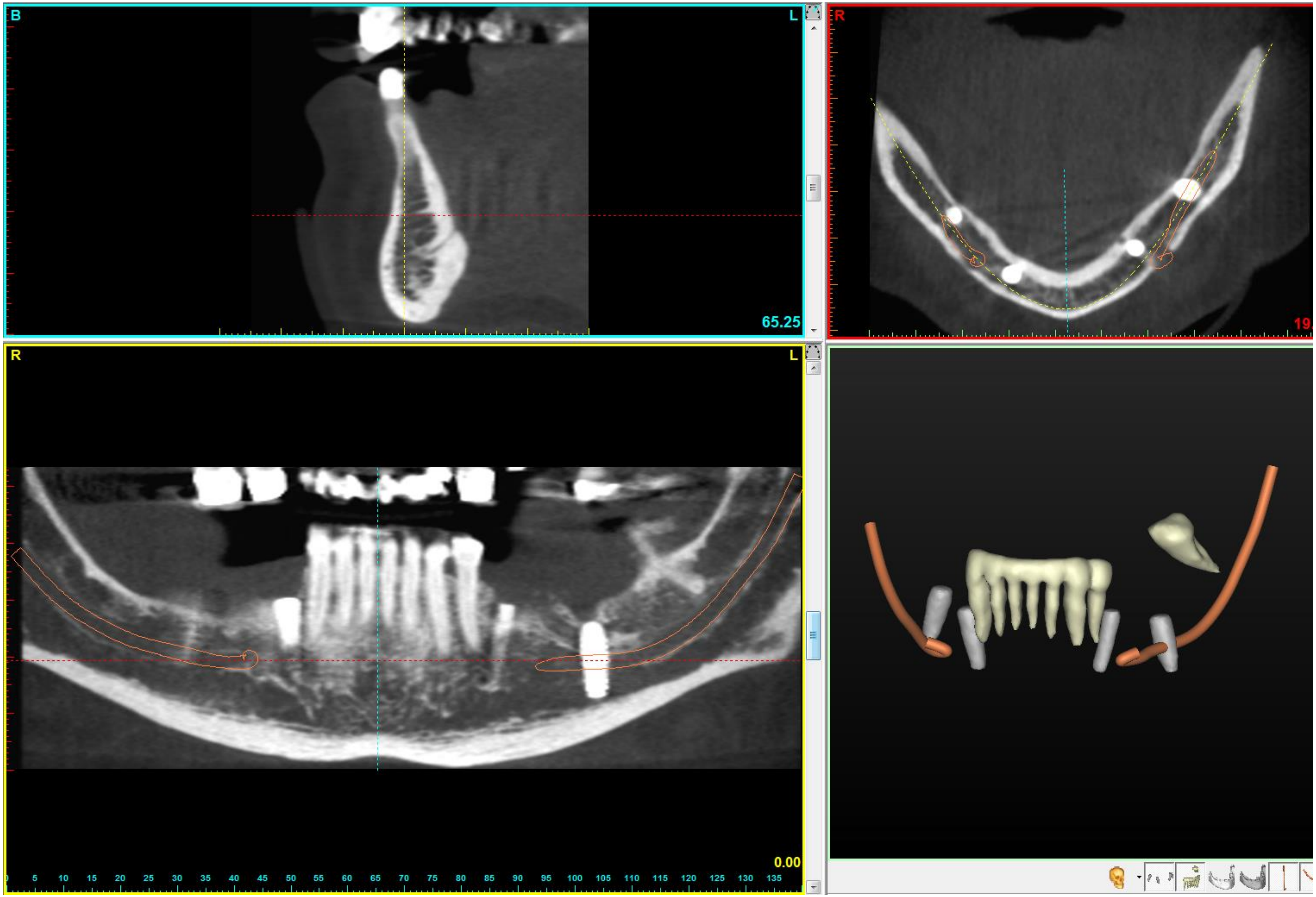
Courtesy of Nicolette Schroeder



Third Molars



Courtesy of Barry Dace



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

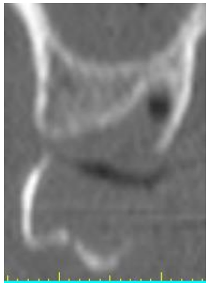
Advantages of using a Scanning Stent

- **Gives inter-arch stability for the patient during the scan**
- **Opens the bite slightly (a few mm) using occlusal stops**
- **Position and size of the desired restoration can be visualised in the CT images**
- **If the maxilla and mandible are scanned together the 3D image will illustrate the inter-arch relationship.**

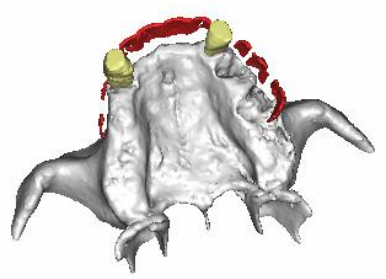
Making a Scanning Stent

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

- To make it show up, you can:



- mix barium sulphate with the acrylic
- paint barium sulphate on the surface
- use radio-opaque teeth
- use markers made from a radio-opaque material

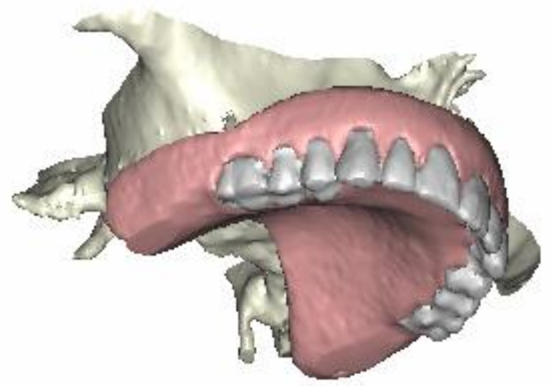


  - lab putty
  - gutta percha
  - glass ionomer
- use a dual-scan technique.

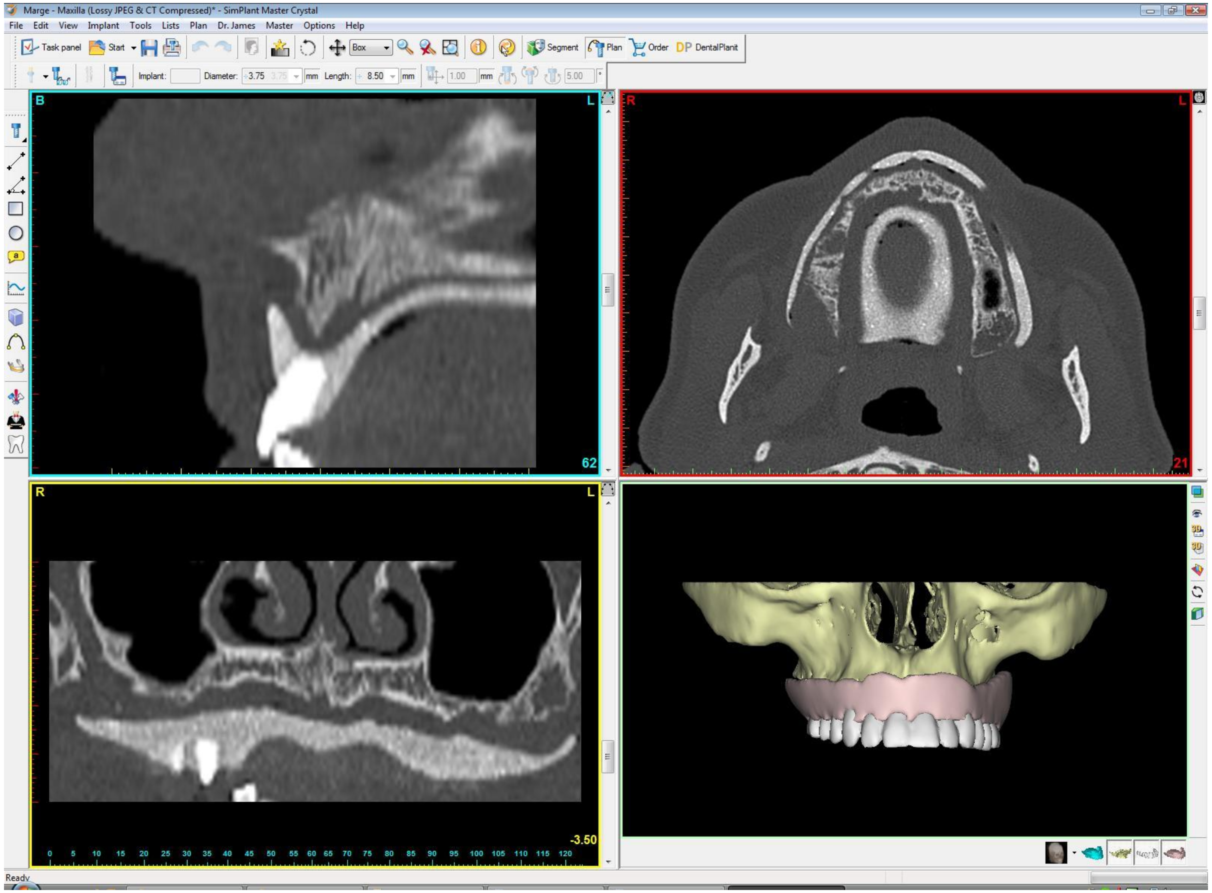
- **We recommend using a barium sulphate-acrylic mix for both the radio-opaque teeth and the baseplate.**

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

- **An accurate fitting stent with radio-opaque baseplate is usually the best option for mucosa-supported surgical drill guides.**

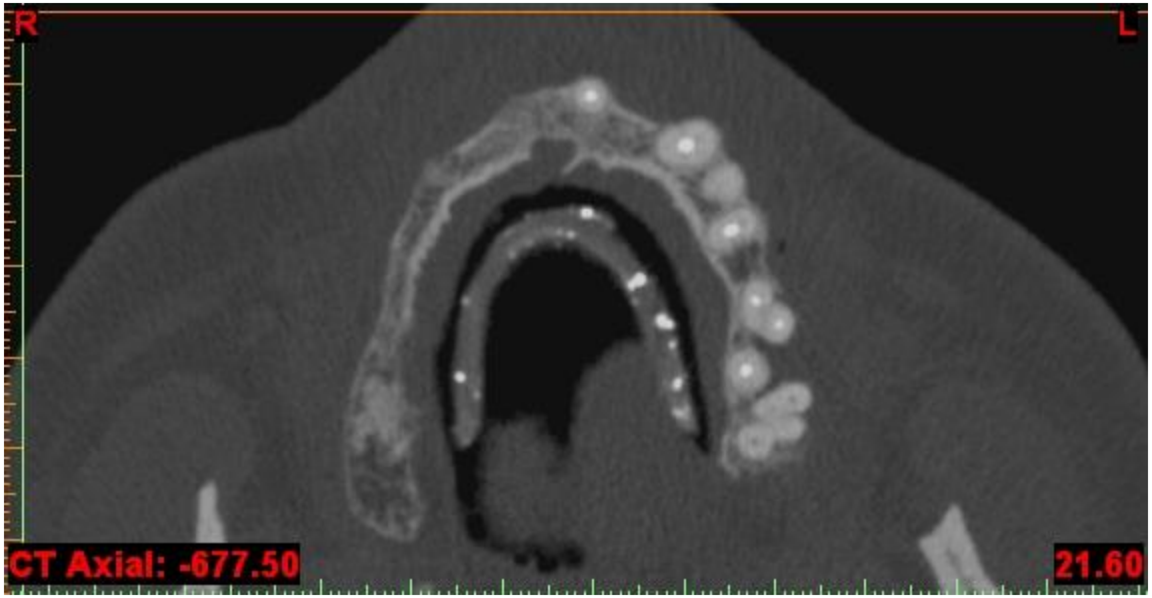


Good Stent



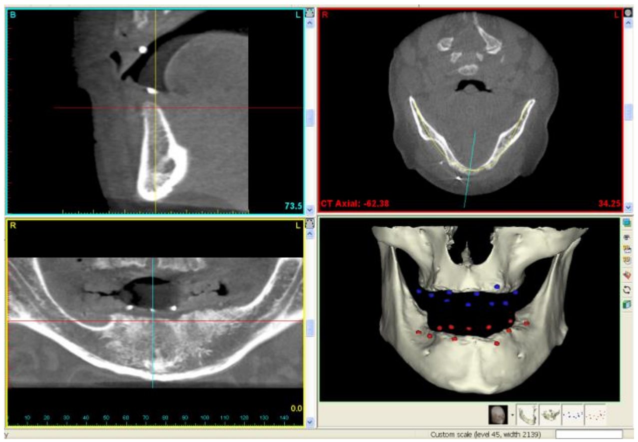
Marge - Maxilla (Lossy JPEG & CT Compressed)* - SimPlant Master Crystal
File Edit View Implant Tools Lists Plan Dr. James Master Options Help
Task panel
Start
Segment
Plan
Order
DentalPlanit
Implant:
Diameter:
3.75
mm
Length:
8.50
mm
B
L
62
R
L
21
R
L
-3.50
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70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

Bad Stent

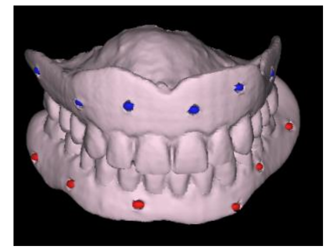



Worse
Stent
B
L
63
R
CT Axial: -25.38
R
L
0.75
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Dual Scan Technique



+



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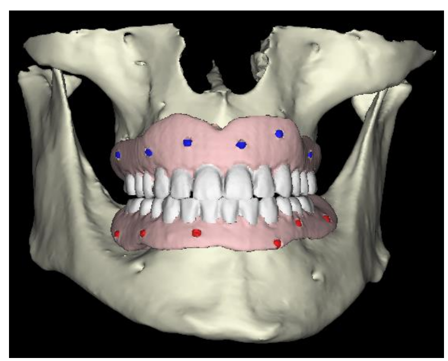
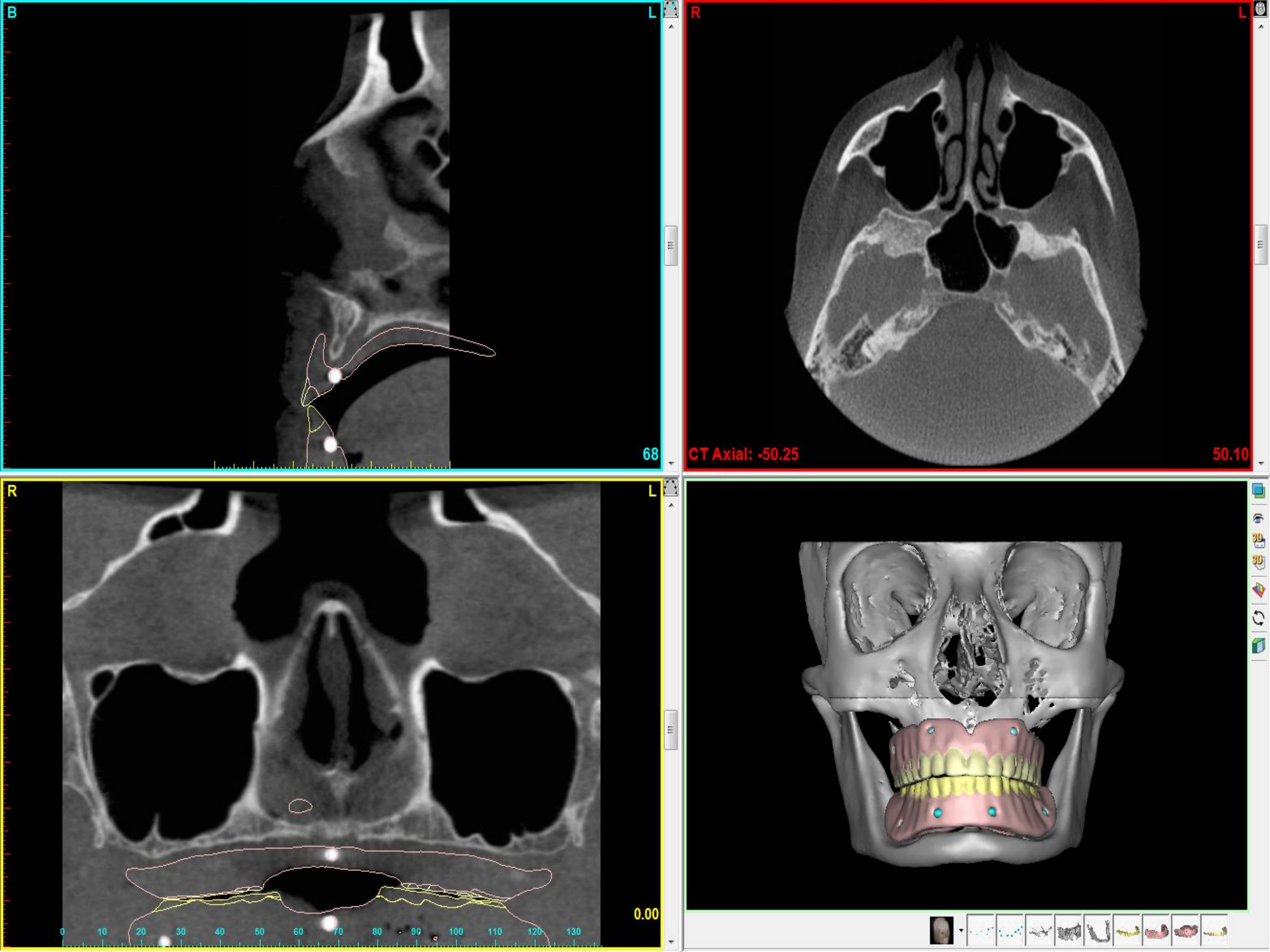
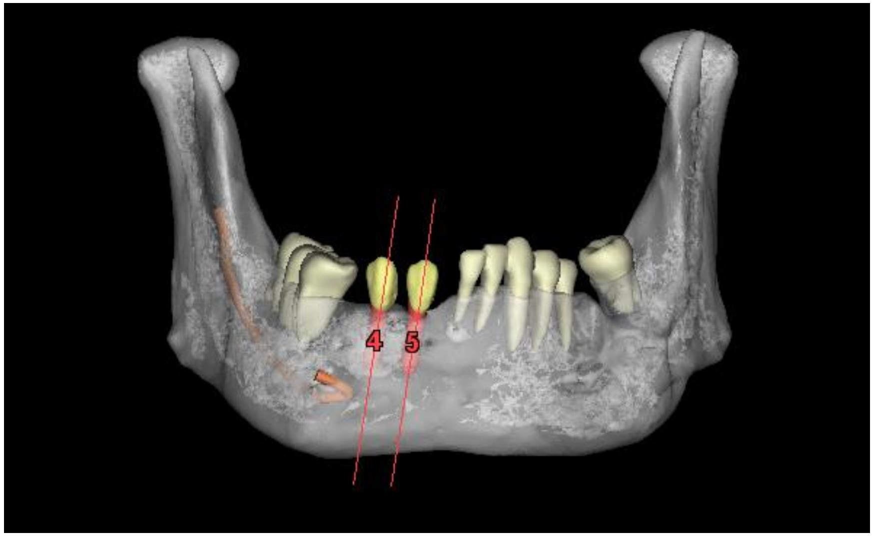
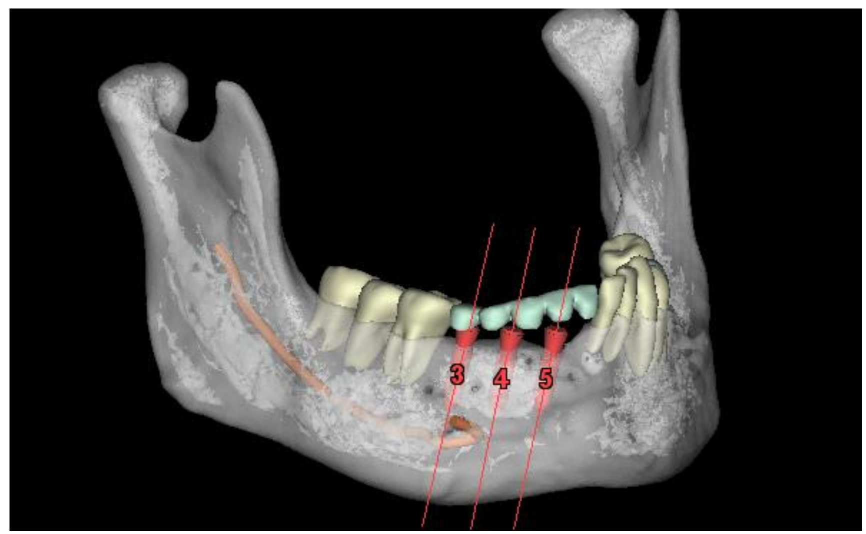



B
L
68
R
L
CT Axial: -50.25
50.10
R
L
0.00
0 10 20 30 40 50 60 70 80 90 100 110 120 130

Software for planning Dental Implants

- **SIMPLANT (DENTSPLY Implants)**
- **NobelGuide (Nobel Biocare)**
- **coDiagnostiX (Straumann)**
- **In Vivo Dental (Anatomage)**
- **Blue Sky Plan (Blue Sky Bio)**
- **Easyguide (Keystone Dental)**
- **ImplantMaster (iDent)**
- **VIP (Biohorizons)**


4
5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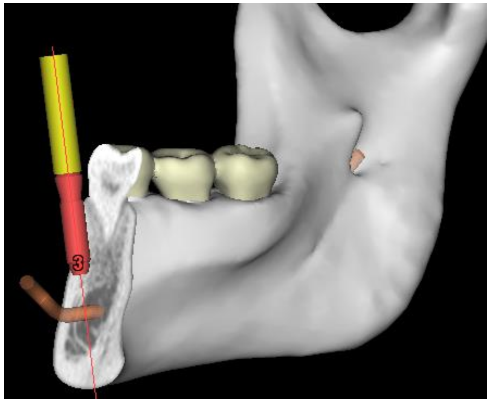
4
5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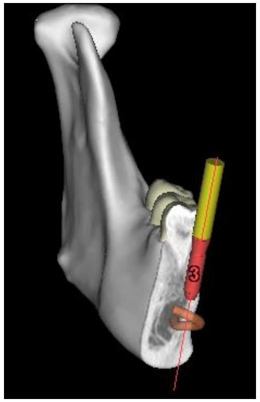
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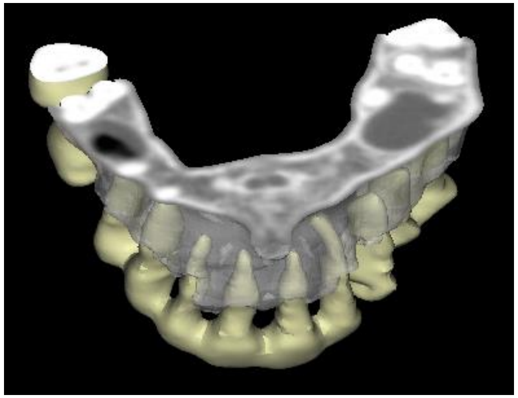

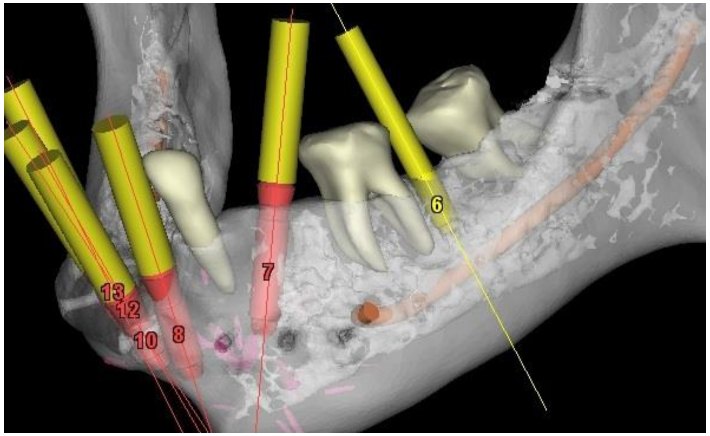
13
12
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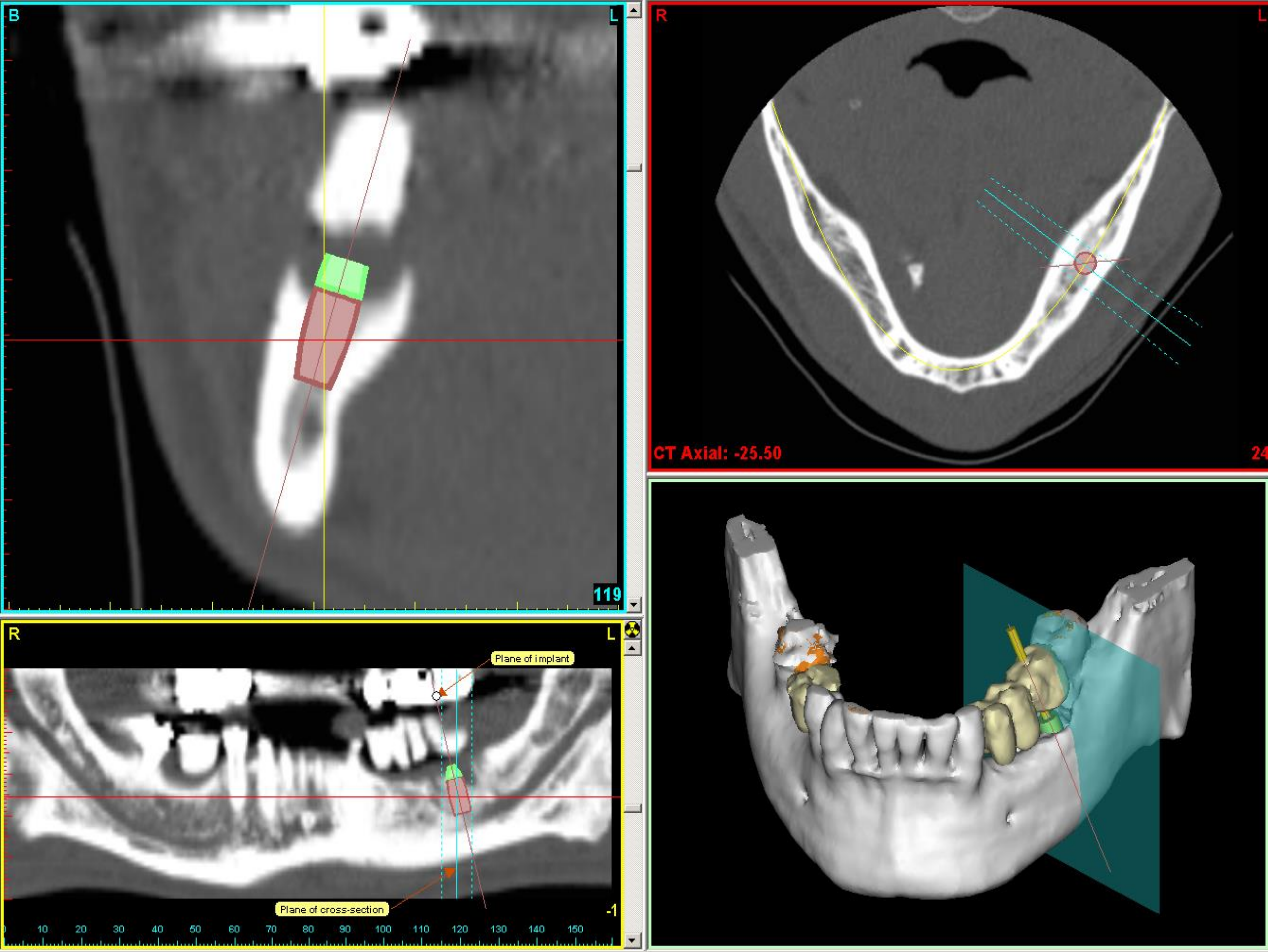
8
7
6


B
L
119
R
L
CT Axial: -25.50
24
R
L
Plane of implant
Plane of cross-section
-1
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Outline of Presentation

- ✔ Introduction / Disclosures
- ✔ Imaging for Dental Implants
  - Conventional Radiography
  - Cross-Sectional Imaging
- Radiation Dose and Risk
- Dose versus Image Quality

Radiation Dose and Risk

- **What are the risks from low radiation doses?**
- **How can we estimate the risks to our patients?**
- **What are the tradeoffs governing dose versus image quality?**

Cancer: science and society and the communication of risk

Kenneth C Calman

BMJ VOLUME 313 28 SEPTEMBER 1996

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		(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

The Problem

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

- **But how do we know what the risks are?**

- **How do we manage the tradeoffs between benefits and risks?**

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

Deterministic Effects are reproducible

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

Stochastic Effects are random

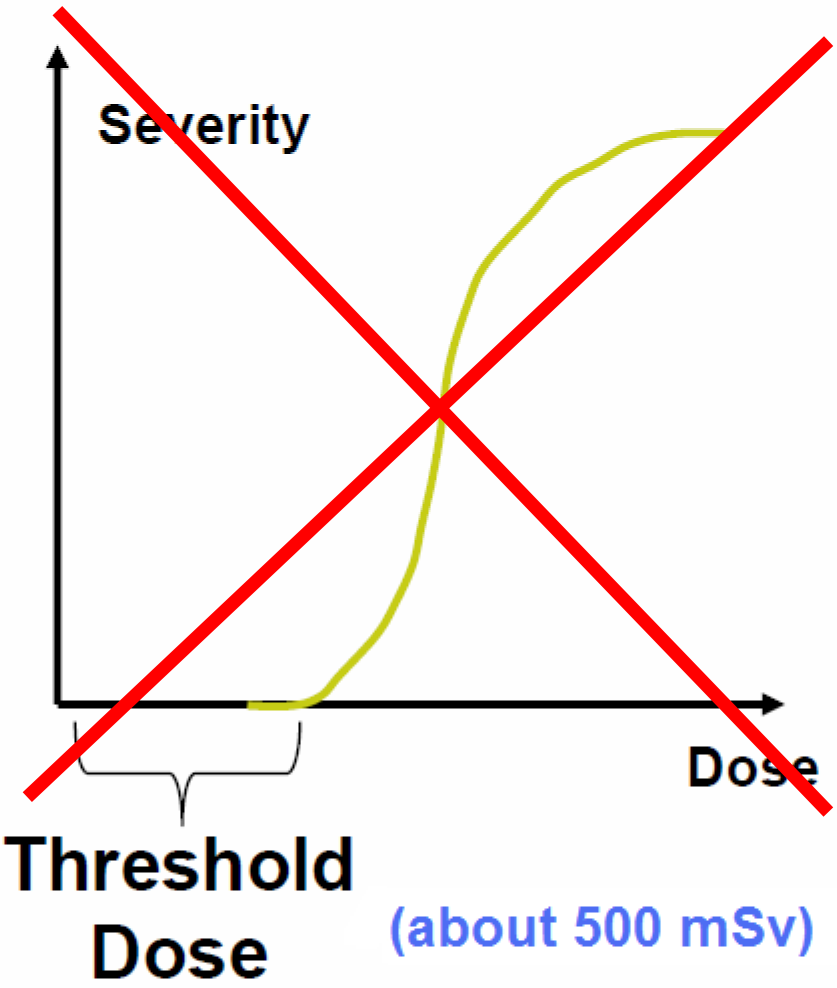
- **the risk (not the severity) increases with the dose**
- **known to occur above 20mSv or so**
- **below about 20mSv we don't know if they occur or not**

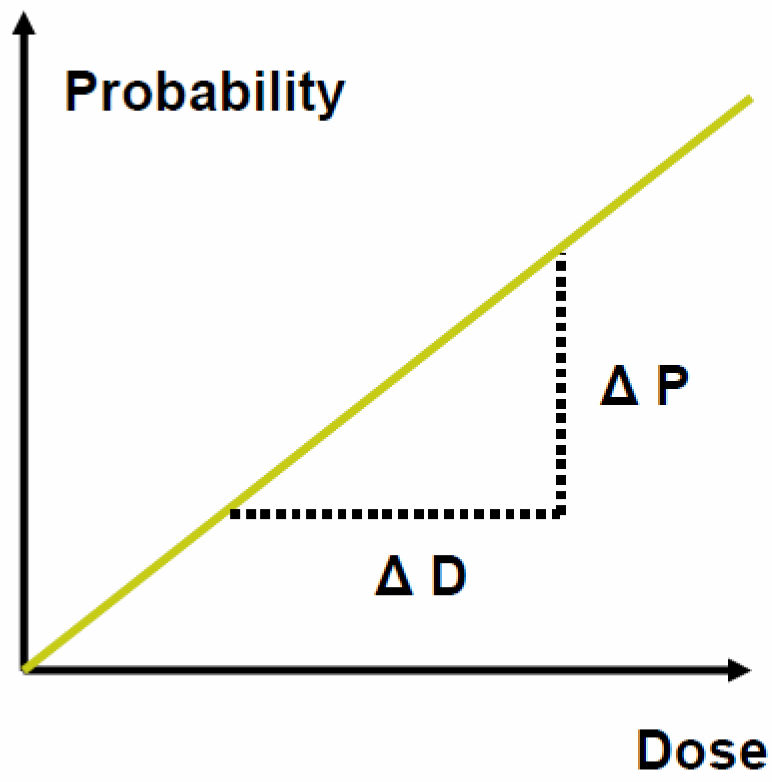
Hereditary Effects are random but the incidence is very low

Dr Mihran Kassabian (1870–1910)




Deterministic Effects	Stochastic Effects

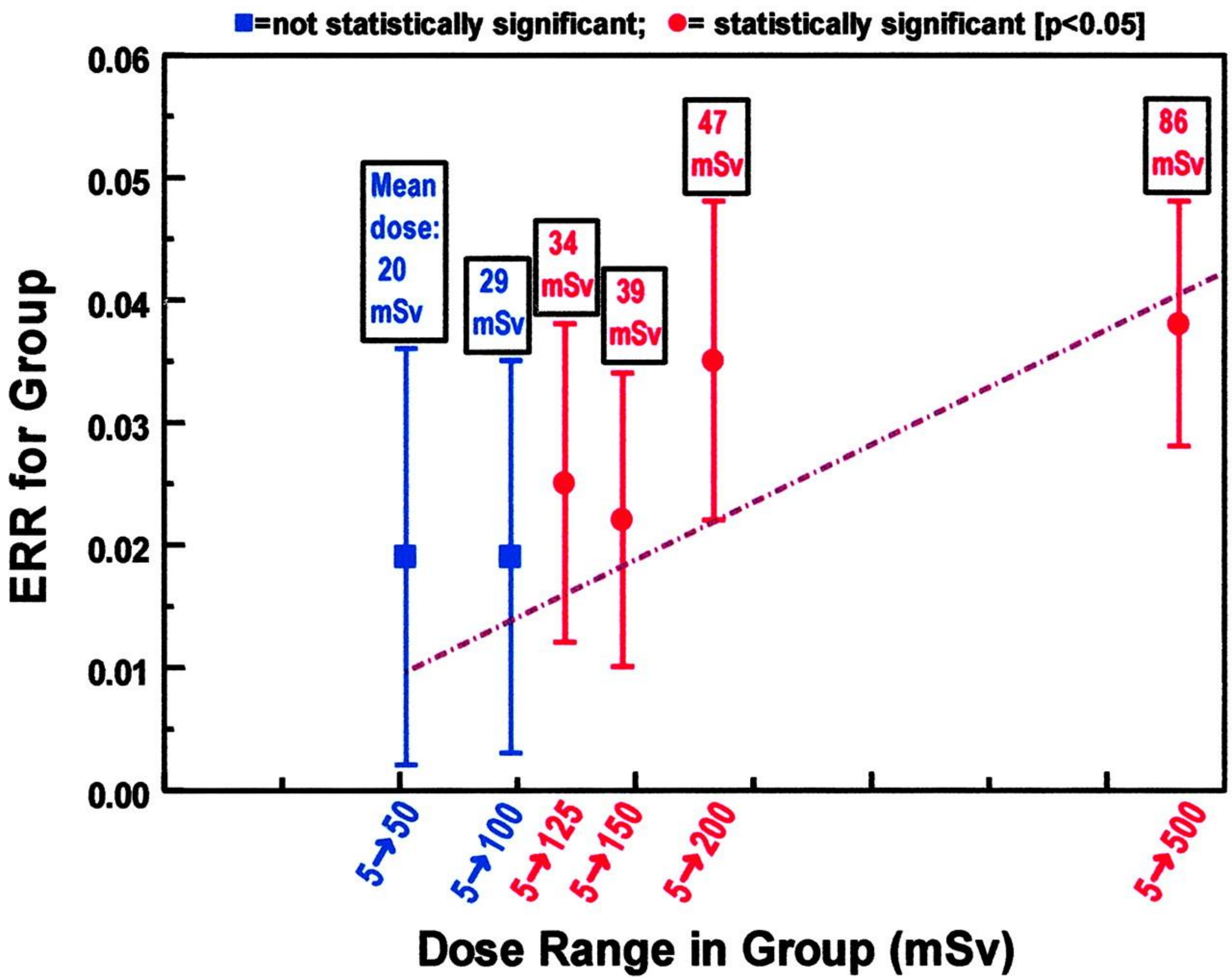




Risk Factor = Δ P / Δ D

(about 5% per Sievert)

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



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

The concept of Effective Dose

We know the risks from high doses of radiation

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

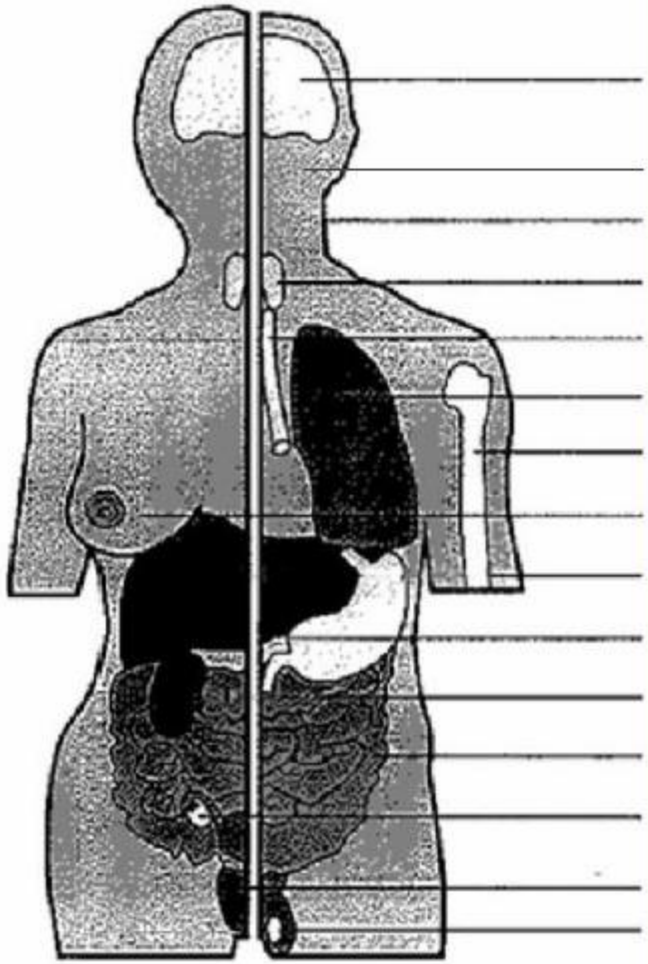
- **Atom Bomb survivors received whole body doses**
- **Dental patients receive doses to a very small region**
- **How can we relate the risks?**

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

Effective Dose is a measure of risk!

More about Effective Dose

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



	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

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

Effective Dose (E)

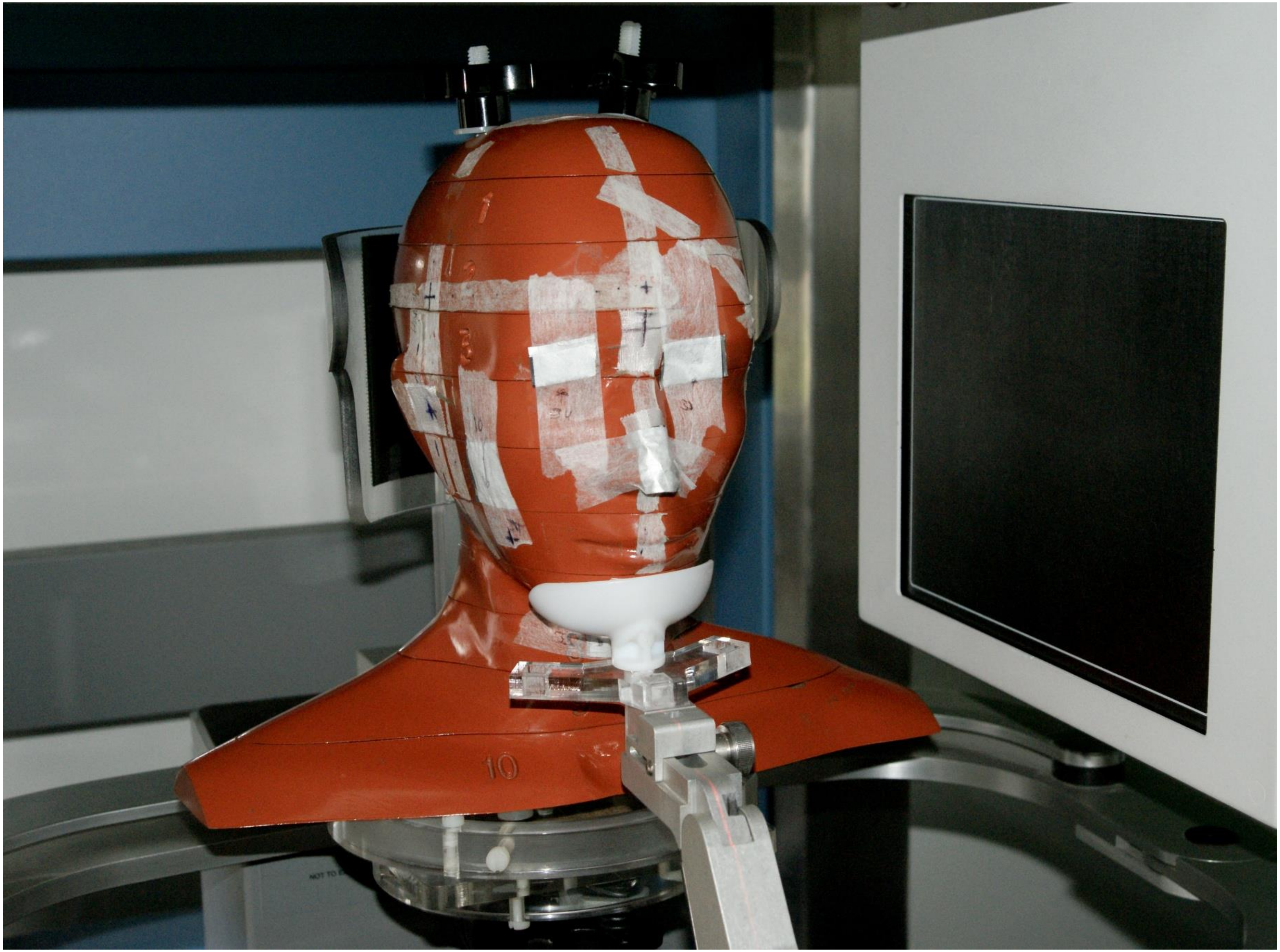
$$E = \sum_T H_T w_T$$

H_T = Organ Equivalent Dose
w_T = Tissue weighting factor

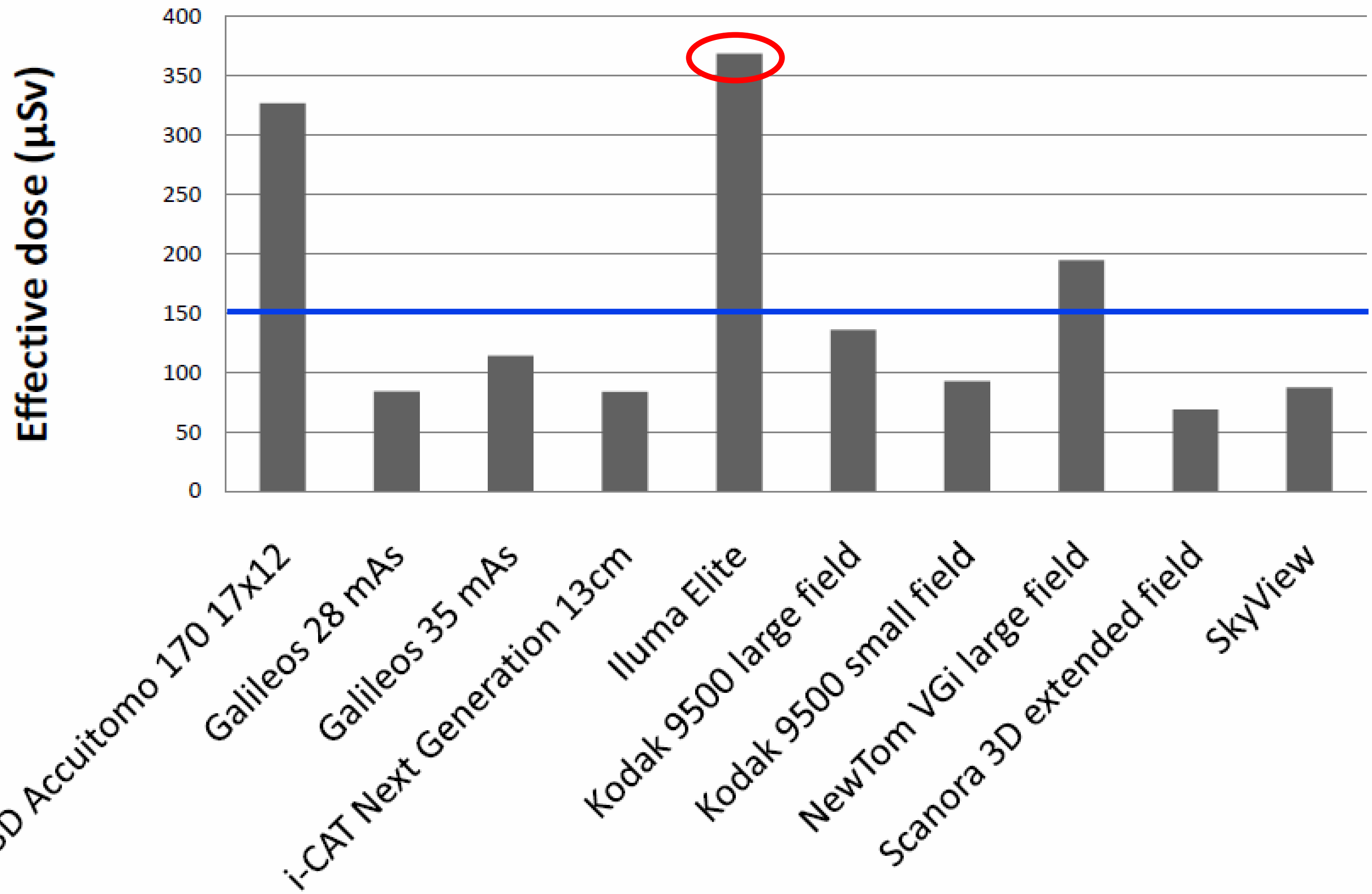
Unit = (Sv) Sievert

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

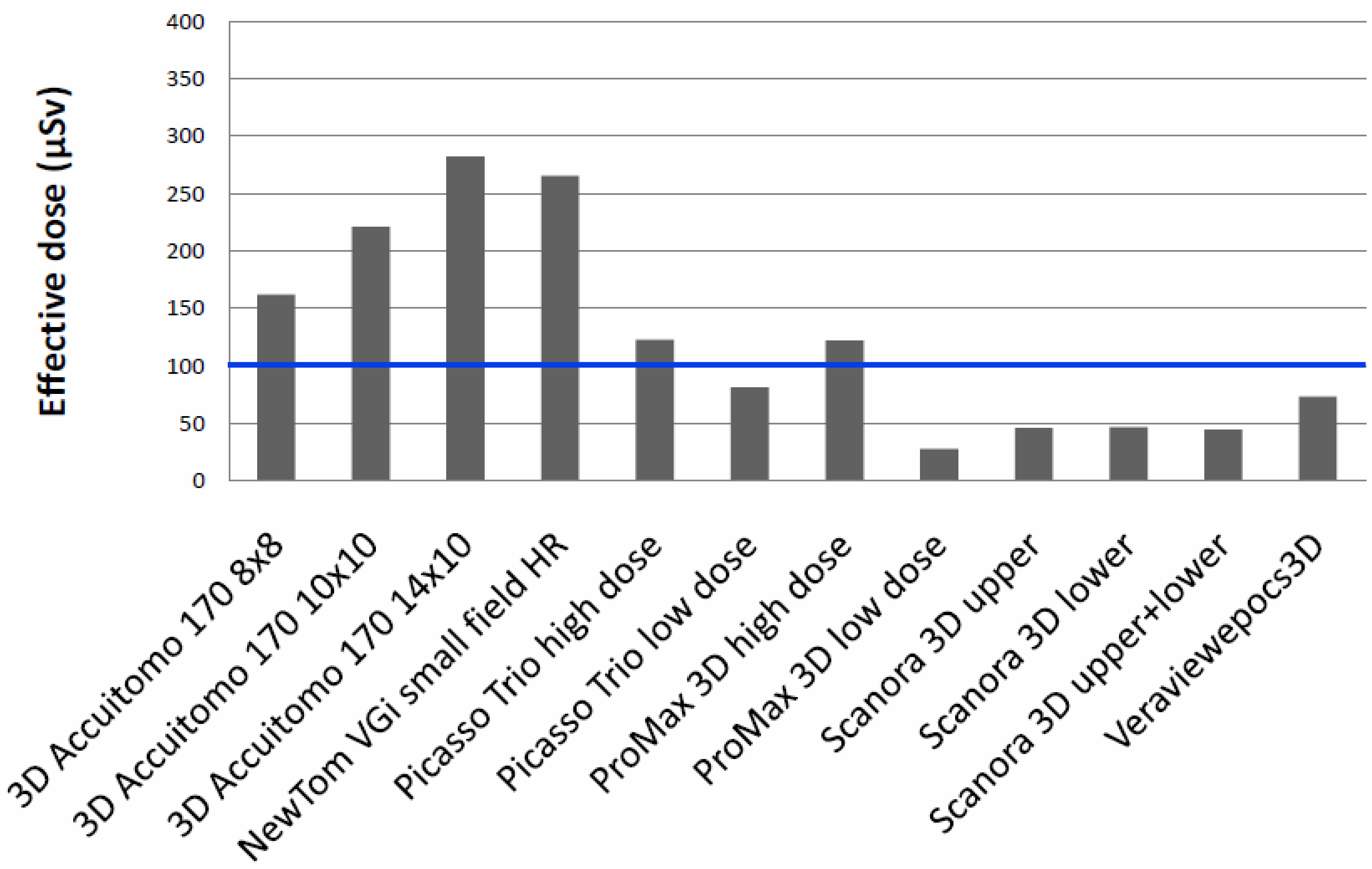

10

Effective dose for large field CBCTs



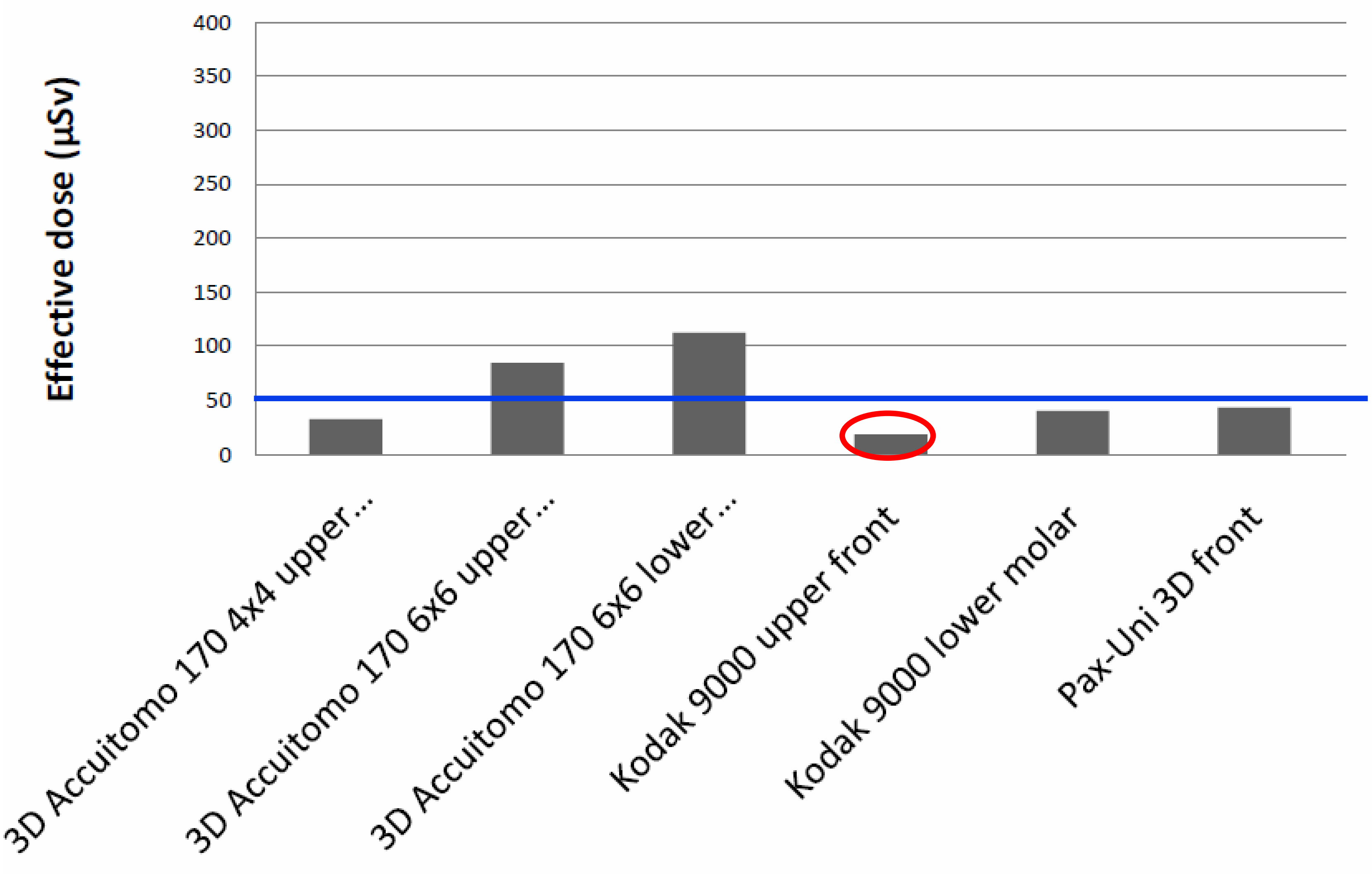
Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

Effective dose for medium field CBCTs



Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

Effective dose for small field CBCTs



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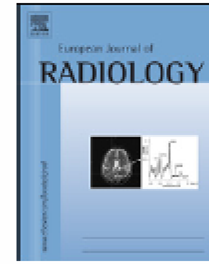

Effective dose range for dental cone beam computed tomography scanners

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]

[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)

Review

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

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

Article first published online: 20 MAR 2012

DOI: 10.1111/j.1600-0501.2012.02441.x

Issue

Clinical Oral Implants Research

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

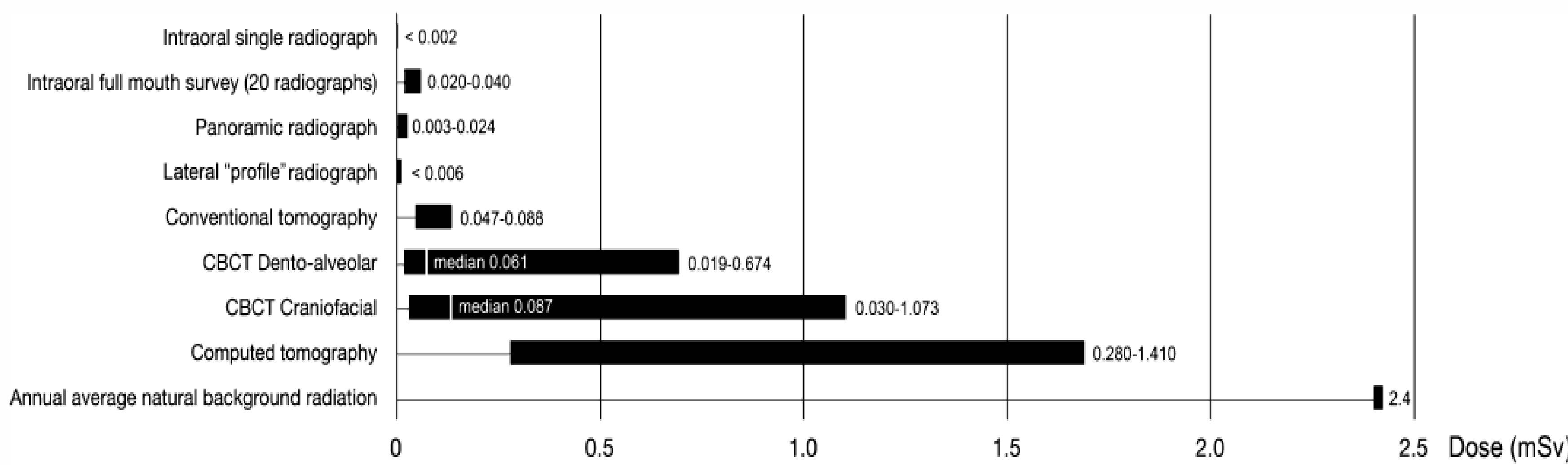

Fig. 1. Ranges of effective dose for the imaging modalities used in implant dentistry.

Typical Doses from Dental X-Rays

	Effective Dose (µSv)
Intraoral (F speed, rect coll)	2
Intraoral (E speed, round coll)	6
Lateral Ceph	10
Panoramic	3 to 24
Cone Beam CT	19 to 1073
Medical CT	280 to 1410

What is the Risk from an Intraoral x-ray?

- **Assume adult patient, F speed, rectangular collimation**
- **Effective Dose might be 2 microSieverts approx.**
- **Risk that patient might develop fatal cancer in 20 years time**

= 5% (1 in 20) per Sievert (from ICRP103)

= 1 in 20 million for 1 microSievert

= 2 in 20 million for 2 microSieverts

= 1 in 10 million for 2 microSieverts

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

Cancer: science and society and the communication of risk

Kenneth C Calman

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		(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

The Risk from an Intraoral x-ray

Lightning: the risk is negligible

Typical Doses from Dental X-Rays

	Effective Dose (µSv)	Risk	
Intraoral (F speed, rect coll)	2	1 in 10 million	Negligible
Intraoral (E speed, round coll)	6	1 in 3.3 million	Negligible
Lateral Ceph	10	1 in 2 million	Negligible
Panoramic	3 to 24	1 in 6.7 million to 833 thousand	Negligible to Minimal
Cone Beam CT	19 to 1073	1 in 1.05 million to 1 in 19 thousand	Mimimal to Very Low
Medical CT (using dental protocol)	280 to 1410	1 in 71 thousand to 1 in 14 thousand	Very Low

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		(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

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

Implant Surgery Complications: Etiology and Treatment

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

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Implant Dentistry
Volume 17 • Number 2

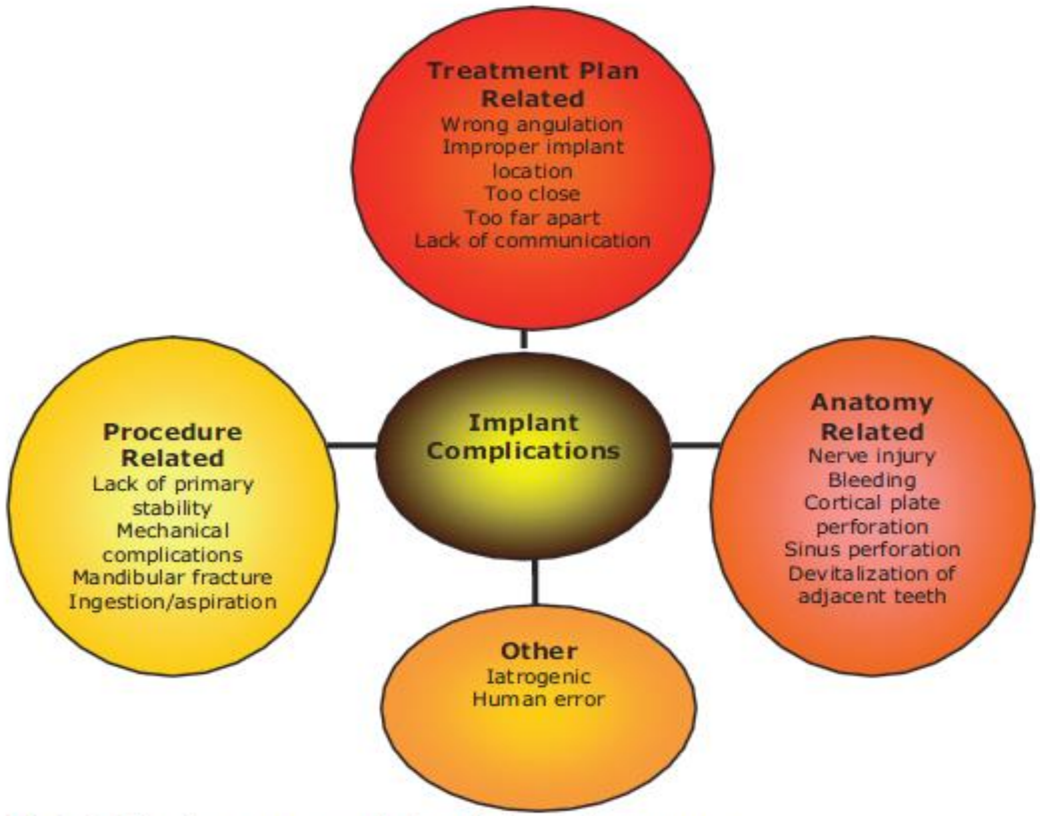


Fig. 1. Outline of common complications during implant surgery.

How can we estimate the Effective Dose in practice?

kVp, mAs etc

- **only works for comparing scans on the same machine**

Dose Length Product (DLP)

- **works very well for comparing medical CT scans**

Dose Area Product (DAP)

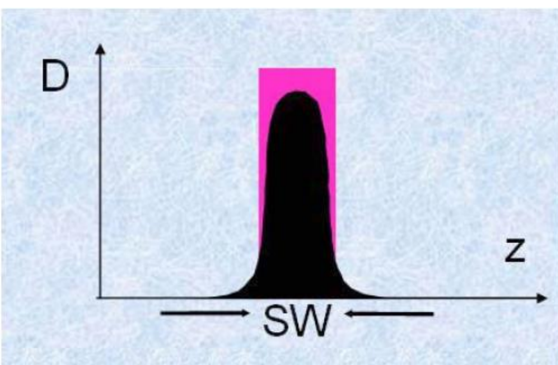
- **works reasonably well for comparing cone beam CT scans**

Dose Length Product (DLP)

$CTDI_{vol}$ is the dose per cm

DLP = $CTDI_{vol}$ x Irradiated Length

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



$$CTDI = \frac{1}{SW} \int_{-5cm}^{+5cm} D(z)dz \quad (mGy)$$

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

Conversion Factor F

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

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

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

Roughly speaking, F = 0.002mSv / mGy.cm for Maxilla and 0.003mSv / mGy.cm for Mandible
2 μSv **3 μSv**

Accuracy: ±50%

Effective Dose for Medical CT Scanners

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

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

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

Accuracy: ±50%

Mx 128μSv ROUGHLY

Medical CT 128µSv

IDT Physics Report

Patient ID 23416

Gender Male

Date of Birth 1953-06-12

Scanning Date 2012-08-16

Region Scanned Maxilla

Reason for Scan Proximity of implant to incisive canal

Scanning Site Bath Clinic

Equipment Toshiba Aquilion (64 slice)

Scan Duration 12 seconds

FOV (diameter) 15 cm

FOV (length) 4.2 cm

Dose Length Product (DLP) 64 mGy.cm

Effective Dose 128 microSv approx (calculated from DLP)

Cone Beam Computed Tomography
radiation dose and image quality assessments

Sara Lofthag-Hansen

Department of Oral and Maxillofacial Radiology
Institute of Odontology at Sahlgrenska Academy

UNIVERSITY OF GOTHENBURG

REGION VÄSTRA GÖTALAND

Gothenburg 2010

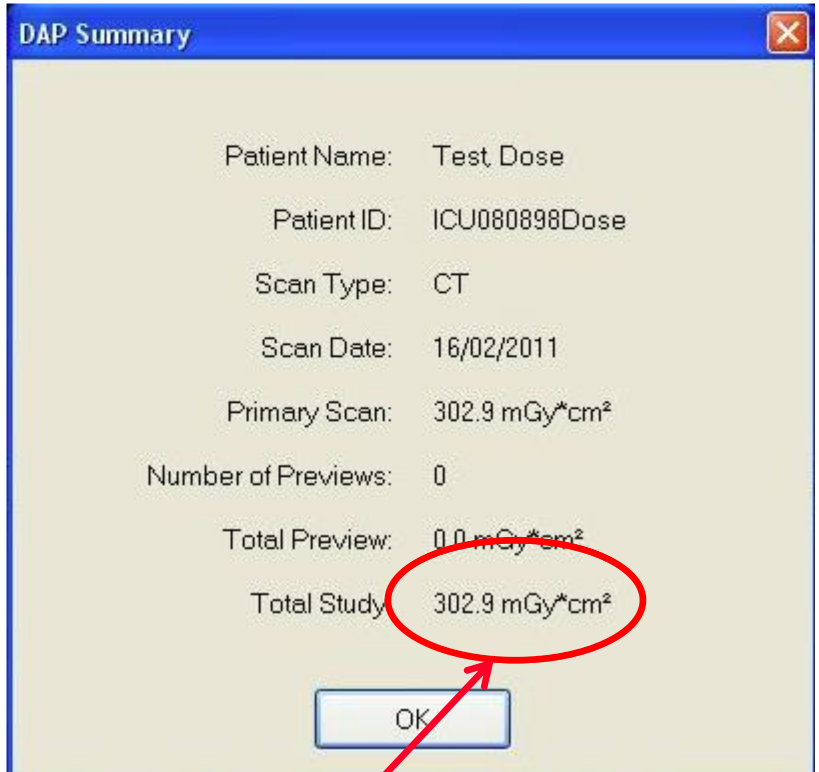
Table 5. Most commonly used exposure parameters in three specified regions and corresponding dose-are product (DAP) value and effective dose according to ICRP 60 (1991)

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

Effective Dose (µSv) = 0.1 x DAP (mGy.cm2) Maxilla
0.15 x DAP (mGy.cm2) Mandible

ROUGHLY

Dose Area Product (DAP) for Cone Beam CT Scanners

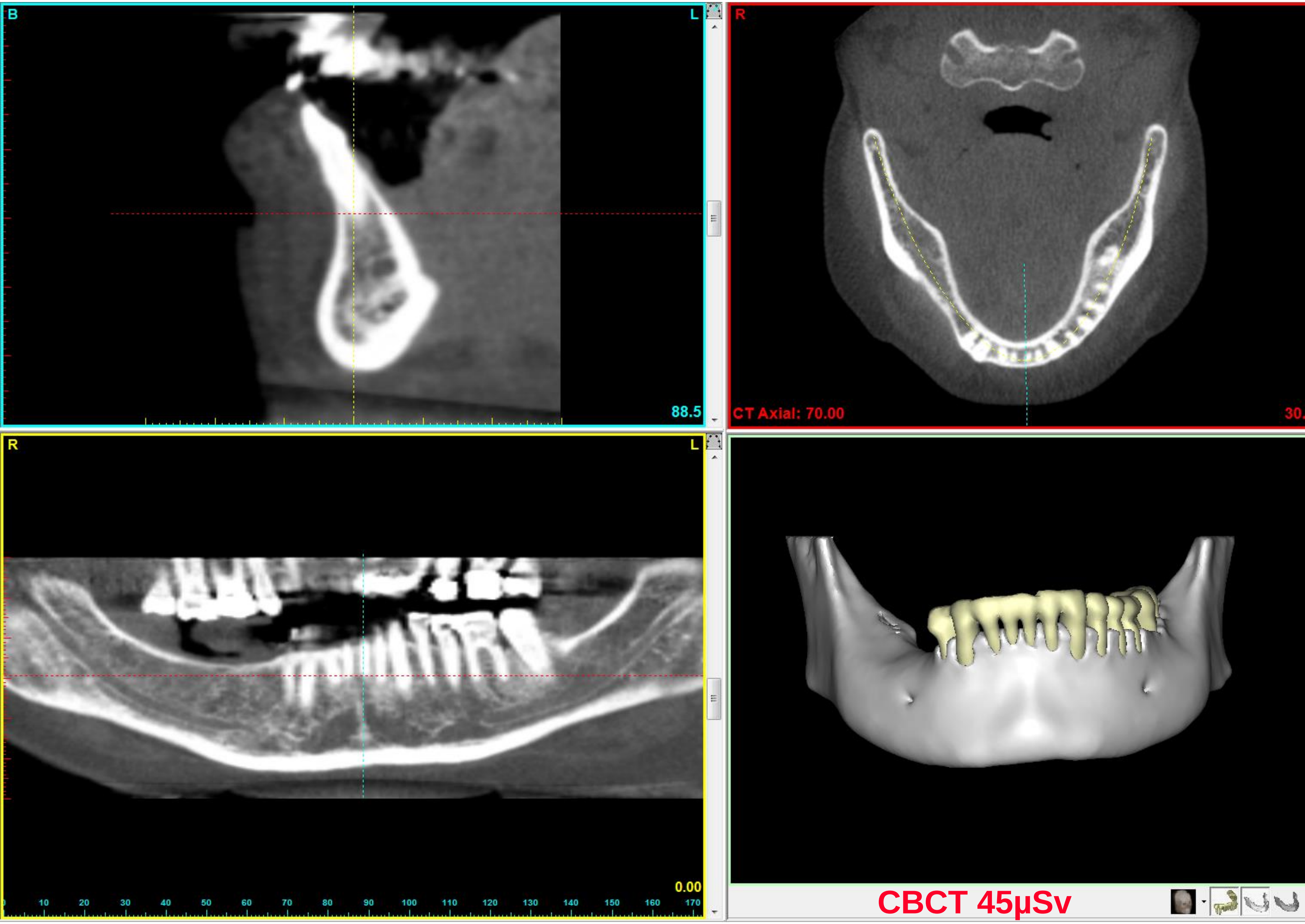


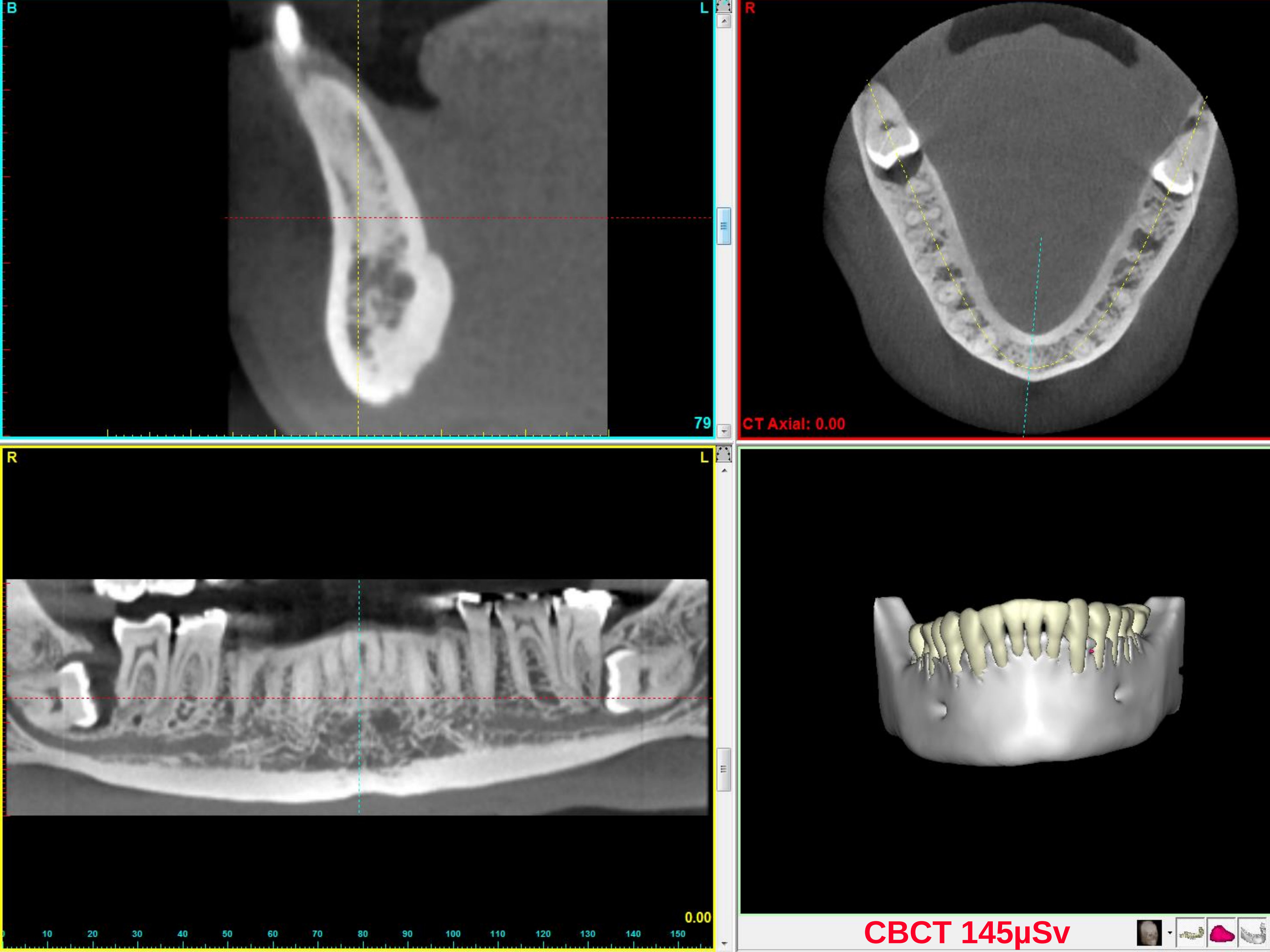
Multiply DAP by 0.1 for Maxilla or 0.15 for Mandible to get the Effective Dose in microSieverts (µSv)

Accuracy: ±50%

Mn 45µSv

ROUGHLY

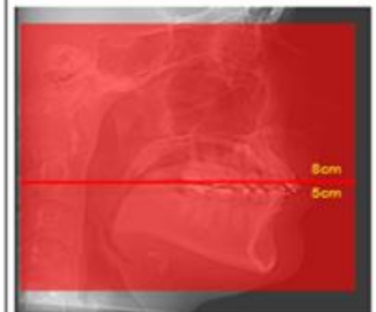

B
L
88.5
R
CT Axial: 70.00
30.
R
L
0.00
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
CBCT 45μSv


B
L
79
R
CT Axial: 0.00
R
L
0.00
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
CBCT 145μSv

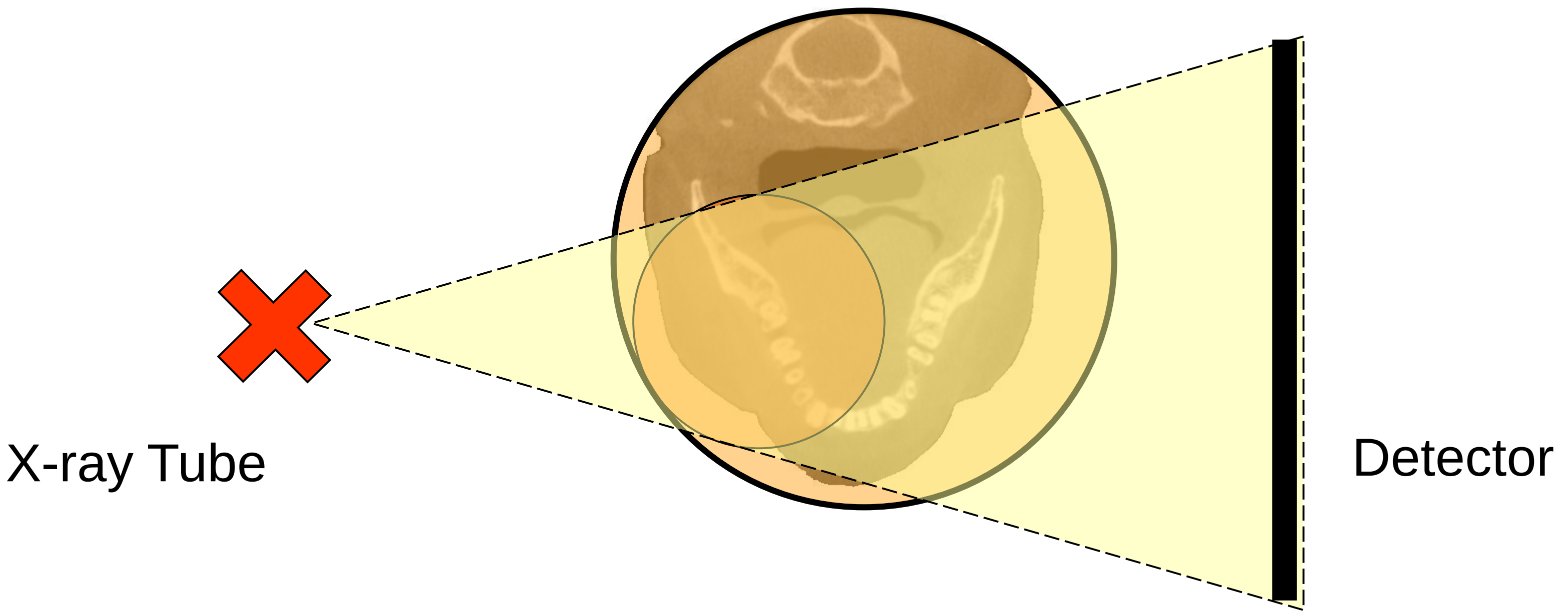
How to Reduce the Dose

1. **Reduce the mAs (tube current, scan time)**

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

	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

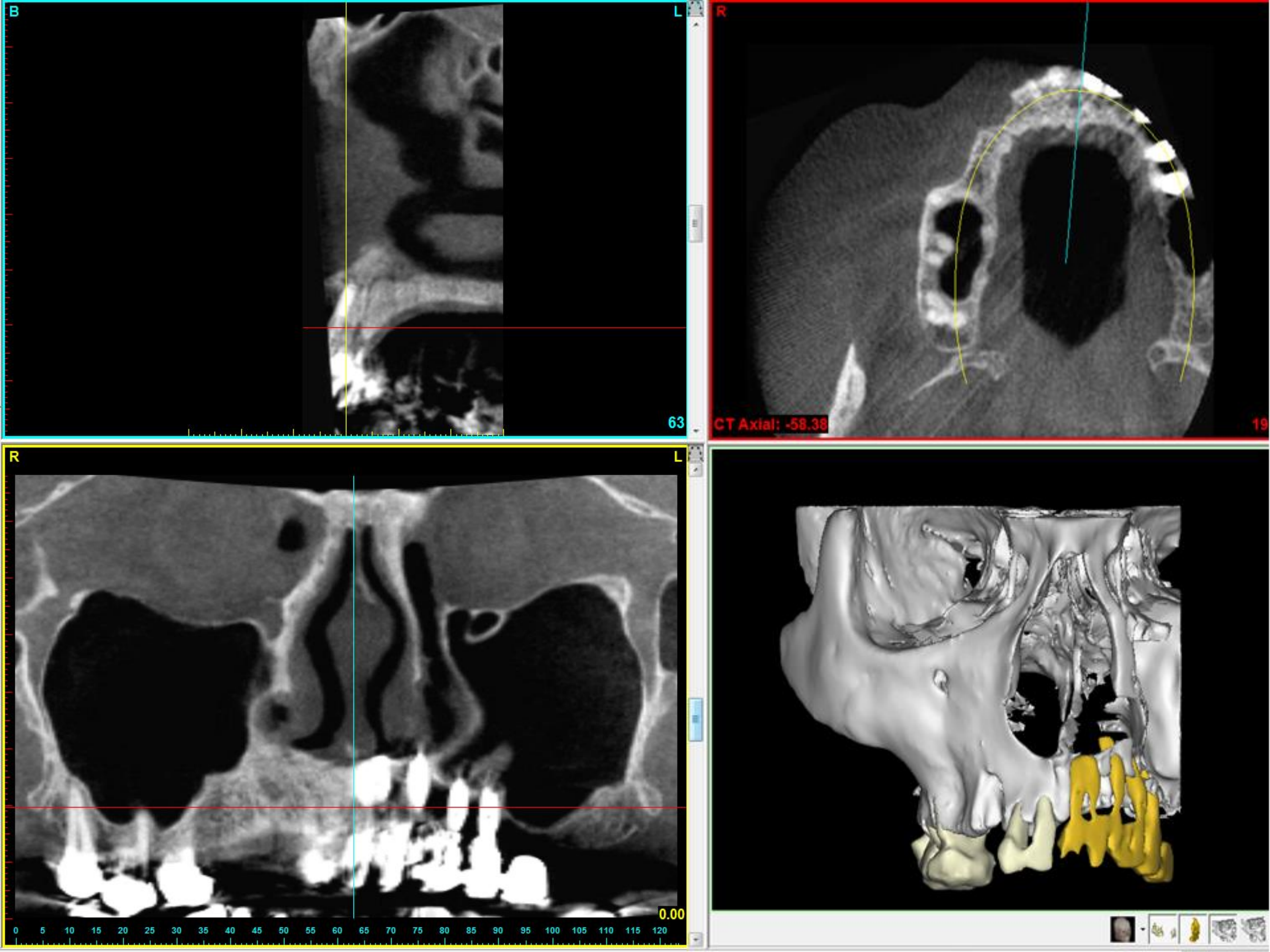
3. Reduce the Width (horizontal collimation)

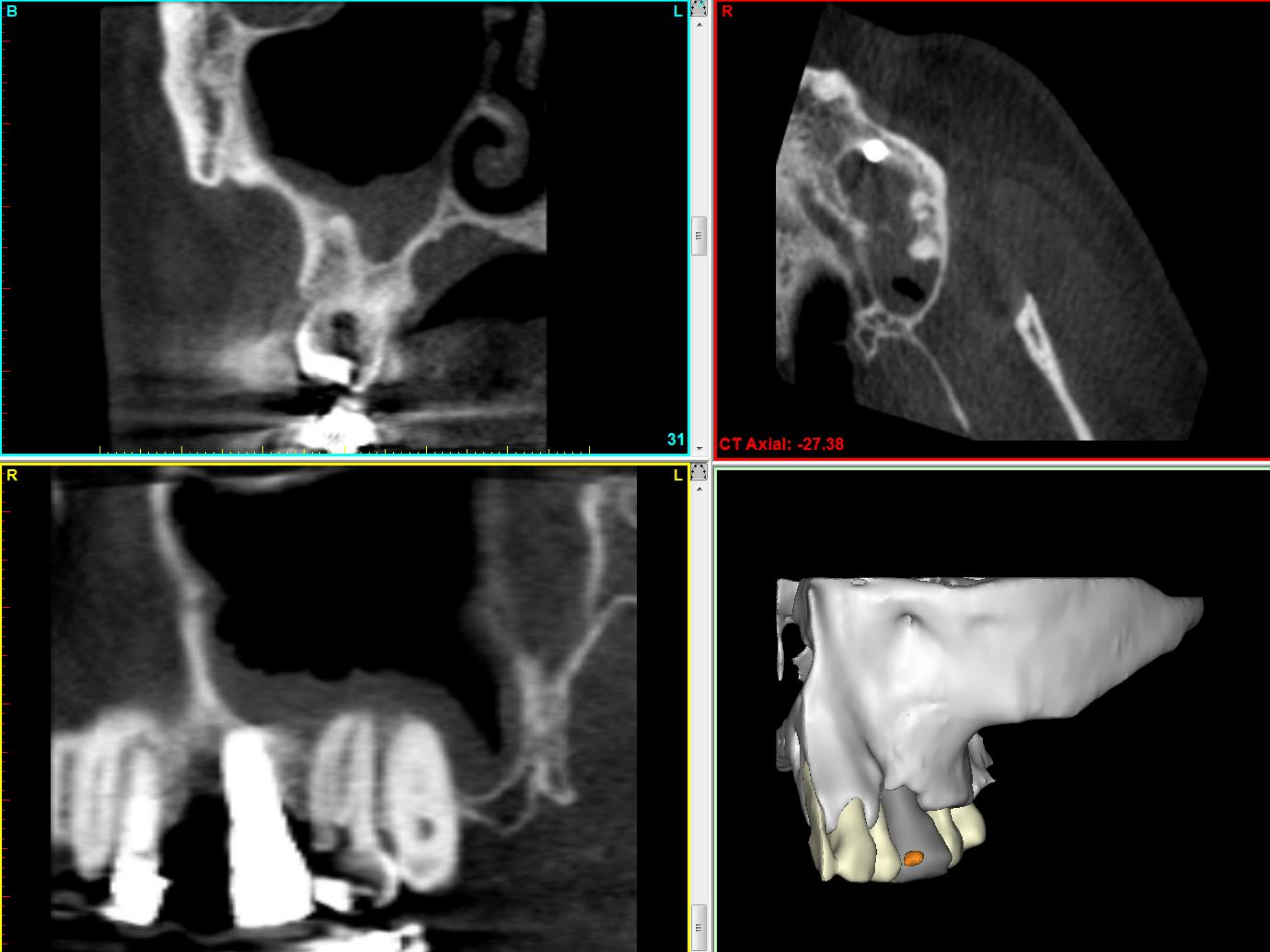


- **Reducing the beam height by 50% reduces the dose by 50%**
- **Reducing the beam width by 50% reduces the dose by 50% at most.**

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

PLEASE AVOID SCANNING THE SPINE


B
L
63
R
CT Axial: -58.38
19
R
L
0.00
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


B
L
31
R
CT Axial: -27.38
R
L

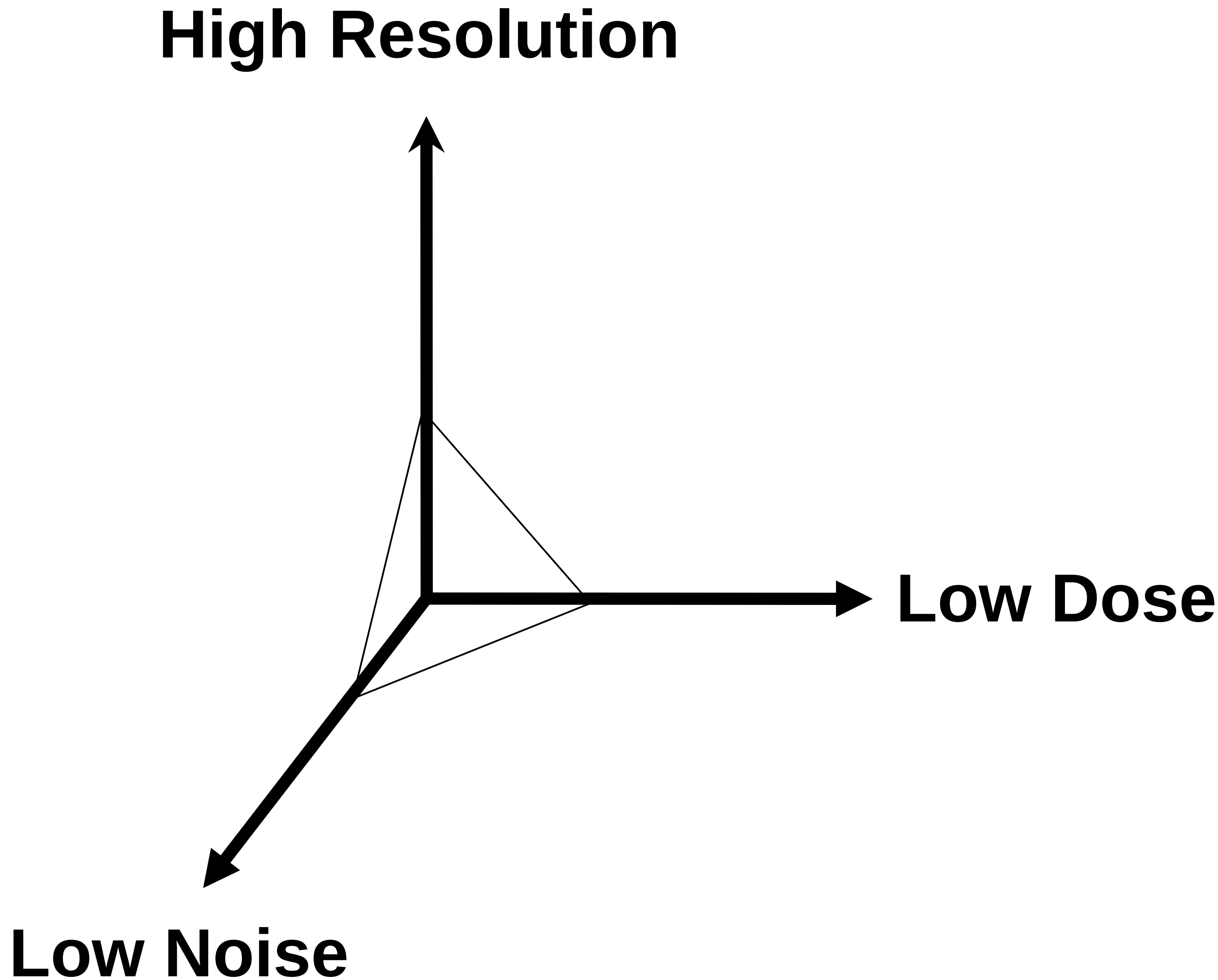
Dose versus Image Quality in CBCT scans

- Noise
- ***depends on radiation dose***

- Artefact
- ***metal objects within the patient***
- ***depends on machine calibration and 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 (filtration and kVp)***


High Resolution
Low Dose
Low Noise

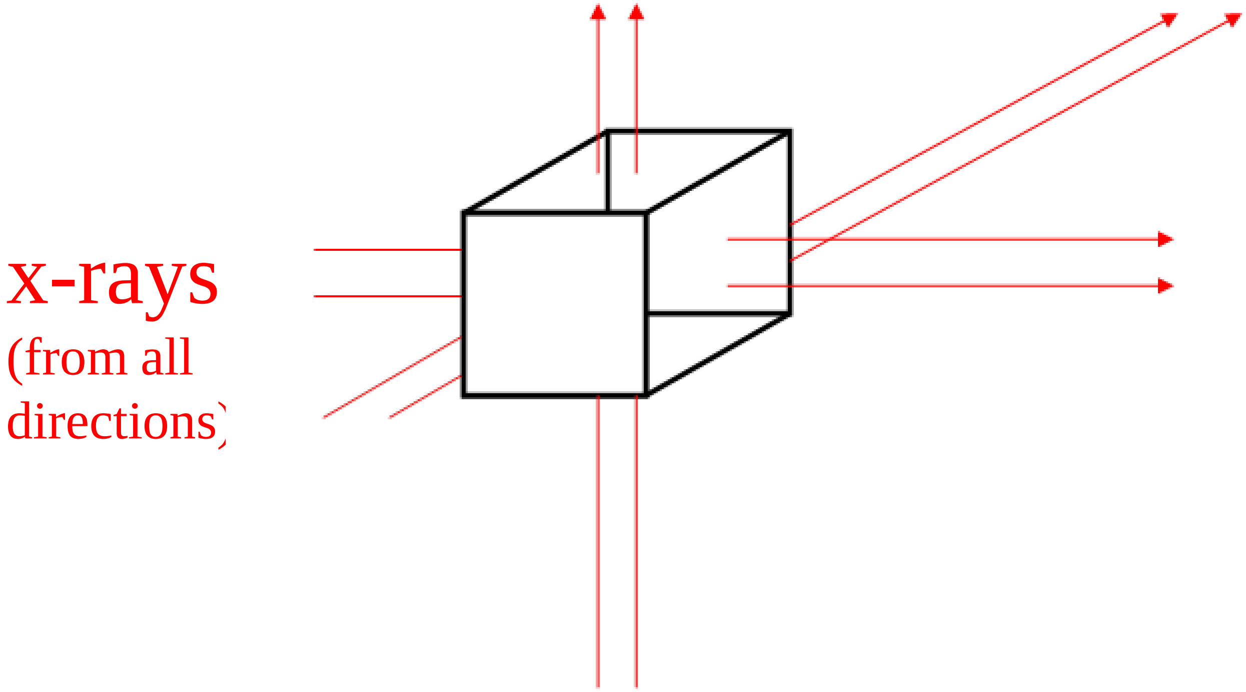
Noise in CT / CBCT images

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

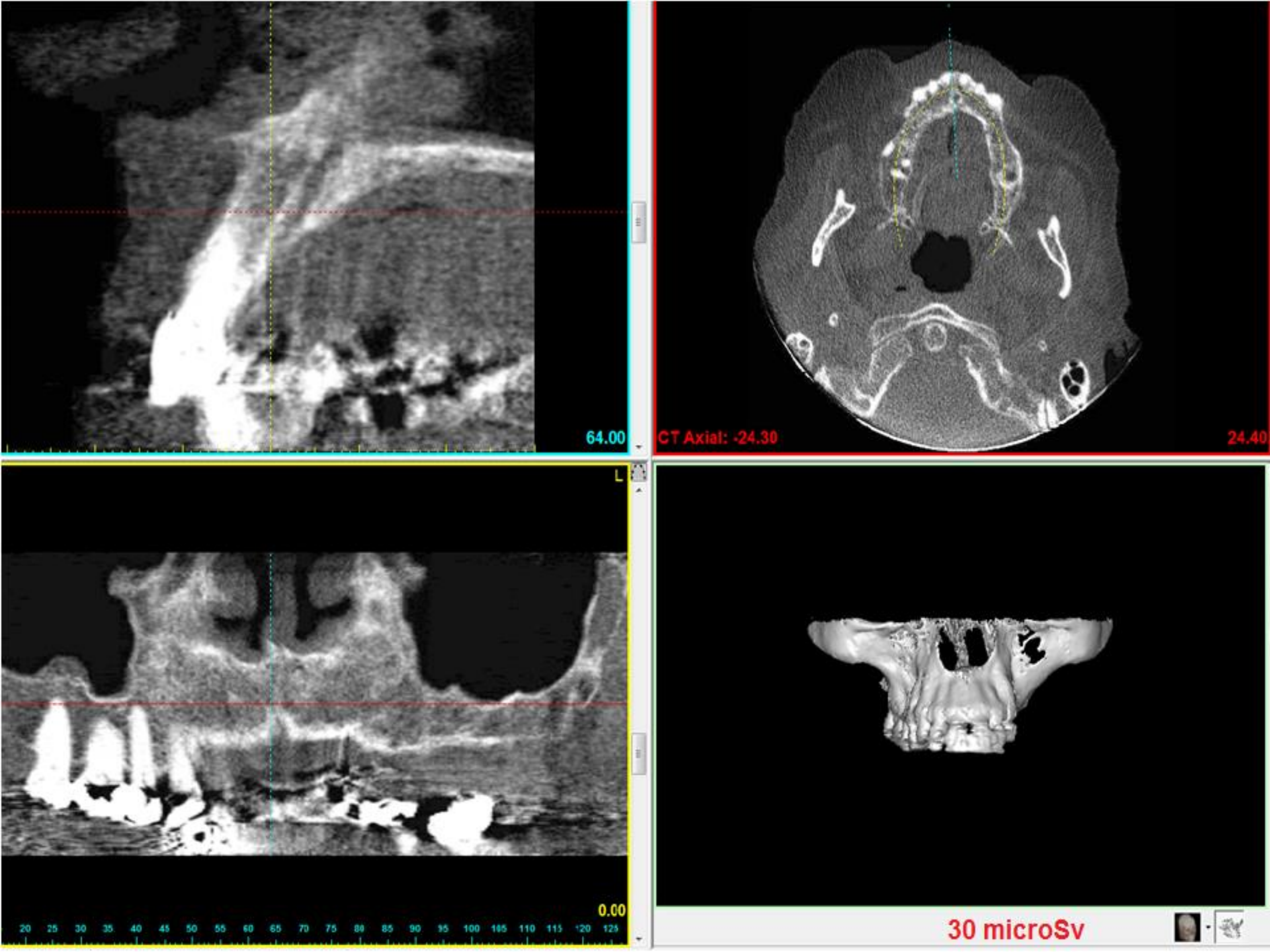
Photon noise (not enough x-rays)

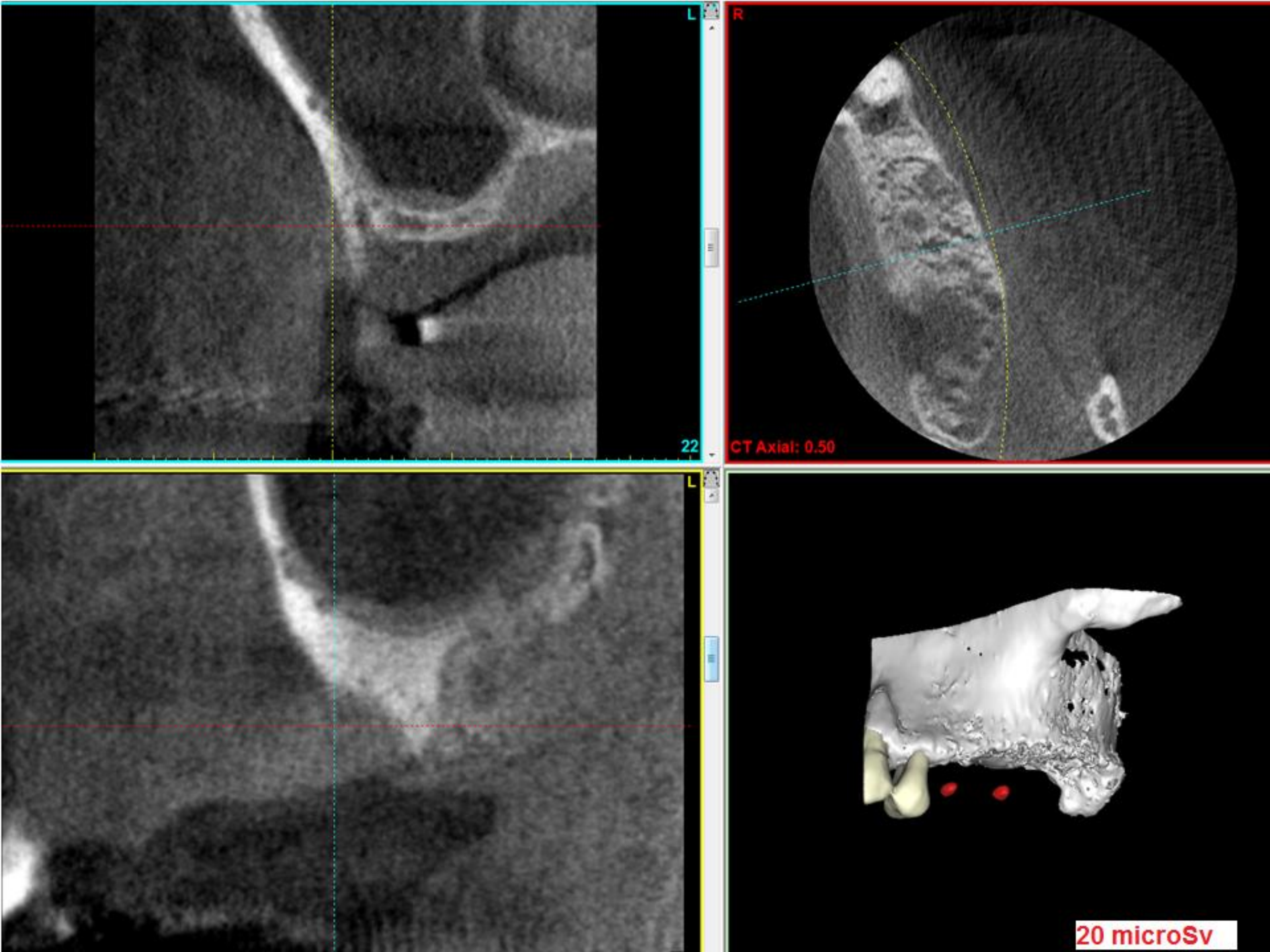
- **Signal-to-Noise Ratio is proportional to $\sqrt{n}$**
- **Where n is the number of x-ray photons**

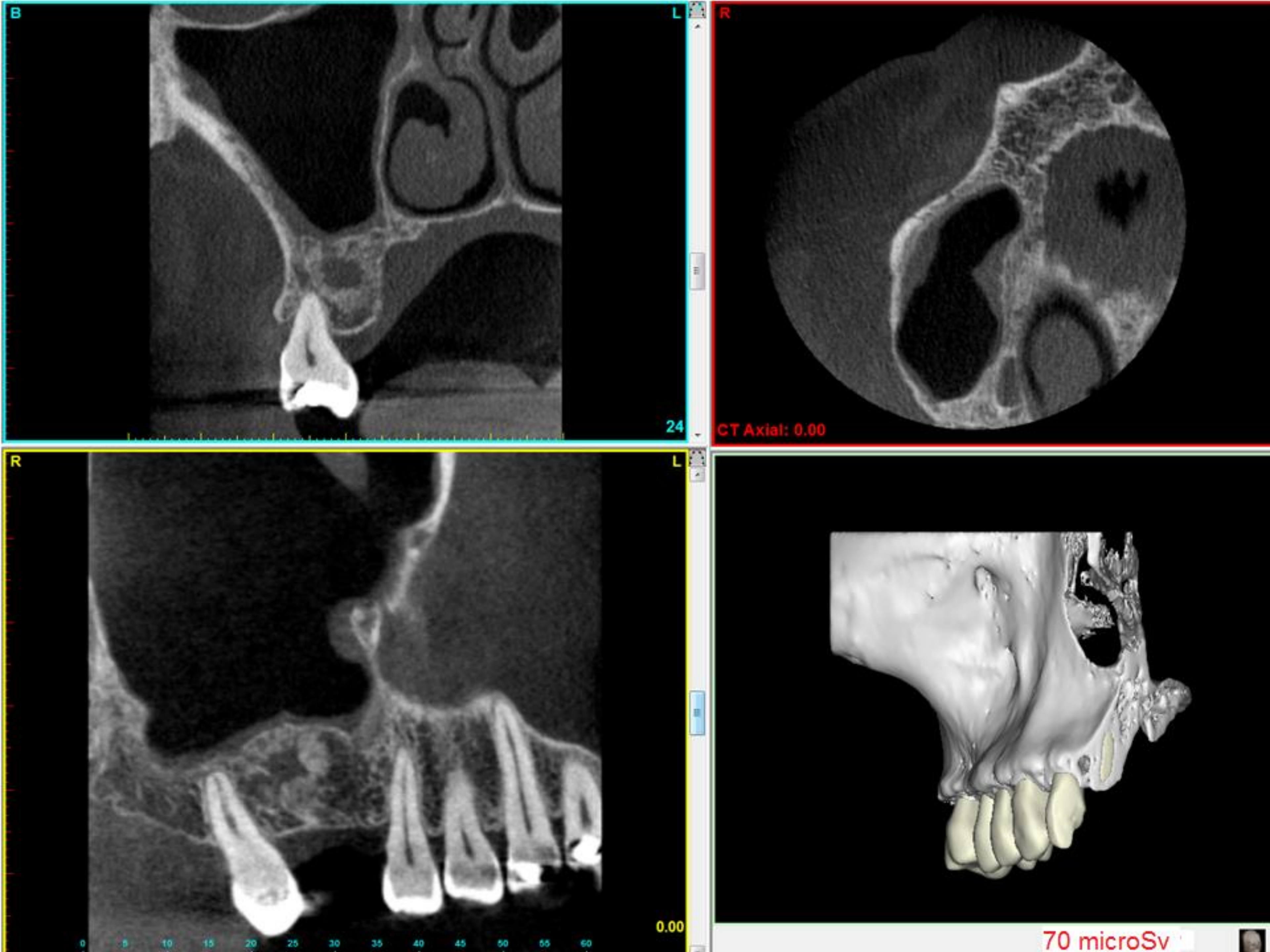
Noise depends on voxel size

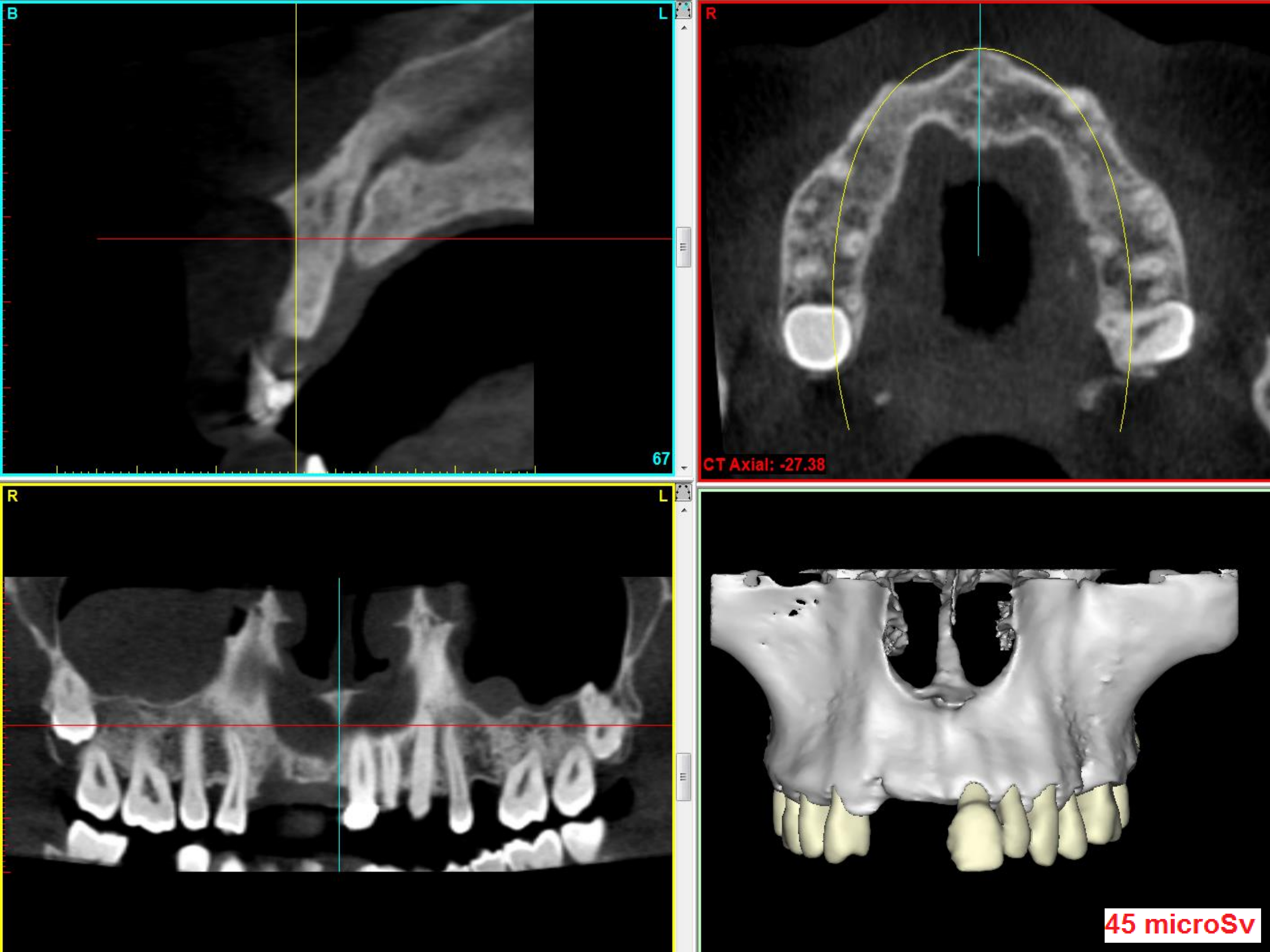


If you halve (1/2) each side of a cube e.g. from 0.4mm to 0.2mm
Number of x-ray photons passing through it goes down by 8 (i.e. 1/8)
Noise goes up by √8 = 2.83
mAs (dose) may have to be increased to compensate


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
30 microSv


L
22
R
CT Axial: 0.50
L
20 microSv


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
70 microSv


B
L
67
R
CT Axial: -27.38
R
L
45 microSv

Artefacts in CT / CBCT images

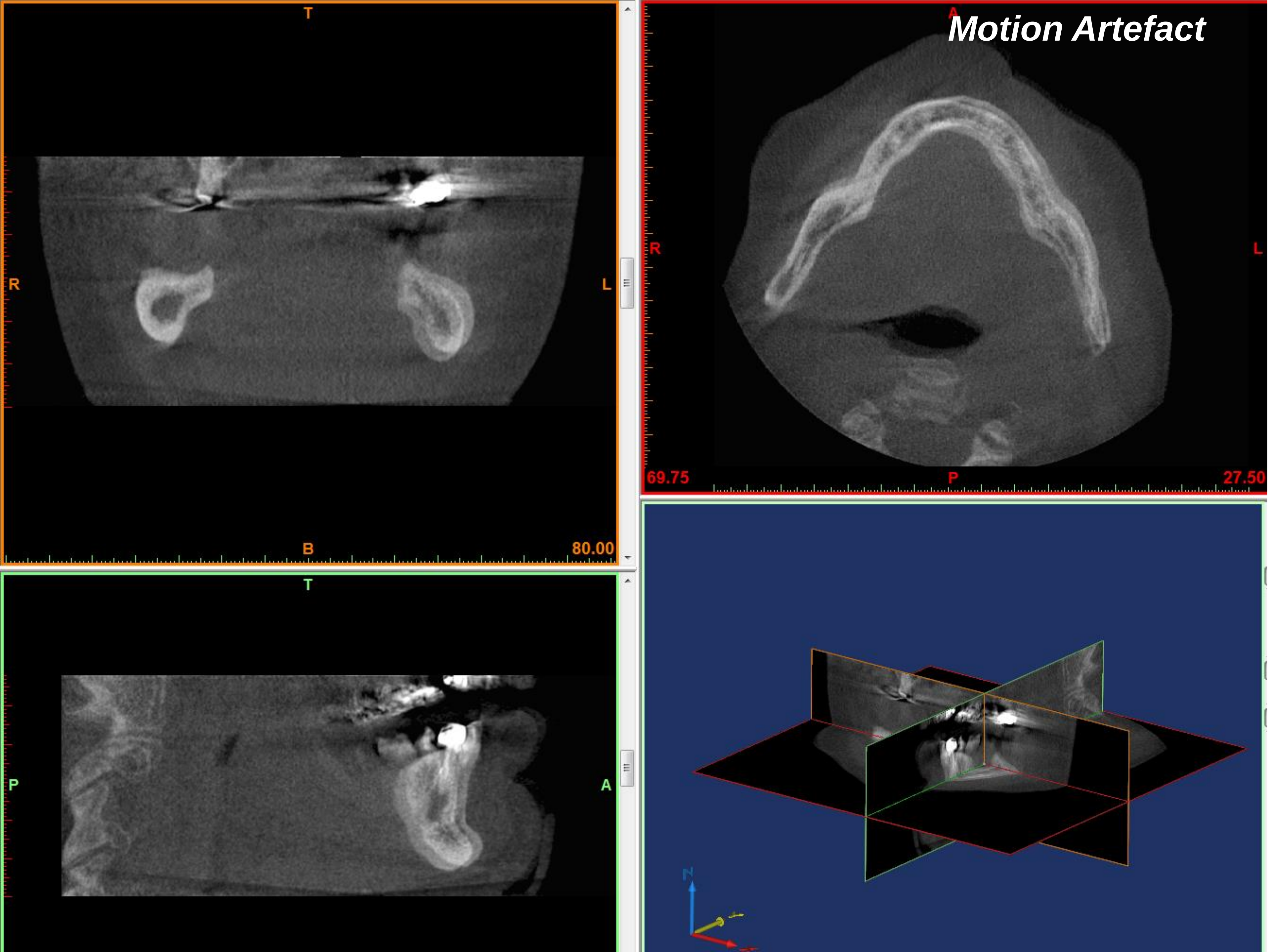
Artefact = structured contribution to the image which has no counterpart in the object.

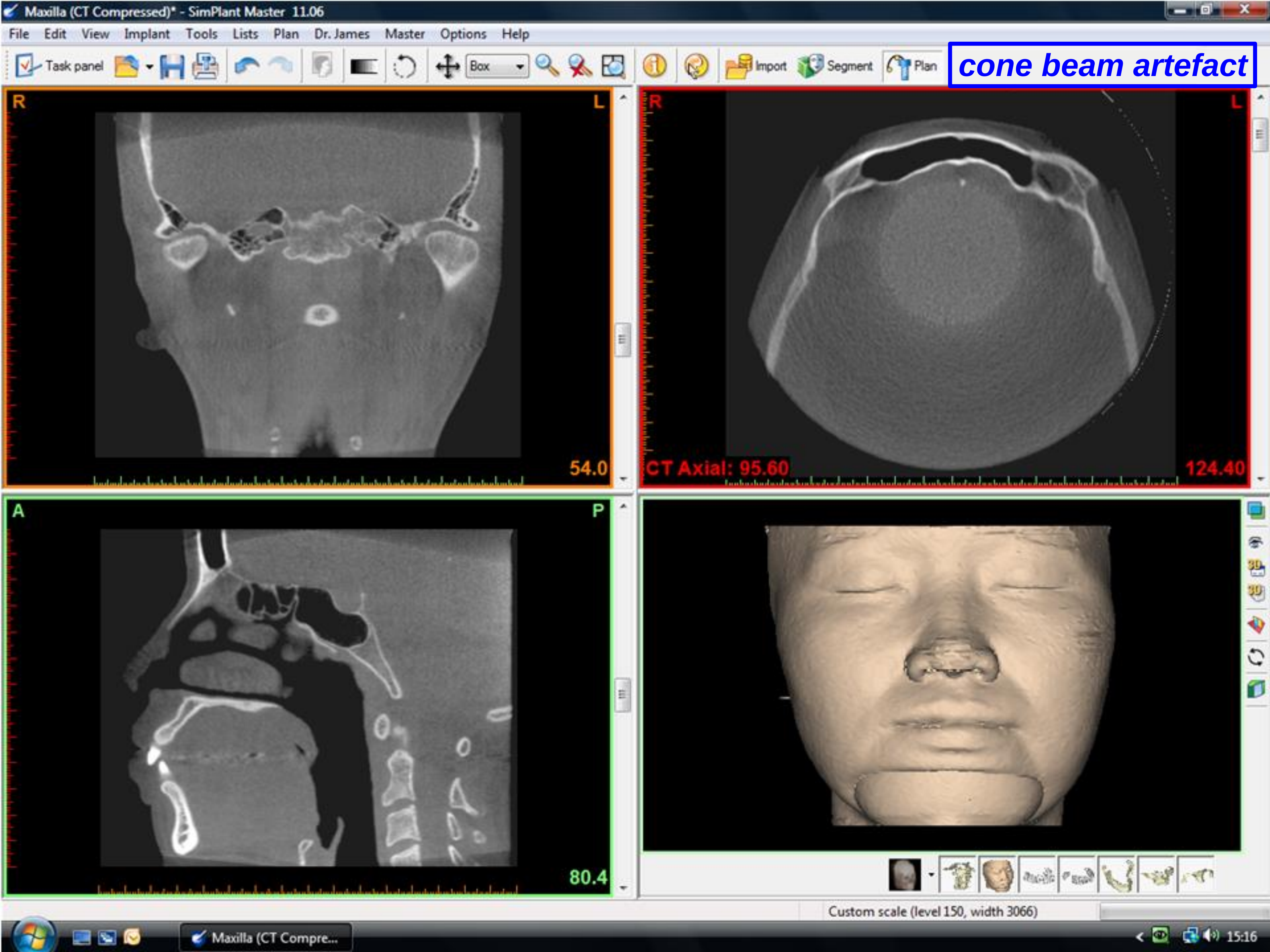
- **Motion artefact**
- **Cone beam artefacts**
- **Ring artefacts**
- **Starburst (streak) artefact**
- **Beam hardening**

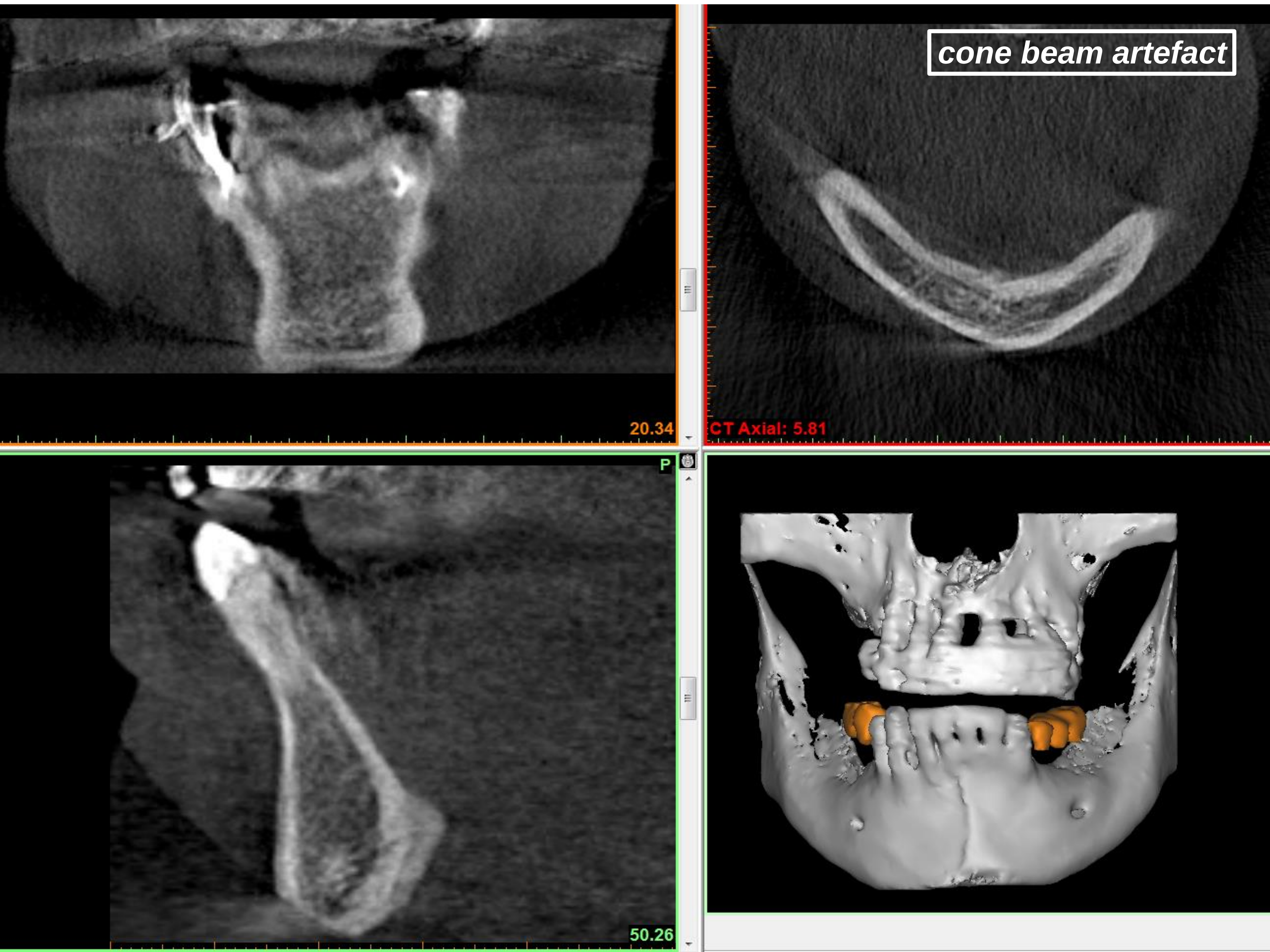
i-CAT *Cone Beam CT Scanner*

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

Motion Artefact




cone beam artefact
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
R
L
54.0
CT Axial: 95.60
124.40
A
P
80.4
Custom scale (level 150, width 3066)
Maxilla (CT Compre...
15:16


cone beam artefact
20.34
CT Axial: 5.81
P
50.26


ring artefact
B
L
74
R
CT Axial: -26.63
R
L

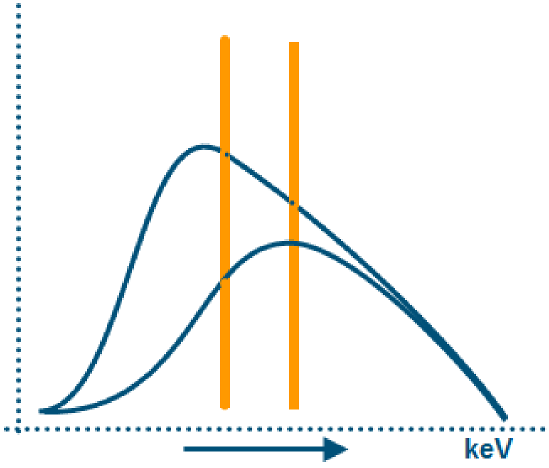
STARBURST ARTEFACT

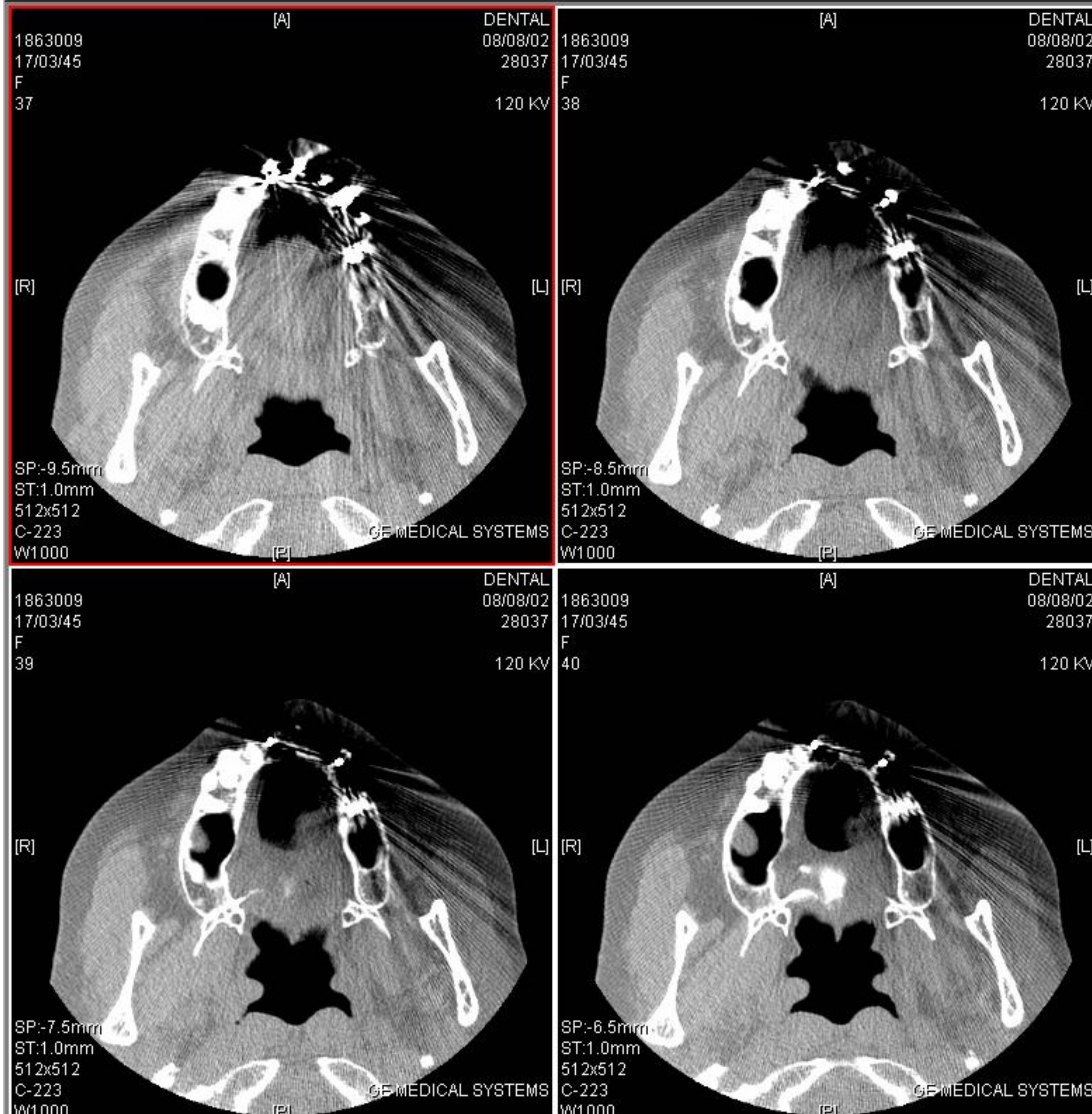
- **Starburst (streak) artefacts arise in CT scans when sharp changes in density are present, e.g. between air and bone or between bone and dense metals**
- **Starburst artefacts are caused by limitations in high frequency sampling**
- **Starburst artefacts are not caused by scattered radiation**

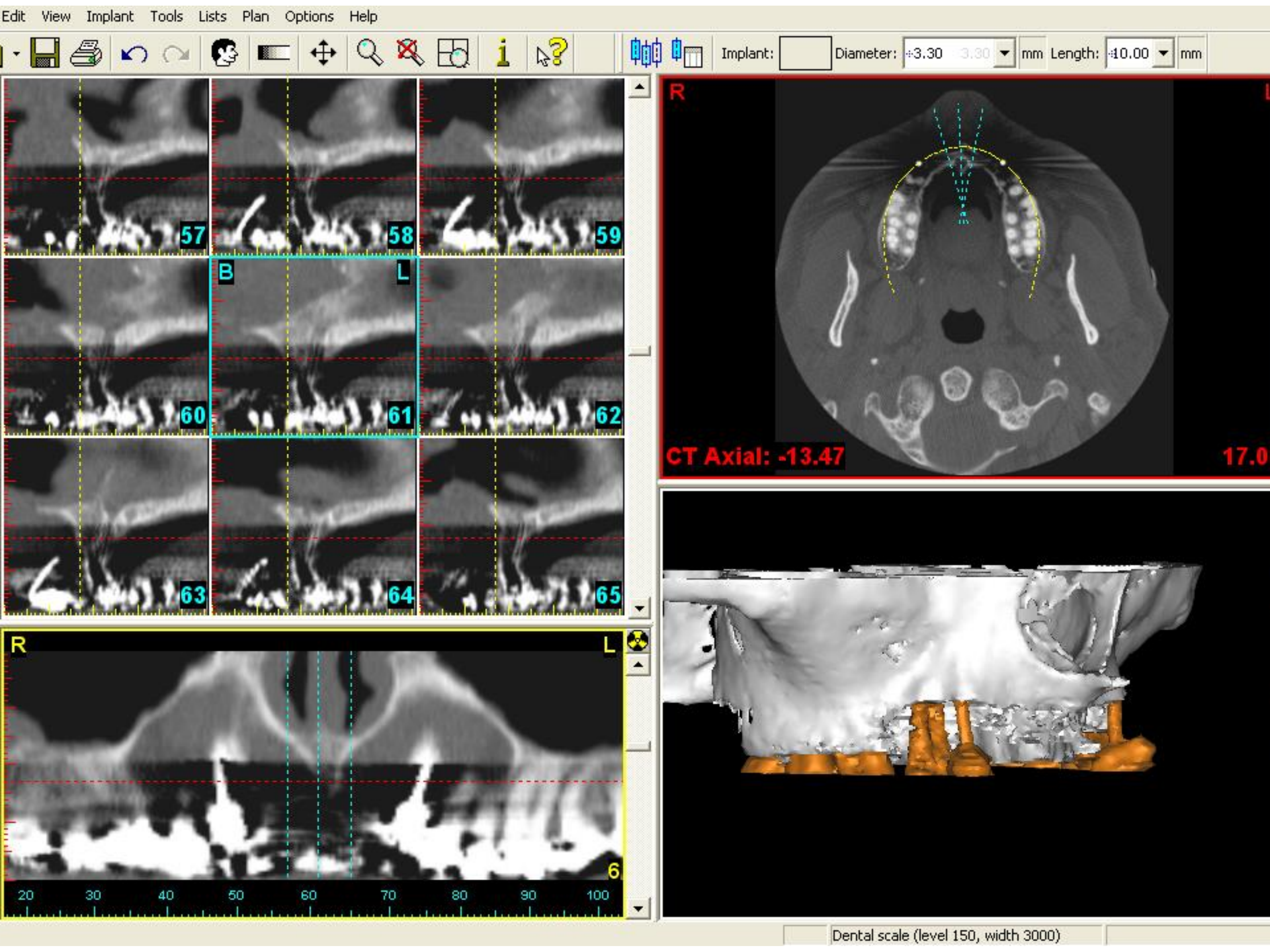

P
11:35:02 4
1.00X
R
L
11:36:29 5
1.00X
R
L
11:37:40 12
R
L
11:38:37 19

BEAM HARDENING ARTEFACT

- **Beam Hardening artefacts also 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**

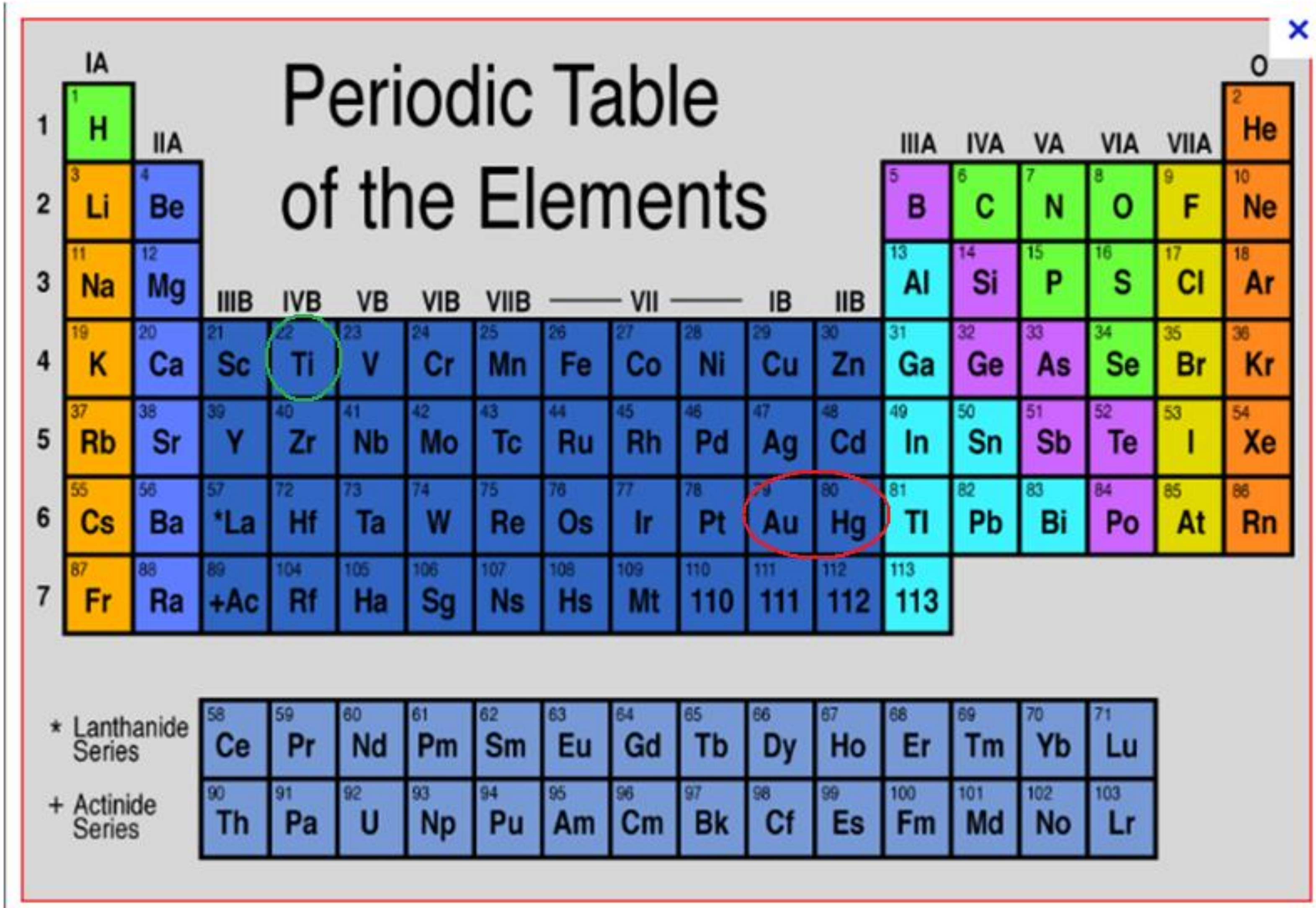



[A]
DENTAL
1863009
08/08/02
17/03/45
28037
F
37
120 KV
[R]
[L]
SP:-9.5mm
ST:1.0mm
512x512
C-223
W1000
GE MEDICAL SYSTEMS
[P]
[A]
DENTAL
1863009
08/08/02
17/03/45
28037
F
38
120 KV
[R]
[L]
SP:-8.5mm
ST:1.0mm
512x512
C-223
W1000
GE MEDICAL SYSTEMS
[P]
[A]
DENTAL
1863009
08/08/02
17/03/45
28037
F
39
120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



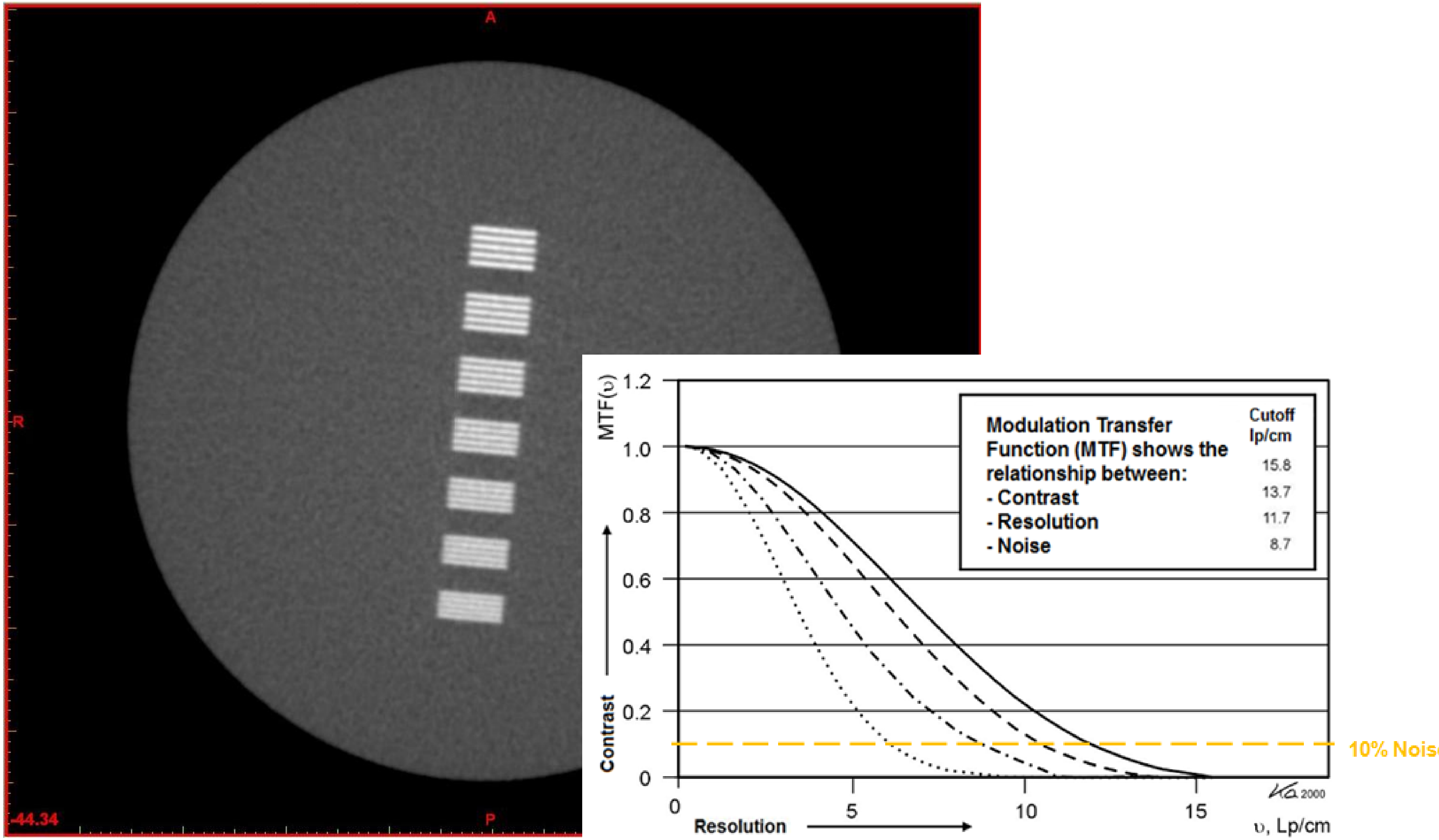
Edit View Implant Tools Lists Plan Options Help
Implant:
Diameter: 3.30
mm
Length: 10.00
mm
57
58
59
B
L
60
61
62
63
64
65
R
L
20 30 40 50 60 70 80 90 100
CT Axial: -13.47
Dental scale (level 150, width 3000)

High-Z materials cause the worst artefacts



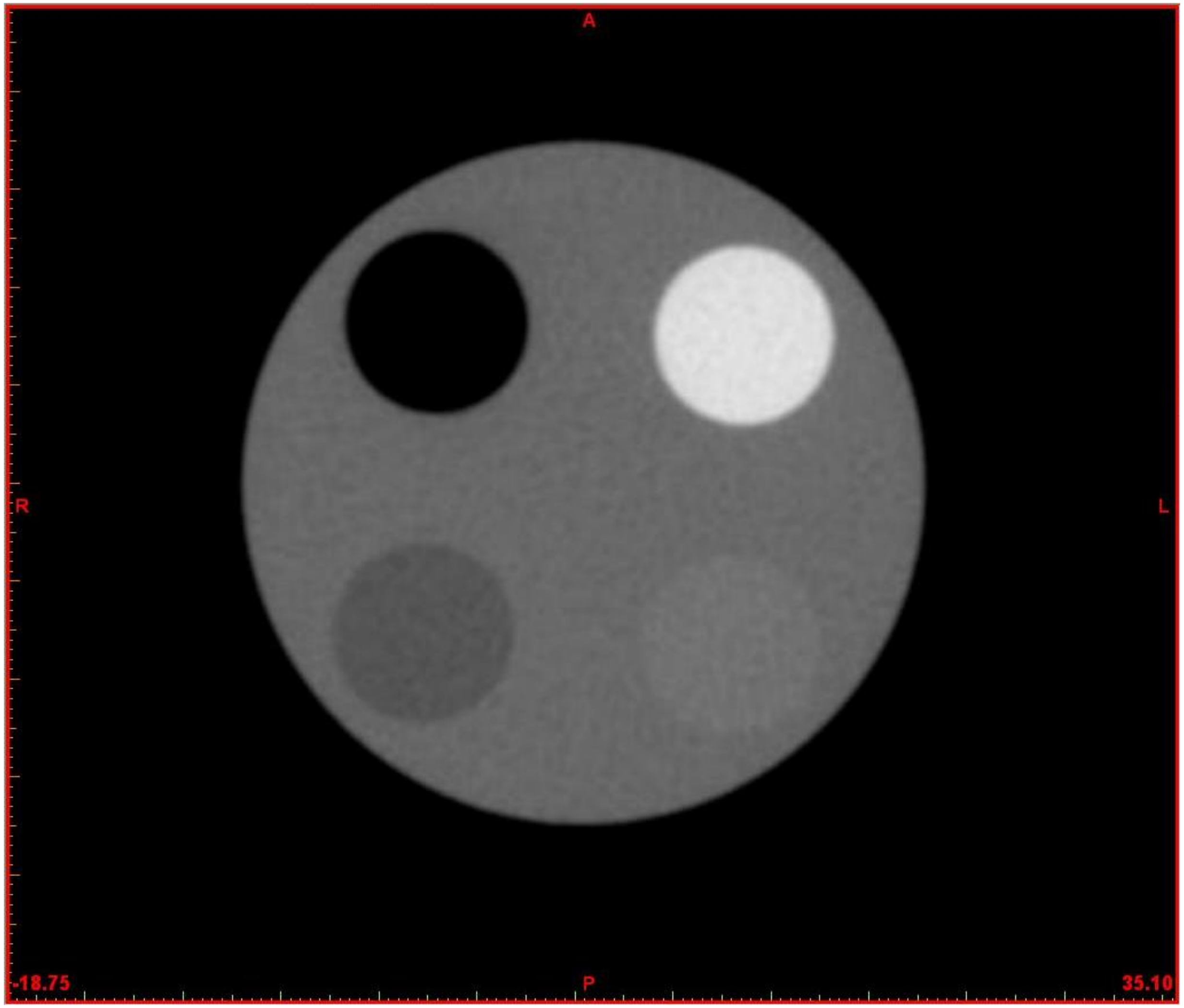
Spatial Resolution

Detail at high contrast



Contrast Resolution

Detail at low contrast



Spatial and Contrast Resolution

Spatial and Contrast Resolution are both important

Comparison of Five Cone Beam Computed Tomography Systems for the Detection of Vertical Root Fractures

Bassam Hassan, BDS, MSc,[*‡] *Maria Elissavet Metska, DDS, MSc,*[†‡] *Ahmet Rifat Ozok, DDS, PhD,*[†] *Paul van der Stelt, DDS, PhD,*[*] *and Paul Rudolf Wesselink, DDS, PhD*[†]

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Abstract

Introduction: This study compared the accuracy of cone beam computed tomography (CBCT) scans made by five different systems in detecting vertical root fractures (VRFs). It also assessed the influence of the presence of root canal filling (RCF), CBCT slice orientation selection, and the type of tooth (premolar/molar) on detection accuracy. **Methods:** Eighty endodontically prepared teeth were divided into four groups and placed in dry mandibles. The teeth in groups Fr-F and Fr-NF were artificially fractured; those in groups control-F and control-NF were not. Groups Fr-F and control-F were root filled. CBCT scans were made using five different commercial CBCT systems. Two observers evaluated images in axial, coronal, and sagittal reconstruction planes. **Results:** There was a significant difference in detection accuracy among the five systems ($p = 0.00001$). The presence of RCF did not influence sensitivity ($p = 0.16$), but it reduced specificity ($p = 0.003$). Axial slices were significantly more accurate than sagittal and coronal slices ($p = 0.0001$) in detecting VRF in all systems. Significantly more VRFs were detected among molars than premolars ($p = 0.0001$). **Conclusions:** RCF presence reduced specificity in all systems ($p = 0.003$) but did not influence accuracy ($p = 0.79$) except in one system ($p = 0.012$). Axial slices were the most accurate in detecting VRFs ($p = 0.0001$). *(J Endod 2010;36:126–129)*

Key Words

Cone beam computed tomography scan, diagnosis, root canal filling, vertical root fracture

From the Departments of *Oral and Maxillofacial Radiology and †Cariology Endodontology Pedodontology, Academic Centre for Dentistry Amsterdam, Amsterdam, The Netherlands
‡Bassam Hassan and Maria Elissavet Metska contributed equally to this manuscript.
Address requests for reprints to Dr Ahmet Rifat Ozok, Department of Cariology Endodontology Pedodontology, Academic Centre for Dentistry Amsterdam (ACTA), Louwesweg 1 1066 EA Amsterdam, The Netherlands. E-mail address: r.ozok@acta.nl.
0099-2399/$0 - see front matter

doi:10.1016/j.joen.2009.09.013

The clinical and radiographic diagnosis of vertical root fractures (VRFs) is often complicated. A local deep pocket, dual sinus tracts, and a halo type of lateral radiolucency are among the symptoms (1–8). Often these symptoms are not convincing to justify tooth extraction, which usually is the elected treatment because the prognosis of VRFs is poor. Therefore, the exact diagnosis of a VRF is crucial to avoid erroneous extraction. However, because of the two-dimensional nature of periapical radiographs (PRs) and the inherent superimposition projection artifacts, visualizing a VRF is difficult, especially when the fracture line is mesiodistally oriented (9). The presence of a VRF is only confirmed by direct visualization (10). This may sometimes be accomplished by means of a surgical diagnostic flap, which is quite invasive.

Cone beam computed tomography (CBCT) scans specifically designed for the maxillofacial region have become largely accessible to clinicians and have replaced conventional computed tomography scans for dentomaxillofacial applications because of their reduced radiation dose and installation and maintenance costs (11–13). Prototype flat-panel CBCT systems were found useful in detecting VRFs (14, 15). Those systems, however, cannot be used to scan patients. Recently, a CBCT system was found more accurate than PR in detecting VRFs in root-filled teeth (16). The superiority of CBCT over PR is primarily because of the high contrast and three-dimensional nature of tomographic imaging, which permits direct visualization of fracture lines otherwise masked in PR.

Several dentomaxillofacial CBCT systems are currently on the market. Those systems differ from each other in detector design, patient scanning settings, and data reconstruction parameters (17–21). Several scanning and reconstruction factors including scan field of view (FoV) selection and voxel size, the number of basis projections (acquisitions) used for reconstruction, and image artifacts have significant influence on image quality in CBCT. CBCT systems vary in their image quality and ability to visualize anatomic structures (22–27). This variation is most prominent with small and delicate anatomic structures such as periodontal ligament and trabecular bone (28). It is, therefore, probable that different CBCT systems vary in their ability to detect VRFs because the fractures are small. The influence of the presence of root canal filling (RCF) on VRF visibility could also vary among the different scanners. Additionally, the selection of the reconstruction plane (axial, sagittal, or coronal) used for the detection or the type of tooth could have an influence on VRF detection. This study aimed to compare the accuracy of five clinical CBCT systems for detecting VRFs in endodontically prepared teeth and to assess the influence of the presence of a RCF, slice orientation selection, and the type of tooth on accuracy for detecting VRF in each system.

Material and Methods

Sample Preparation

We used the method described by Hassan et al (16). Briefly, 40 extracted premolars and 40 molars were inspected on a stereomicroscope (Wild Photomakroscop M400; Wild, Heerbrugg, Switzerland) for the absence of VRFs. Endodontically prepared root canals (size F3, ProTaper; Dentsply Maillefer, Tulsa, OK) were divided into two experimental (Fr-F and Fr-NF) and two control groups (control-F and control-NF). Each group consisted of 10 premolars and 10 molars ($n = 20$). The teeth were decoronated to eliminate a bias of enamel fractures.

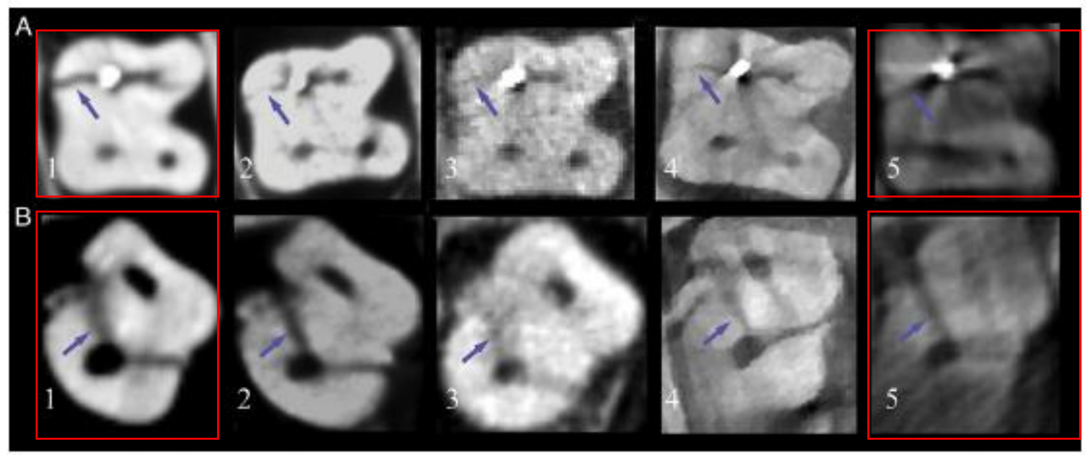

Figure 1. An example of an axial cross-section showing a vertical root fracture line (arrow) in an endodontically filled root (row *A*) and in a nonfilled root (row *B*). CBCT systems from left to right: (1) Next Generation i-CAT, (2) Scanora 3D, (3) NewTom 3G, (4) AccuiTomo MTC-1, and (5) Galileos 3D.

Image 1 has good Spatial Resolution and good Contrast Resolution

Image 5 has poor Spatial Resolution and poor Contrast Resolution

Conclusions

- **If your patient will truly benefit from a CT or CBCT Scan the risks are likely to be minimal or very low compared to the benefits.**

- **A certain amount of Dose is essential for good image quality but Spatial Resolution, Contrast Resolution and freedom from artefacts are important too.**

Thank You!

- **Any Questions?**