Effective Dose from Cone Beam CT Examinations in Dentistry

CT Users Group Meeting 2009

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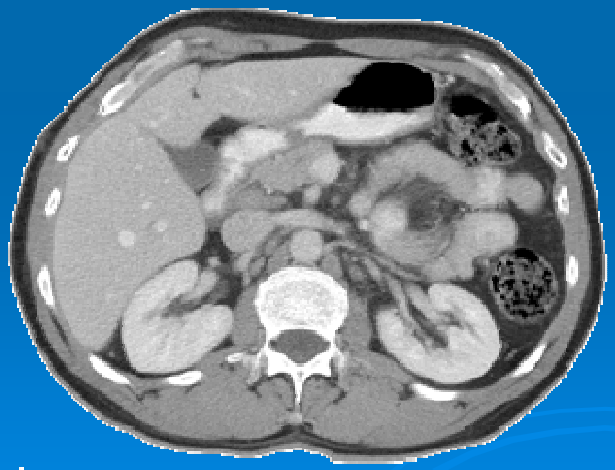
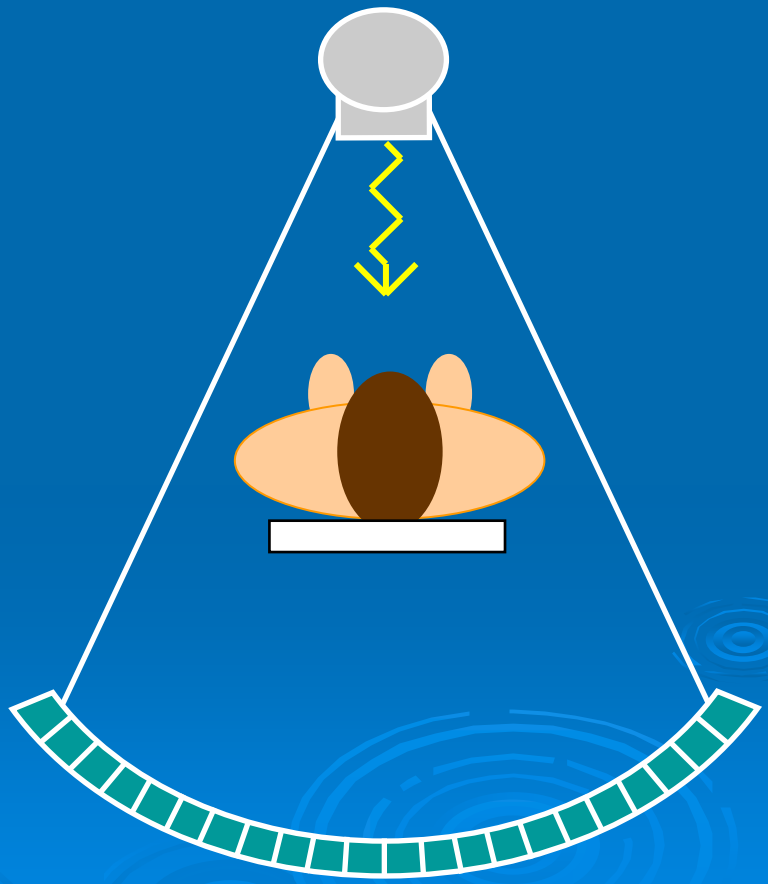
Breakdown

- Computed Tomography (CT)
- Dental CBCT Background
- Project Description
  - Background & Aim
  - Methodology
  - Results
  - Discussion
  - Conclusion

Computed Tomography (CT)

- CT Scanners produce computer generated three-dimensional medical images formed from large numbers of two-dimensional projection images acquired during rotation around a single axis (the patient).





Current CT Scanners

Dental Cone Beam CT

- Cone beam CT (CBCT) images formed from a range of projection images acquired during source/detector rotation around the patient.
- Produces 3-dimensional information on the facial skeleton and teeth.
- Increasingly used in the UK for orthodontics, orthognathic surgery, trauma and implantology.
- Most dental equipment manufacturers now offer CBCT scanners in addition to other specialists.

Study Background

- i-CAT CBCT unit installed at University Dental Hospital Cardiff (UDHC) in 2008.
- Widely reported that "*Effective doses from CBCT examinations are higher than traditional dental radiography but lower than conventional CT*" – This is a wide range!
- To allow clinicians to justify performing CBCT exposures a firmer grasp of the actual effective dose delivered was needed.
- RPS Cardiff were approached by the leading radiologist at UDHC to aid in determining the effective dose from the range of i-CAT protocols that would be adopted.

i-CAT CBCT scanner, Imaging Sciences International

Study Aim

To calculate the effective dose to patients (using latest and previous ICRP tissue weighting factors) undergoing a CBCT examination using the i-CAT scanner for those programs that may be used for all aspects of dental work.

The i-CAT scanner

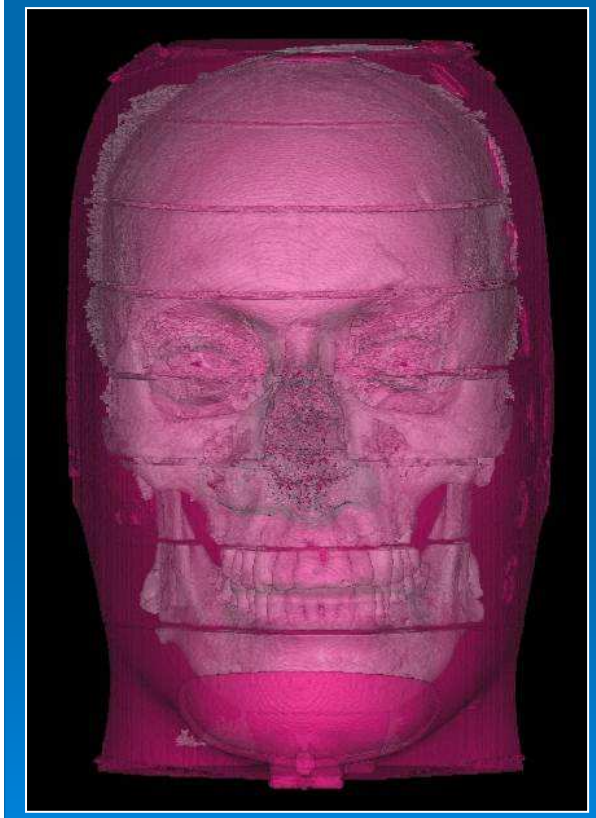
- Manufactured by *Imaging Sciences International*, USA.
- Standard, high-frequency fixed anode X-ray tube.
- 120 kVp, 3–8 mA.
- 6cm mandible, 6cm maxilla, 13cm mandible/maxilla and full FOVs.
- 20 x 25 cm amorphous silicon (a-Si) flat panel detector.
- Tube and generator performance levels well within IPEM91 tolerance levels prior to study.

Study Methodology

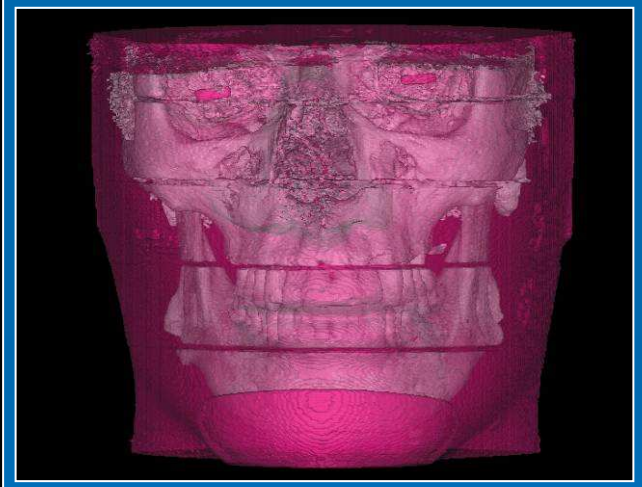
- All dose measurements were performed using TLD-100 (LiF:Mg,Ti) chips calibrated in CT beam conditions and read using a calibrated hot gas reader.
- Three chips were positioned at each of 24 separate locations within the head and neck region of an adult tissue-equivalent Rando phantom.
- The chosen locations represented the most radiosensitive organs in the head and neck region and mirrored those locations identified by *Ludlow et al* [1] .
- The fraction of each organ irradiated during the scans was based on the values determined by *Ludlow et al* for a full FOV scan and modified by the local radiologists for all other scan volumes.

Investigated Scan Volumes

22cm full FOV

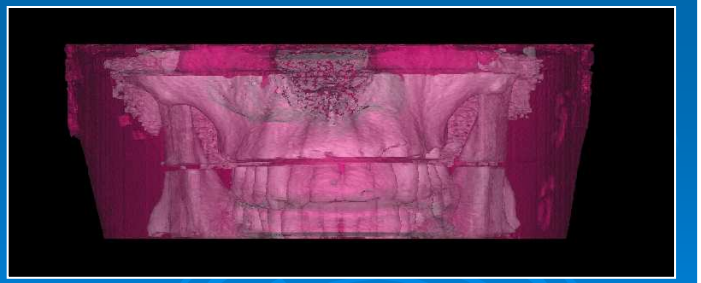


13cm mandible/maxilla



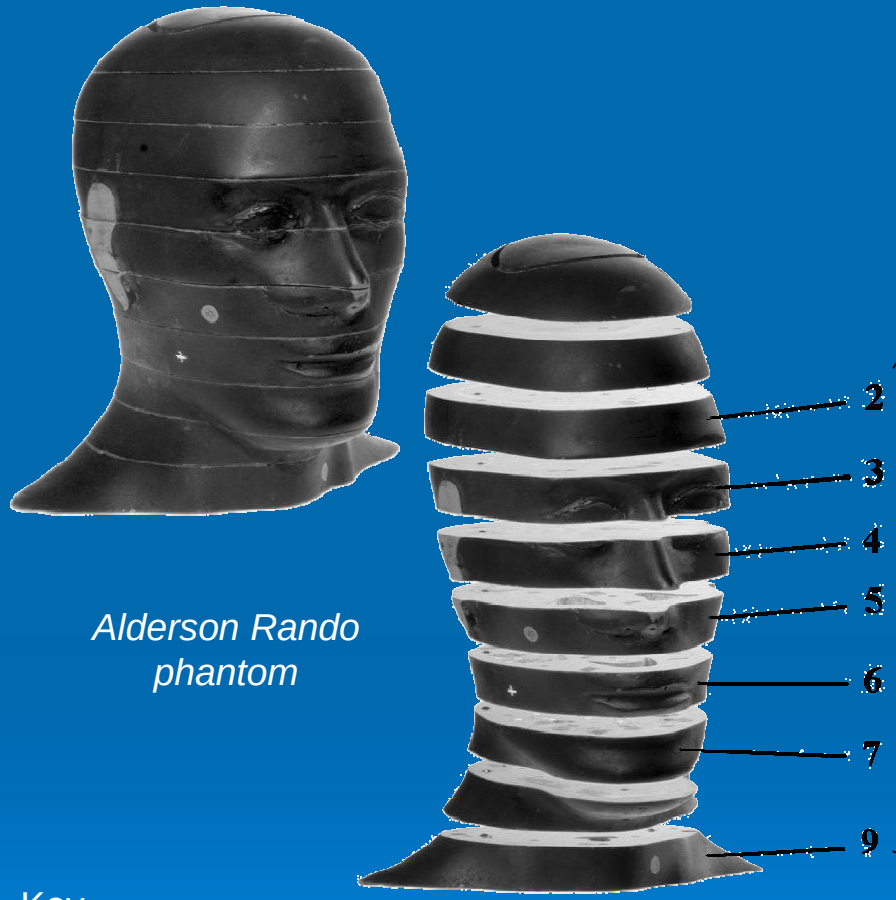
6cm mandible*

6cm maxilla*



* Standard and High Resolution modes

TLD Locations in Rando



Alderson Rando phantom

1 Calvarium anterior
2 Calvarium left
3 Calvarium posterior
4 Mid brain

5 Pituitary
8 Right lens of eye*
9 Left lens of eye*

6 Right orbit
7 Left orbit

10 Right cheek*

11 Right parotid
12 Left parotid
13 Right ramus
14 Left ramus
15 Centre cervical spine

16 Left back of neck*
17 Right mandible body
18 Left mandible body
19 Right submandibular gland
20 Left submandibular gland
21 Centre sublingual gland

22 Midline thyroid
23 Left thyroid surface*
24 Oesophagus

Key
TLD ID Phantom location
* TLD positioned on phantom surface

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Fractions Irradiated and TLDs used for Dose Calculation

	Fraction Irradiated (%)				TLD ID
	*Full FOV**	*6cm Mandible*	*6cm Maxilla*	*13cm Man/Max*	
Bone Marrow	**16.5**	**5.0**	**5.0**	**10.0**	
Mandible	1.3	1.3	0.7	1.3	13,14,17,18
Calvaria	11.8	2.0	2.6	5.3	1,2,3
Cervical Spine	3.4	1.7	1.7	3.4	15
Thyroid	**100.0**	**100.0**	**100.0**	**100.0**	**22,23**
Oesophagus	**10.0**	**10.0**	**7.0**	**10.0**	**24**
Skin	**5.0**	**2.0**	**2.0**	**4.0**	**8,9,10,16**
Bone surface	**16.5**	**5.0**	**5.0**	**10.0**	
Mandible	1.3	1.3	0.7	1.3	13,14,17,18
Calvaria	11.8	2.0	2.6	5.3	1,2,3
Cervical Spine	3.4	1.7	1.7	3.4	15

Continued…

*,Values derived by Ludlow et al; +, Submandibular gland dose used to indicate Oral mucosa dose

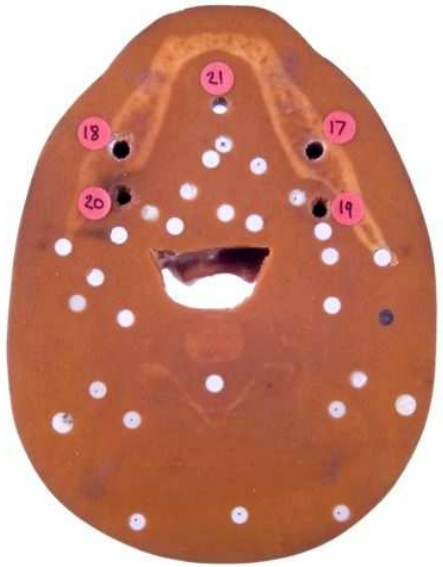
Fractions Irradiated and TLDs used for Dose Calculation

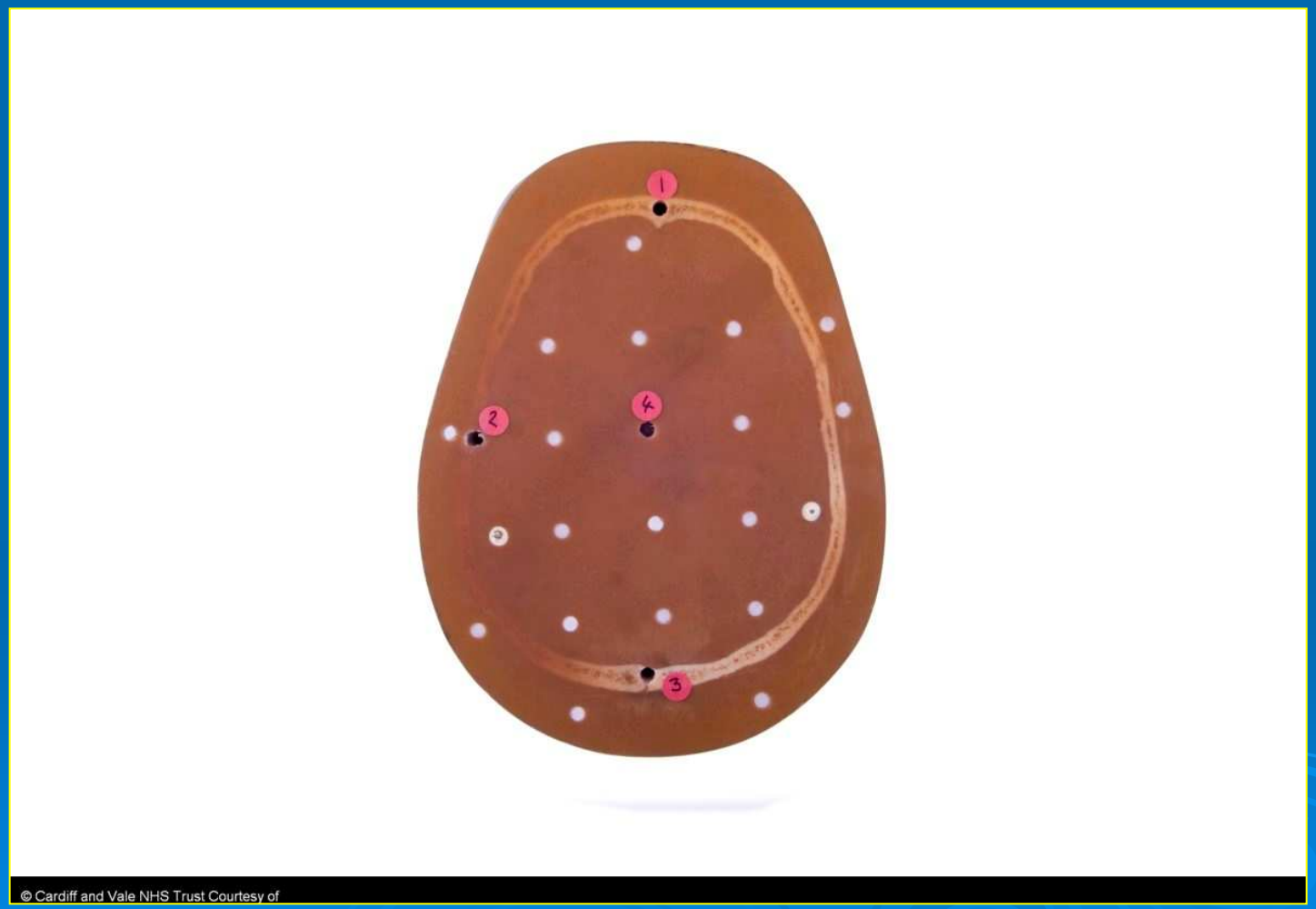
Continued…

	Fraction Irradiated (%)				TLD ID
	*Full FOV**	*6cm Mandible*	*6cm Maxilla*	*13cm Man/Max*	
Salivary Glands	**100.0**	**100.0**	**100.0**	**100.0**	
Parotid	100.0	100.0	100.0	100.0	11,12
Submandibular	100.0	100.0	100.0	100.0	19,20
Sublingual	100.0	100.0	100.0	100.0	21
Brain	**100.0**	**20.0**	**40.0**	**60.0**	**4,5**
Remainder					
Brain	100.0	20.0	40.0	60.0	4,5
Lymphatic Nodes	5.0	5.0	5.0	5.0	11,12,19,20,23
Muscle	5.0	5.0	5.0	5.0	6,7,15,21,24
Extrathoracic tissue	100.0	100.0	100.0	100.0	11,12,19,20,21
Oral Mucosa	100.0	100.0	100.0	100.0	19,20+
Pituitary	**100.0**	**100.0**	**100.0**	**100.0**	**5**
Eyes	**100.0**	**100.0**	**100.0**	**100.0**	**6,7,8,9**

*,Values derived by Ludlow et al; +, Submandibular gland dose used to indicate Oral mucosa dose

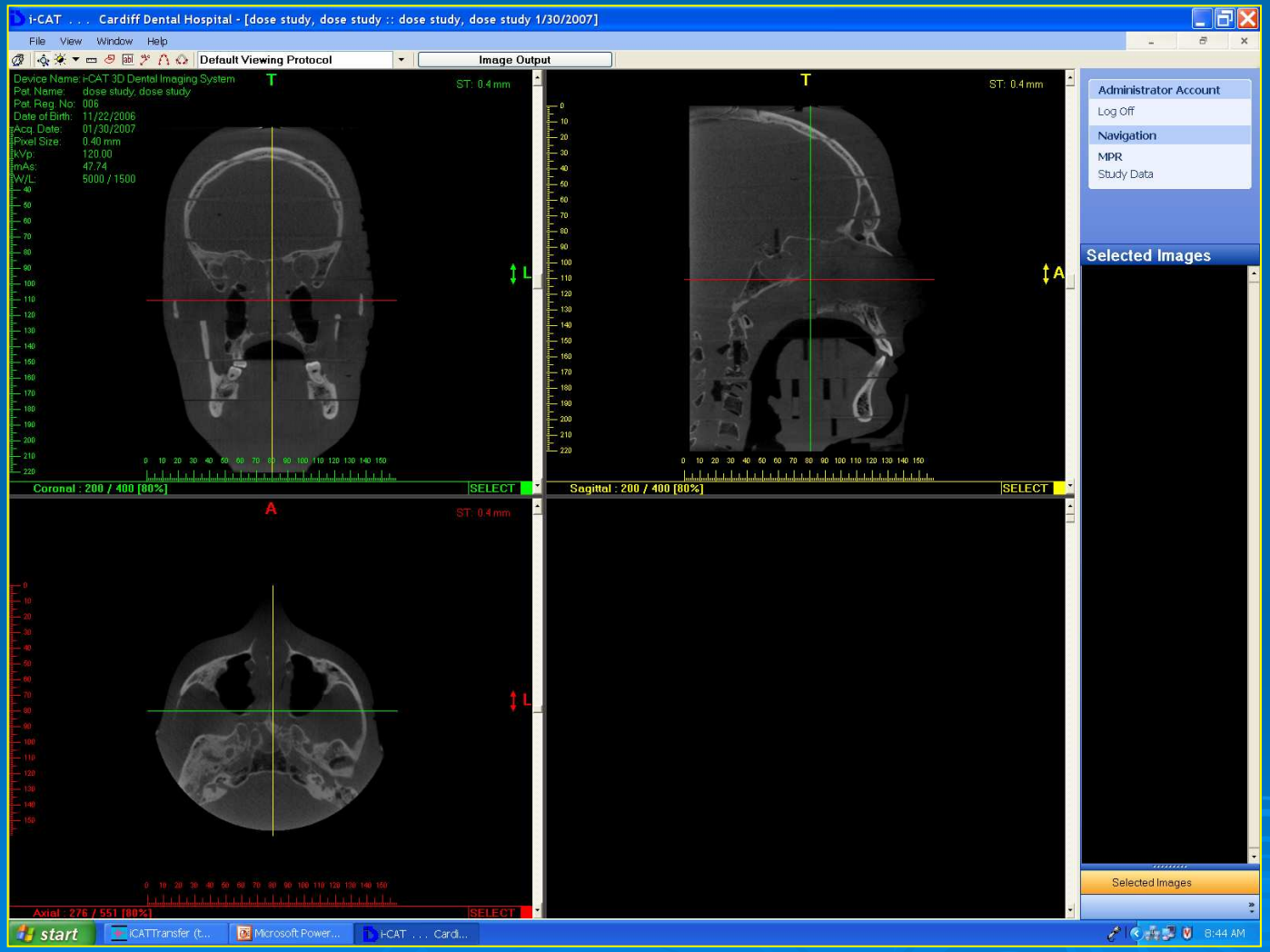
Phantom Preparation





Phantom Setup

Resultant i-CAT Images

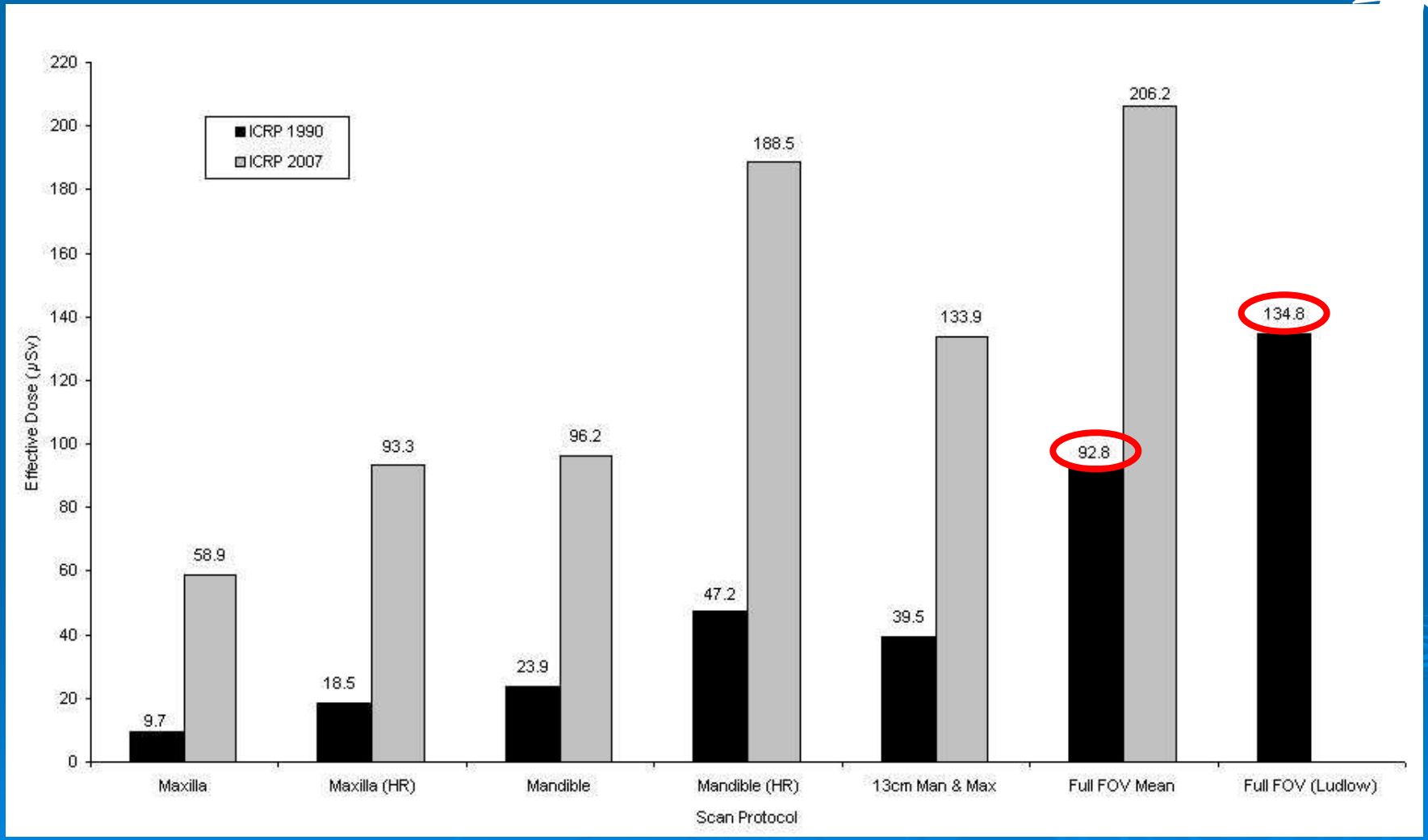


Dose Calculations

- Each scan repeated 10 times to ensure doses recorded well above detection limit.
- Mean site dose calculated between the three chips per scan.
- Radiation weighted dose (H_T) calculated as the product of the background subtracted mean organ TLD dose and the fraction of that organ in the irradiated field.
- Effective dose (μSv) calculated as product of radiation weighted dose (H_T) and relevant ICRP tissue weighting factor (w_T) summed over all of the tissues/organs exposed ($E = \Sigma w_T \times H_T$).

Tissue	*1990 w_T*	*2007 w_T*
Bone Marrow	0.12	0.12
Breast	0.05	0.12
Colon	0.12	0.12
Lung	0.12	0.12
Stomach	0.12	0.12
Bladder	0.05	0.04
Oesophagus	0.05	0.04
Gonads	0.20	0.08
Liver	0.05	0.04
Thyroid	0.05	0.04
Bone Surface	0.01	0.01
Brain	Rem	0.01
Kidneys	Rem	Rem
Salivary Glands	n/a	0.01
Skin	0.01	0.01
Remainder Tissues	0.05	0.12

Effective Dose Results for all Examinations



HR, High Resolution

Comparative Results

Exam Type	Examination	Effective Dose (μSv) [ICRP1990]
i-CAT CBCT	Full FOV	92.8
	6cm Mandible	23.9
	6cm Maxilla	9.7
	6cm Mandible (High Res)	47.2
	6cm Maxilla (High Res)	18.5
	13cm Mandible/Maxilla	39.5
Conventional Dental	Panoramic	~13
	Cephalometry	~3
Conventional CT	CT Head	~2000
	CT Dental (5cm FOV) *(Siemens)*	250 – 300

Discussion

- Reasonably good agreement with Ludlow et al for full FOV examination.
- Marked difference between $ICRP_{1990}$ and $ICRP_{2007}$ effective doses. Indicative of factor changes in head region e.g. salivary glands, brain, oral mucosa etc…
- Doses greater than traditional techniques e.g. panoramic radiography ~13uSv Vs iCAT 13cm Man/Max ~40uSv.
- Doses significantly less than conventional CT head examination (~2000uSv) and specific CT dental protocols.

Conclusion

- Despite calculated doses being an order of magnitude less than a conventional CT head scan it was demonstrated that on average a full FOV CBCT scan delivers significantly greater radiation dose to the patient than traditional dental imaging techniques.

- Important that dental CBCT examinations be fully justified with evidence-based selection criteria produced to aid the clinician.

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Thank You

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Further details available - *Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. Br J Radiol 2009; 82: 35-40.*

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