# Comparison of technical performance between CBCT and low-dose MDCT for oral and maxillofacial radiology

Olerud HM[1], Hol C[2], Landmark ID[1], Friberg EG[1]
Torgersen G[2], Svanaes DB[2], Larheim TA[2]

1. Norwegian Radiation Protection Authority, PO box 55, NO-1332 Østerås, Norway
2. The Department of Maxillofacial Radiology, Institute of Clinical Dentistry, University of Oslo, PO box 1142 Blindern, NO-0317 Oslo, Norway

## The aim of the pilot study

- to do some tests of the Promax 3D unit; to compare the measured DAP values with the figures provided on the operators consol after an examination,
- to compare the effective dose associated to the use of CBCT with other published results and two suggested low dose MDCT protocols at the Department of Maxillofacial Radiology

## Another future aim is

- to identify or develop some quantities or criteria that may be used for evaluation of image quality both in CBCT and MDCT for comparison of the two modalities
- for the latter, only the interpretation of image noise is discussed briefly in this pilot.

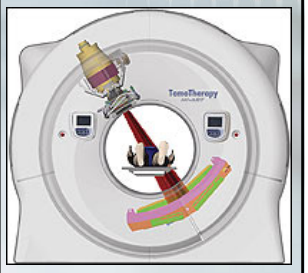
## Computed Tomografi

imaging of transversal slices

**DATA ACQUISITION**
The X-ray tube and the detectors rotates around the patient while the detectors register the transmitted radiation.

**RECONSTRUCTION**
The computer reconstruct transversal slices of the volume of interest and emphasize small differences in X-ray attenuation between different tissues.

**IMAGE VIEWING**
The pixels in the image are assigned grey values depending of the attenuation. The contrast may be manipulated by window settings (WL and WW). Software and tools on work stations provide 3D views, etc

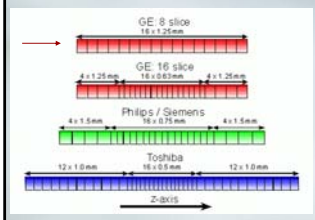



www.medicalimagingmag.com (21.05.2008)

## The multidetector CT (MDCT)

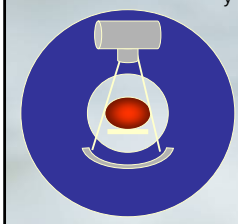
(Lightspeed Ultra, GE, MI)

- A traditional 8-slice MDCT
  - 3.generation fan beam CT
  - data registration during 360° rotations, interpolation, reconstruction, viewing

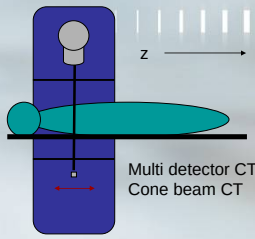



## CT coordinate system

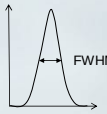
Fan beam




Narrow collimation



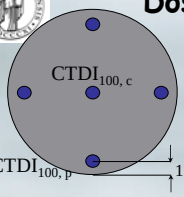

Multi detector CT
Cone beam CT




Periphery to center dose

| | |
|---|---|
| Head (16 cm) | 1:1 |
| Body (32 cm) | 2:1 |

## Dosimetry in CT




$$CTDI_a = C_K = \frac{1}{N \times T}\int_{-\infty}^{+\infty} K_a(z)\,dz$$

ICRU REPORT 74 www.msct.eu

$$CTDI_w = C_{K,PMMA,w} = \frac{1}{3}\cdot C_{K,PMMA,100,c} + \frac{2}{3}\cdot C_{K,PMMA,100,p}$$

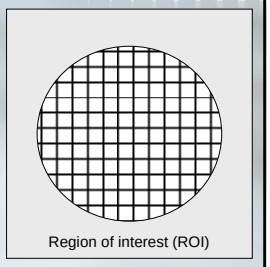
$$\text{CT pitch factor} = \frac{\Delta d}{N \times T}$$

$$CTDI_{vol} = CTDI_w / \text{CT pitch factor} = C_{K,PMMA,w} / \text{CT pitch factor}$$

$$DLP = CTDI_{vol} \times L$$

## The ROI measurement

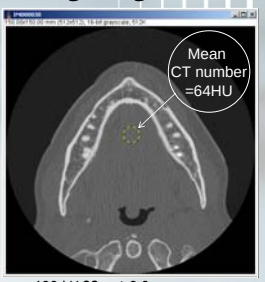
- The graphical tool on the work station allow you to draw a ROI in the image
- You may get the mean value and standard deviation of the pixel values in the ROI
- The pixel values or grey values are the CT-numbers (HU) in CT
- The mean value of the pixels in the ROI represents the characteristics of the tissue in the ROI
  - NB partial volume effect in CT
- The interpretation of the sd is the image noise
  - reversed proportional to the dose and reconstructed slice width




$$\text{CT number} = \frac{\mu_{\text{tissue}} - \mu_{\text{water}}}{\mu_{\text{water}}} \cdot 1000$$

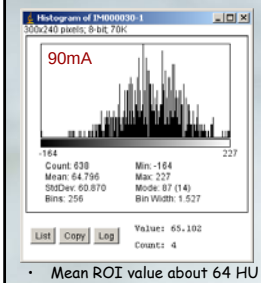
## MDCT – ROI in *musculus genioglossus*

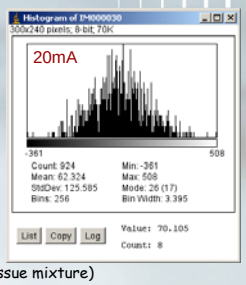
- 120 kV **90 mA** 0.8sec
- 2x0.625mm slice thickness, Axial 2i,
- speed 1.26mm/rot, 1:1




- 120 kV **20 mA** 0.8sec
- 2x0.625mm slice thickness, Axial 2i,
- speed 1.26mm/rot, 1:1

## MDCT – ROI in *musculus genioglossus*



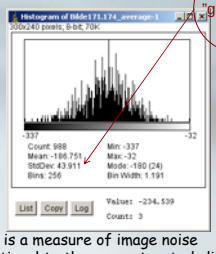

- Mean ROI value about 64 HU (soft tissue mixture)
- As a measure of image noise, sd inverse proportional to the mAs product
- From theory the 20mA image should have sd= 61/sqrt(20/90)=128HU

## The cone beam CT (CBCT)

(Promax 3D, Planmeca OY, Helsinki)

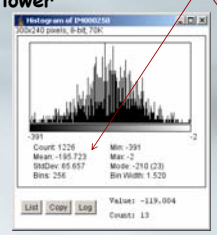
- Based on a traditional Orthopantomogram (OPG) unit
- Beam hight 80mm or 50mm (upper or lower)
- FOV 80mm or 40mm (width)
- The film cassette is exchanged with a digital detector plate, detector resolution is 624x624 pixels
- the voxel size is isotropic; 160x160x160 mm (125M).
- The attenuated radiation is registered during a 180° tube rotation
- Cross sectional slices of the volume of interest are reconstructed by a so called "proprietary Feldkamp based back projection".

## CBCT 84kV, 12mA, 80 FOV, beam height 50 "lower", using the spatial slice averaging to give a slice thickness of 0.61mm (pixel size 160mm)




- We presume that the sd in ROI still is a measure of image noise
- From CT theory sd is inverse proportional to the reconstructed slice thickness
- The sd in the CBCT image ROI was 67. Four CBCT images averaged gave sd=44. From theory it should be sd=67/2=34 in the 0.61mm slice image

## CBCT 84kV, 12mA (6s), 80mm FOV isotropic voxel size; 160x160x160 mm beam height 50mm "lower"




- Is the voxel value/grey value in CBCT defined as the CT number in Hounsfield units?
- The values are different…

$$\text{CT number} = \frac{\mu_{\text{tissue}} - \mu_{\text{water}}}{\mu_{\text{water}}} \cdot 1000$$

## Dosimetric approach

CBCT

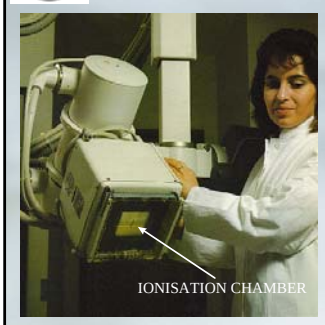
- A DAP meter (PTW, Freiburg) calibrated for the relevant X-ray energies at NRPA's secondary standard laboratory
- Conversion coefficients between dose area product and effective dose were provided from the research community in Linköping, Sweden (0.13mSv/Gycm$^2$)

MDCT

- Excel based CT dosimetry spreadsheet developed by the Impact CT evaluation centre at St. George's Hospital in London
- Based on conversion coefficients provided by Health Protection Agency (HPA) in UK (former NRPB), resulted from Monte Carlo simulations

ICRP 1991 – ICRP2007 effective dose calculation - remainder organs?

## Use of DAP meters



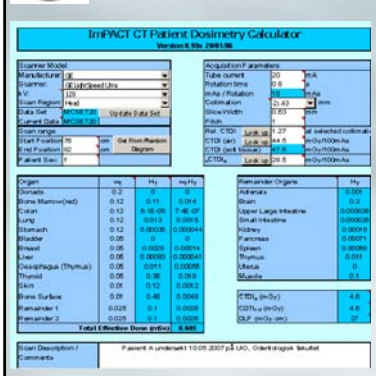

$$KAP = \int_A K_{c,air}\, dA$$

- The dose area product is measured with a transmission ionization chamber positioned at the X-ray tube exit
- Close relation between DAP/KAP, energy imparted and radiation risk
- Published conversion coefficients between KAP and ICRP organ doses from which the effective dose may be calculated

NRPB-R262 (adults)
NRPB-R279 (children)

## CT dose calculator

http://www.impactscan.org/index.htm




Input parameters

- Scanner model
- kV, Head/body
- Scan region
- mA , rotation time
- "collimation"
- Pitch
- CTDI $_{10cm,\ air}$

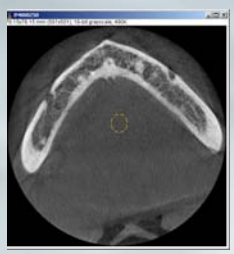
Calculation of

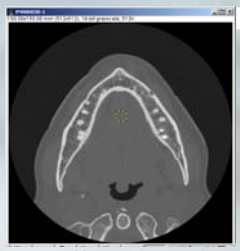
- Organ doses
- $CTDI_w$ – $CTDI_{vol}$
- DLP – effective dose

## Results

| | CBCT | MDCT low dose I | MDCT low dose II |
|---|---|---|---|
| Scan parameters | 84kV, 12mA (6s), 80mm FOV isotropic voxels; 160x160x160µm beam height 50mm "lower" | 120 kV **90 mA** 0.8sec 2x0.625mm slice, Axial 2i, speed 1.26mm/rot 6 cm scan length | 120kV **20mA** 0.8sec 2x0.625mm slice, Axial 2i, speed 1.26mm/rot 6cm scan length |
| Dose figures | DAP=1.536 Gycm$^2$ (0.13mSv/Gycm$^2$) | $CTDI_{vol}$= 20.5 mGy DLP= 123 mGycm | $CTDI_{vol}$= 4.6 mGy DLP= 27 mGycm |
| Effective dose | 0.20mSv | 0.20mSv | 0.045mSv |
| Mean (grey values) | – 198 | 65 HU | 62 HU |
| sd (grey values) | 67 | 61 HU | 126 HU |

## Discussion - further work

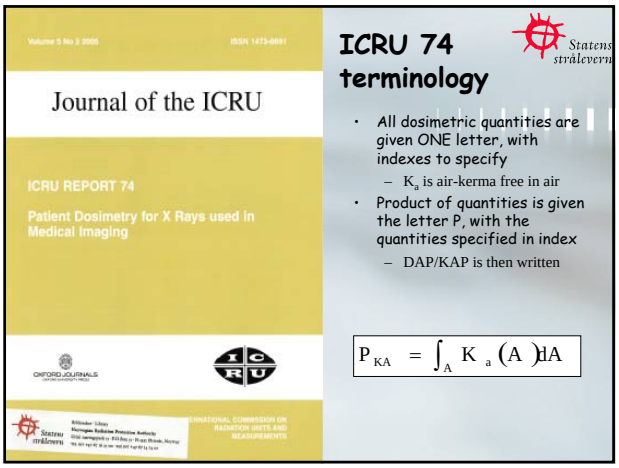




- These two images taken with CBCT and MDCT gave effective doses and noise levels in the same magnitude
- For oral and maxillofacial radiology noise may not be the main issue
- What about spatial resolution? What about visualization and reproduction?
- Comparison based on clinical image quality criteria www.msct.eu

## Concluding remarks'

- The CBCT technology applied in oral/maxillofacial radiology seems to give doses in the range 4 – 50 times higher than a traditional OPG examination, but still significantly lower compared with a MDCT scan
- In oral and maxillofacial radiology it still should be possible to optimize scan protocols to give doses in the same range as CBCT, since there is natural high subject contrast
- Different CBCT's reveals a manufacturer dependent variation in doses of almost a factor of ten, probably due to underlying differences in technology, detector sensitivity, FOV, etc
- Regarding the maxillofacial region of the body, the effective dose values calculated according to the 2007 ICRP recommendations are generally higher compared to what would be the case using the 1990 recommendations. This is probably due to upward revision of the weighting factors for brain and salivary gland, and also the calculation of "remainder" organs
- There are uncertainties in the comparison of effective dose values based on different approaches




## ICRU 74 terminology

- All dosimetric quantities are given ONE letter, with indexes to specify
  - $K_a$ is air-kerma free in air
- Product of quantities is given the letter P, with the quantities specified in index
  - DAP/KAP is then written

$$P_{KA} = \int_A K_a(A)\,dA$$