How CBCT Scanners are being used in practice

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Who or what is IDT?

Image Diagnostic Technology Ltd aka “IDT Scans”

Specialises in:

- arranging dental CT/CBCT scans
- 3D processing
- radiology reports
- implant simulation
- 3D models
- surgical drill guides

25,000 scans processed since 1991

FOV, kVp, mAs, DAP, DLP, Effective Dose stored in database for last 5000 scans
Outline of Presentation

- Introduction / Disclosure
- Analysis of Stored Data
- Interpretation of Results
- Why QA and Training are Important
<table>
<thead>
<tr>
<th></th>
<th>Sirona XG3D</th>
<th>i-CAT 17-19</th>
<th>Gendex CB-500</th>
<th>Carestream 9000 3D</th>
<th>Vatech PaX-Flex3D</th>
<th>NewTom VG</th>
<th>J.Morita Accuitomo 170</th>
<th>Planmeca Promax 3D</th>
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<tbody>
<tr>
<td>Min DAP</td>
<td>157</td>
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<td>63</td>
<td>105</td>
<td>31</td>
<td>497</td>
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Table 1A. Average DAP (mGy.cm²) retrieved from DICOM headers
Dose Length Product (DLP)

DLP = CTDI_{vol} \times \text{Irradiated Length}

Effective Dose = DLP \times F \ (\text{where } F \text{ is a conversion factor})

- most CBCT manufacturers don’t display CTDI_{vol} (exception: J.Morita, NewTom)

- CTDI_{vol} = \text{Effective Dose} \ F \times \text{Irradiated Length}

- Can use CTDI_{vol} to interpolate published data
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**Table 1B. Effective Doses (μSv) interpolated from published data***

*Ludlow JB et al. Effective dose of dental CBCT – a meta analysis of published data and additional data for nine CBCT units. *Dentomaxillofac Radiol* 2015; 44; 20150197*
Interpretation

- Users prefer the higher dose settings
  - Some machines deliver better low dose images than others
  - QA is vital to ensure optimal performance at low dose

- Operator Training is very important
  - Operators do not have a good understanding of practical ways to reduce the radiation dose.
Principles of Radiation Protection

- **Justification**  
  (benefits must outweigh the risks)

- **Optimisation**  
  (keep doses As Low As Reasonably Achievable)  
  Diagnostically Acceptable

- **Dose Limits**  
  (1 mSv per year for members of the public)  
  (no dose limits for medical exposures)
Want to Optimise

Benefit to Patient*
Risk to Patient

* not to the dentist!
What is the Risk from a CBCT scan?

- Assume adult patient, dento-alveolar scan, both jaws
- Effective Dose might be 100 microSieverts
- Risk that patient might develop fatal cancer in 20 years time
  
  \[= 5\% \ (1 \text{ in } 20) \text{ per Sievert (from ICRP103)}\]

  \[= 1 \text{ in } 20 \text{ million for } 1 \text{ microSv}\]

  \[= 100 \text{ in } 20 \text{ million for } 100 \text{ microSv}\]

  \[= 1 \text{ in } 200,000 \text{ (roughly) for } 100 \text{ microSv}\]

Health & Safety people would call this a “Minimal Risk”

* If your patient is a child the risk is 3x more
Practical ways to Reduce the Risk

1. Reduce the Height (vertical collimation)

Reduces the risk without loss of benefit in most cases.

Absorbed Dose outside primary beam is effectively zero
More ways to Reduce the Dose

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

- Reducing the mAs may have a negative impact on image quality

- On some scanners, the voxel size is linked to the mAs
3. Reduce the Width (horizontal collimation)

- Absorbed Dose outside primary beam is not zero (about 50% from SEDENTEX CT measurements)
- There may be some loss of benefit
Basic problem with Small Field Of View

- CBCT measures the density within the Field Of View only
- Material outside the Field Of View has an unpredictable effect
Air should be black
Variation of Effective Dose* with Field Width

Summary of ways to Reduce the Dose

1. Reduce the Height
   - linear reduction in risk, no loss of benefit in most cases

2. Reduce the mAs
   - linear reduction in risk, some loss of benefit

3. Reduce the Width
   - less than linear reduction in risk, more loss of benefit
CBCT State of the Art (circa 2005)

- Pulsed x-ray tube
- Adjustable collimator: 4 to 13 cm height, 9.5 or 16 cm width
- Adjustable chair
- Large detector: 18 cm x 24 cm
- Adjustable collimator: 4 to 13 cm height, 9.5 or 16 cm width
- Around £150K

Fixed mA
- 2 scan times
  - 20s or 40s

Low dose
- Typical Mx: 30 µSv
- Typical Mn: 45 µSv
CBCT State of the Art (circa 2015)

- Variable mA
- Fixed scan times
  - 11s for SFOV
  - 45s for MFOV
- Medium dose
  - Typical Mx 60µSv
  - Typical Mn 100µSv
- Small detector
- No chair
- Fixed collimator
  - 4cm x 6cm SFOV
  - 8cm x 6cm MFOV
- Around £50K

Gendex™ is a trademark of Gendex Dental Systems of Lake Zurich, USA
A Brief History of Dental CBCT

- Technical aspects have not advanced significantly over the last 10 years
- We’ve lost the ability to collimate vertically
- Average doses have not decreased
- Machines have become much less expensive
The Best CBCT Scanner on the Market

Toshiba Aquilion ONE medical CT Scanner

320 detector rows
operates in cone beam mode
0.5s scan time
volume capture
24cm x 16cm max

Effective doses
typical Mx 100μSv
typical Mn 150μSv

Around £1M

Aquilion™ is a trademark of Toshiba Medical Systems Corporation
Dental Protocols on medical CT Scanners

• Operator has more control over kVp, mAs, pitch than on a dental CBCT scanner.

• The dentoalveolar region has high natural contrast, so we can get away with a low radiation dose.

• Training is required to help operators choose a low dose protocol for dental CT scans.
<table>
<thead>
<tr>
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<th>Siemens Definition AS</th>
<th>GE LightSpeed VCT</th>
<th>Siemens Sensation 64</th>
<th>Philips Brilliance 64</th>
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<td>70</td>
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Table 2A. Average DLP (mGy.cm) retrieved from DICOM headers
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<td>70</td>
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Table 2B. Effective Doses (μSv) estimated from DLP*

*conversion factors from Shrimpton PC et al. Effective dose and dose-length product in CT. *Radiology 2009; 250; 604-605.
Why Training is Important

Some Popular Misconceptions:

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

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

3. Even if the Effective Dose is high, it’s just a small region so the risk is low  
   FALSE

4. If I can’t see it in the images I don’t have to report on it  
   TRUE
Rogues Gallery
Moving patient to the side (without reducing the Field Of View) – does it reduce the dose?
Accuitomo F170
14cm x 10cm
0.25mm voxels
DAP 2170 mGy.cm²
DLP 81.8 mGy.cm
Effective Dose
240μSv approx.
Gendex DP-700
4cm x 6cm
0.2mm voxels
132.5 mAs
DLP 58.5 mGy.cm
Effective Dose
230μSv approx.

Gendex DP-700
4cm x 6cm
0.133mm voxels
79 mAs
DLP 35.9 mGy.cm
Effective Dose
150μSv approx.

Gendex DP-700
8cm x 6cm
0.2mm voxels
132.5 mAs
DLP 58.5 mGy.cm
Effective Dose
230μSv approx.
Toshiba Aquilion ONE
12cm x 6cm
0.25mm voxels
DLP 54mGy.cm
Effective Dose 150μSv approx.
IDT27563
i-CAT Classic
9.5cm x 5.4cm
0.25mm voxels
DLP 13mGy.cm
Effective Dose 50μSv approx.
Conclusions

• Effective Doses from Dental CBCT are not as low as they could be.

• QA is important to keep machines running optimally

• Training is important to give Operators a good understanding of how to monitor and reduce the dose.