The SEDENTEXCT project on dental cone beam computed tomography: outcomes and impact

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Cone Beam Computed Tomography

- Conventional imaging
- 3D-volumetric imaging
- Isotropic voxel < mm resolution
- Volume rendering
- Multiplanar reformatting
Issues related to CBCT

• Radiation dose to patient and staff
  ♦ Higher than conventional dental imaging

• Paediatric patients
  ♦ Higher radiosensitivity

• Large variety of CBCT machines and imaging protocols
  ♦ Lack of quality assurance programmes

• Clinical role
  ♦ Lack of referral criteria and justification

• Emerging technology
  ♦ Training
  ♦ Economic evaluation
• European Atomic Energy Community’s Seventh Framework Programme FP7/ 2007-2011
• Safety and Efficacy of a New and Emerging Dental X-ray Modality
• Period covered: 1st January 2008 to 30th June 2011
• Aim: To acquire key information necessary for sound and scientifically based clinical use of dental Cone Beam Computed Tomography (CBCT)
Project Objectives

1. Justification and Guideline Development (WP1)
   • To develop evidence-based guidelines on referral criteria, quality assurance and optimisation

2. Dosimetry (WP2)
   • To determine patient (adult/paediatric) and staff doses

3. Optimisation (WP3)
   • To develop a phantom, software and protocol for quality assurance testing

4. Diagnostic accuracy (WP4)
   • To determine the segmentation, linear and diagnostic accuracy

5. Cost effectiveness (WP5)
   • To analyse the cost-effectiveness in clinical situation, health care contexts and countries

6. Training and valorisation (WP6)
   • To develop a website with resources and training material for professionals with interest in CBCT and general public
Justification and Guideline Development

• Systematic review of the scientific literature, inc. national or specialist guidelines

• Guideline Development Panel
  - Dentists, dental radiologists, medical physicists and an expert on evidence-based dentistry

• Evidence-based guidelines on:
  - Radiation dose and risk
  - Basic principles of CBCT use
  - Justification and referral criteria
  - CBCT equipment factors in the reduction of radiation risk to patients
  - Quality standards and quality assurance
  - Staff protection
  - Economic evaluation
  - Training
  - Appendices (Summary, Recommendation for R&D, Glossary and Abbreviations, Quality Control Manual for Dental CBCT systems)

RADIATION PROTECTION:
CONE BEAM CT FOR DENTAL AND MAXILLOFACIAL RADIOLOGY
Provisional guidelines 2009
(v1.1 May 2009)
Justification and Guideline Development

- EC published the Guidelines in 2012
  - "Radiation Protection No 172; Cone beam CT for Dental and Maxillofacial Radiology- Evidence Based Guidelines"

<table>
<thead>
<tr>
<th>Guideline statement</th>
<th>Grade</th>
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<tbody>
<tr>
<td>Limited volume, high resolution CBCT may be indicated in selected cases of infra-bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management.</td>
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<td>Kilovoltage and mAs should be adjustable on CBCT equipment and must be optimized during use according to the clinical purpose of the examination, ideally by setting protocols with the input of a medical physics expert.</td>
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<td>As a minimum target, no greater than 5% of CBCT examinations should be classified as &quot;unacceptable&quot;. The aim should be to reduce the proportion of unacceptable examinations by 50% in each successive audit cycle.</td>
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Dosimetry

Standardised dose index to characterise dose distribution

• Current CT dose indices are not appropriate to characterise the CBCT dose distributions
  • Asymmetry across the axial plane
  • z-axis dose distribution extends beyond the integration length of CTDI\textsubscript{100}
• Development of dose index phantom and dose indices

http://www.leedstestobjects.com/
Dosimetry

Measurement of dose distribution in anatomical phantoms and effective dose calculation

- Wide dose range (~20 µSv to 400 µSv: 20-fold)
- Thyroid gland, salivary glands, remainder organs
- Field-of-View size & position of isocentre
- Optimised (“customised”) patient dose:
  - FOV selection based on region of interest + exposure selection based on image quality requirement
Dosimetry

Development of mathematical dosimetric models

- Development of computational models
- Calculation of conversion factors to effective dose using Monte Carlo (MC) simulations
- MC simulations are a class of computational algorithms that are based on repeated random sampling to compute the results

Field of view (diameter x height in cm$^2$) and imaging protocol

<table>
<thead>
<tr>
<th>Field of View</th>
<th>Effective Dose Conversion Factors (mSv/mGy)</th>
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<tbody>
<tr>
<td>17x12</td>
<td>0.022</td>
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<tr>
<td>17x5, Mandible</td>
<td>0.015</td>
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<tr>
<td>17x5, Maxilla</td>
<td>0.010</td>
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<tr>
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<td>0.010</td>
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<tr>
<td>10x10</td>
<td>0.005</td>
</tr>
<tr>
<td>8x8</td>
<td>0.005</td>
</tr>
<tr>
<td>6x6</td>
<td>0.005</td>
</tr>
<tr>
<td>4x6 Canine</td>
<td>0.005</td>
</tr>
</tbody>
</table>

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Optimisation

To develop a phantom, software and protocol for quality assurance testing

- Balance of image quality and dose
  - Quality assurance of CBCT machines involves assessment of image quality
  - To design a test tool for image quality assessment
  - To design a quality control protocol

- Phantom consists of a cylindrical PMMA holder (16cm diameter) with a number of inserts for different evaluation purposes

- Software to analyse the images and calculate a number of parameters

http://www.leedstestobjects.com/
Training and valorisation

To develop a website with resources and training material for professional with interest in CBCT and general public

• Need for a CBCT educational programme
• Core curriculum
  ◆ How does CBCT work?
  ◆ Principles of radiation dose and risk
  ◆ Justification: net benefit
  ◆ Referral criteria
  ◆ Radiation dose: optimization for patients and staff
  ◆ Radiation dose: quality assurance
  ◆ Anatomy
  ◆ Interpretation of pathology
• Wiki
• Diagnostic forum/discussion boards
• 10 modules with Powerpoints and voiceover
• Assessment
  ◆ Certificate (Pass>70%) is valid for CPD in UK
Impact and main exploitation results

• Key stakeholder groups:
  ✷ Policy makers, e.g. national and international radiation protection agencies and professional bodies in dentistry and medical physics
  ✷ Researchers in dentistry, medical physics and health economics
  ✷ Practising dentists and medical physicists
  ✷ Manufacturers of cone beam CT equipment
  ✷ The general public

• Basic Principles and Guidelines, Diagnostic Accuracy studies, Health economics → development of national and international guidelines

• Quality Assurance manual and Quality Control phantom → clinical users, manufacturers, medical physicists, researchers

• Dosimetry, dose indices and conversion factors → researchers, clinical users and manufacturers

• Training material and website → all key stakeholder groups
Impact and main exploitation results

- Newsletter (twice-yearly)
- "The State of the Art" SEDENTEXCT Workshop on Dental Cone Beam CT, 31st March 2011, Leeds, UK
- Journal papers: 6 published and 24 in progress
- Conference presentations
- Influencing national and international guidelines
- Commercial dissemination activities (Leeds Test Objects)
Future needs

- Work on dose optimisation of exposure factors
  - *How low can we go?* → *patients, staff, manufacturers and medical physics experts*

- Clinical Image Quality criteria for CBCT, linked with objective measures of image quality → medical physics experts to provide meaningful guidance to clinicians

- Input from epidemiological and radiation biology studies would be of great value to dose optimisation studies
SEDENTEXCT Guidelines
Guidelines on CBCT for Dental and Maxillofacial Radiology
online here

Content

CBCT Info
Learn about the science of CBCT in dentistry

Forums
Discuss CBCT imagery with other site users

CBCT Training
Training and guidance in the use of CBCT

Guidelines
Guidelines outlining the proper use of CBCT in dentistry

The Project
Information on the SEDENTEXCT project

CBCT Publications
This month's publications on dental CBCT

Featured Items
- National Guidance on CBCT
- Leeds Workshop Presentations
- Basic Principles of Cone Beam CT Use
- Project Newsletter *Updated*

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