IN VIVO PATIENT DOSE OF DENTAL CONE BEAM CT

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Introduction

‘Safety and Efficacy of a New and Emerging Dental X-ray Modality’

Cone beam computed tomography (CBCT)

Diagnostic usefulness? Quality assurance?
Radiation doses? Economic aspects?
Introduction

General aim: provide key information necessary for scientifically based use of CBCT in order to develop guidelines

Patient radiation dose (Risk)

Image quality
Image applicability (Benefit)

JUSTIFICATION
OPTIMISATION
PATIENT DOSIMETRY PACKAGE:

- Development of a dose index for CBCT
- Antropomorphic phantom studies for a wide range of CBCT devices and settings (ART, Rando, ATOM)
- In vivo TLD skin dose measurements
- Monte Carlo simulations with focus on paediatric patients
Aims

All dosimetry studies on CBCT were performed with standard anthropomorphic phantoms:

• show wide radiation dose range
• report effective dose

ACTUAL PATIENT RISK?

• to measure entrance skin doses on patients undergoing cone beam CT (CBCT) examinations
• to establish conversion factors between skin and organ doses
• to estimate individual patient risk from CBCT exposures
Methods

- 269 CBCT patients (age 8 - 83)
- 3 devices (SCANORA 3D, 2x NewTom 9000)
- In vivo dose, 8 TLDs (EXTRAD Harshaw, TLD-100)
- Recording of demographic and anatomic data
## Methods

<table>
<thead>
<tr>
<th>Clinical indication</th>
<th>KUL Scanora 3D</th>
<th>VU NewTom 9000</th>
<th>NKUA NewTom 9000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implant placement</td>
<td>43 (13-61)</td>
<td>30 (20-68)</td>
<td>15 (28-62)</td>
</tr>
<tr>
<td>Orthodontic planning</td>
<td>4 (10-13)</td>
<td>0 /</td>
<td>1 (13)</td>
</tr>
<tr>
<td>Impacted teeth</td>
<td>8 (10-20)</td>
<td>43 (10-83)</td>
<td>10 (18-33)</td>
</tr>
<tr>
<td>Maxillofacial trauma/tumors/development abnormalities</td>
<td>1 (20)</td>
<td>29 (11-49)</td>
<td>0 /</td>
</tr>
<tr>
<td>Sinus visualisation</td>
<td>4 (35-60)</td>
<td>42 (22-76)</td>
<td>0 /</td>
</tr>
<tr>
<td>Others</td>
<td>10 (10-54)</td>
<td>0 /</td>
<td>8 (24-62)</td>
</tr>
</tbody>
</table>
Methods

- ART phantom
- ~150 TLDs
- Organ doses
- Effective dose
- 14 CBCT devices

ART phantom study used to convert skin → organ dose

Methods

- ART: pick skin TLDs corresponding to *in vivo* study
- Correlate skin TLDs to organ doses, determine conversion factors
Methods

• Apply conversion factors to patient skin doses:
  - Patient
  - Phantom

Skin dose

Conversion factors

Skin dose

• Calculate individual effective dose
Methods

- Estimate individual risk (cancer incidence) based on BEIR VII report on dose/risk relation

Results: phantom doses

Effective dose for small field CBCTs

- 3D Accuitomo 170 4x4 upper front
- 3D Accuitomo 170 6x6 upper front
- 3D Accuitomo 170 6x6 lower molar
- Kodak 9000 upper front
- Kodak 9000 lower molar
- Pax-Uni 3D front
Results: phantom doses

Effective dose for medium field CBCTs
Results: phantom doses

Effective dose for large field CBCTs

<table>
<thead>
<tr>
<th>Device</th>
<th>Effective dose (µSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Accuitomo 170 17x12</td>
<td></td>
</tr>
<tr>
<td>Galileos 28 mAs</td>
<td></td>
</tr>
<tr>
<td>Galileos 35 mAs</td>
<td></td>
</tr>
<tr>
<td>i-CAT Next Generation 13cm</td>
<td></td>
</tr>
<tr>
<td>Iluma Elite</td>
<td></td>
</tr>
<tr>
<td>Kodak 9500 large field</td>
<td></td>
</tr>
<tr>
<td>Kodak 9500 small field</td>
<td></td>
</tr>
<tr>
<td>NewTom VGi large field</td>
<td></td>
</tr>
<tr>
<td>Scanora 3D extended field</td>
<td></td>
</tr>
<tr>
<td>Skyview</td>
<td></td>
</tr>
</tbody>
</table>
Results: phantom doses

range of effective doses $\sim 15 - 360 \, \mu Sv$
Results: in vivo skin dose

- Similar exposure levels for 3 CBCT devices
- No effect of clinical indication
- SCANORA 3D: ↓ dose to eyes (FOV ↓)
- NewTom 9000 (C1): ↑ dose to thyroid (positioning)
Results: skin dose

- No effect of BMI (incl. after normalisation to mAs)
Results: correlation in vivo skin dose - organ doses estimation (ART phantom)
Results: organ dose estimation

- Conversion factors < ART measurements

<table>
<thead>
<tr>
<th>Skin TLD locations</th>
<th>Number of skin TLD locations</th>
<th>Conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone surface</td>
<td>7</td>
<td>0.080</td>
</tr>
<tr>
<td>Brain</td>
<td>2</td>
<td>0.376</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>3</td>
<td>0.194</td>
</tr>
<tr>
<td>RBM</td>
<td>8</td>
<td>0.075</td>
</tr>
<tr>
<td>Remainder</td>
<td>6</td>
<td>0.173</td>
</tr>
<tr>
<td>Salivary</td>
<td>5</td>
<td>1.073</td>
</tr>
<tr>
<td>Skin</td>
<td>8</td>
<td>0.043</td>
</tr>
<tr>
<td>Thyroid</td>
<td>3</td>
<td>0.352</td>
</tr>
</tbody>
</table>

- ‘Individual effective dose’ < ICRP 103 (2007): range ~ 20-150 µSv
Results: risk estimation

- Estimation of cancer risk vs. dose & age

- Min: ~0.00006% (83 y.o. M) (~1/1700000)
- Max: ~0.003% (11 y.o. F) (~1/3500)
- Avg: ~0.0007% (~1/150000)

- Ratio highest/lowest risk: 50
- Female: risk is factor ~1.5 larger for age distribution of current study population
Discussion

• The variation of the in vivo skin doses in this study arises from the combined effect of exposure and patient factors, the clinical CBCT protocols are patient customized already (FOV selection, exposure selection based on image quality requirement, paediatric protocols), hence no apparent dose dependence on type of investigation.

• There is no distinct correlation between the in vivo skin dose and the BMI, it is however possible that doses to deeper lying organs are affected by the BMI more clearly: limitation of this study: the conversion factors organ/skin dose are based on a standard (adult) phantom but will depend on patient size & anatomy → refine using MC simulation.
Discussion

Effective dose (µSv) for paediatric phantoms

- child
- adolescent

Bar chart showing the effective dose (µSv) for paediatric phantoms, with different imaging procedures and their corresponding dose levels.
Radiation risk: dominated by the age at exposure
- CBCT database: youngest patient 3y5m F, risk x5.4 compared to 30y
- there is no distinction in dose for different clinical indications, but due to the age differences the paediatric indications (impacted teeth, orthodontic planning) show higher risk levels than adult indications (implant planning)

Based on current patient sample and CBCT devices: one cancer incidence for about 150000 patients, e.g. 100 practices open 250 days/year, 6 scans/day: one incidence per year…
BUT: still large uncertainty on dose/risk relation at low exposures
It is pivotal to keep optimising doses esp. for paediatric patients:

• CBCT in dentistry: variety of potential paediatric applications replacing 2D / MSCT (e.g. trauma, orthodontics, cleft palate)

• The actual risk range in dental CBCT practice much ↑ due to wide dose range between/within devices: CBCT devices included can be considered as ‘low to medium dose’: effective doses in literature can be 5x ↓ (FOV) or 10x ↑ (FOV, mAs) for other devices
EC published the SEDENTEXCT guidelines in 2012: “Radiation Protection No 172; Cone beam CT for Dental and Maxillofacial Radiology-Evidence Based Guidelines”
