Dosimetry of Orthodontic Diagnostic FOVs Using Low Dose CBCT protocol

0920

JB Ludlow[a], J Koivisto[b]

[a]University of North Carolina-Chapel Hill, School of Dentistry, Chapel Hill, North Carolina,

[b]University of Helsinki, Department of Physics, Helsinki, Finland

Introduction

Use of ionizing radiation in diagnostic medical examinations has increased over the last 20 years to the point where the annual per capita dose to the US population from all sources has doubled.(1) The risk of this exposure is significant, and it has been estimated that from 1.5% to 2% of all US cancers may be attributed to computed tomography (CT) studies alone.(2) Use of CT scans in children delivering cumulative doses of about 50 mGy might almost triple the risk of leukaemia and doses of about 60 mGy might triple the risk of brain cancer.(3) The range of doses produced by dental CBCT units is large with some examinations approaching doses associated with medical CT imaging. (4) Dosimetry of CBCT examinations for pediatric patients has not been established for many units that are currently used in orthodontic imaging.

Objectives

The purpose of this study was to evaluate doses resulting from various combinations of field size and exposure parameters using child and adult phantoms on a Promax 3D Mid CBCT unit. A second aim was to acquire contrast/noise ratio (CNR) data and modulation transfer function (MTF) data to examine the relationship of these measures of image quality to examination dose.

Effective doses resulting from combinations of field size and exposure parameters that might be used for orthodontic diagnosis tasks were acquired using a Promax 3D Mid CBCT unit (Planmeca Oy, Finland). Specifically doses for a protocol involving reduced exposure and proprietary reconstruction called "ultra low dose" (ULD) was compared with standard exposures. Contrast to noise ratio (CNR) and modulation transfer function (MTF) were calculated as quantitative measures of image quality.

Methods

Doses resulting from various combinations of field size, exposure protocol, and child or adult anthropomorphic phantoms using the Promax 3D MID CBCT unit (Helsinki, Finland) were measured with Optical Stimulated Luminescent (OSL) dosimetry using previously validated protocols. (5-6)

Optical Stiumlated Luminescence dosimeters (OSLDs) (NanoDot, Landauer, Glenwood, IL)

- Placed at 24 locations in 10-year-old child and adult phantoms (CIRS, Norfolk, VA) (figure 1).
- Multiple exposures made for each dosimeter run
- Dosimeters read 3 times with Microstar ii reader (Landauer, Glenwood, IL) – average dose used
- Dose values were adjusted for sensitivity of dosimeters to effective kV of x-ray source
- Doses divided by number of exposures to obtain dose per scan

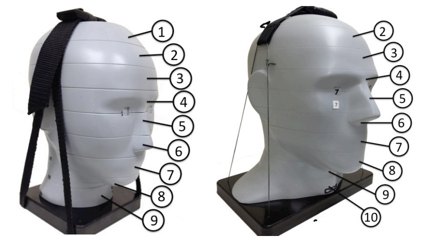

Figure 1. Child (left) and adult (right) dosimetry phantoms

Equivalent dose (H_T) determination

- Doses were determined in the organs and tissues listed in ICRP Report 103 (7)
- Average absorbed dose in each tissue or organ was used to calculate equivalent dose (H_T) $H_T = \sum W_R \times D_T$,

Effective dose (E) determination

- Calculated in µSv as: $E = \sum w_T \times H_T$, where E is the product of the tissue weighting factor (w_T), which represents the relative contribution of that organ or tissue to the overall risk, and the equivalent dose (H_T).

Image Quality Assessment

- QUART DVT phantom and image reader (QUART GmbH, Munich, Germany) - used to measure CNR and MTF.

Analysis

- Standard and ULD image quality parameters were compared in a paired analysis.

Results

Table 1. Dose by phantom type, FOV, and protocol

Protocol	Phantom	volume (ø*h) in mm	Effective Dose in µSv
ULD Low Dose	Adult	100*100	12
ULD Normal			45
Low Dose			60
Normal			189
ULD Low Dose		200*170	18
ULD Normal			51
Low Dose			72
Normal			215
ULD Low Dose	Child	85*85	10
ULD Normal			36
Low Dose			48
Normal			153
ULD Low Dose		200*170	15
ULD Normal			42
Low Dose			74
Normal			175

Figure 2. QUART phantom and analysis software display

Table 2. Image quality differences due to protocol and statistical p value of difference

	mean difference	prob > |t|
CNR	0.408	0.56
MTF 10%	0.038	0.56
MTF 50%	0.055	0.47

Conclusion

While the risk from dentomaxillofacial imaging is small for an individual, when multiplied by the large population of patients who are exposed to diagnostic imaging, radiation risk becomes a significant public health issue. Therefore, strategies to reduce patient dose, keeping doses "as low as reasonably acceptable" (ALARA) are desirable. An average reduction in dose of 77% was achieved using ULD protocols when compared with standard protocols. While this dose reduction was significant, no statistical reduction in image quality between ULD and standard protocols was seen. This would suggest that patient doses can be reduced without loss of diagnostic quality. Further investigation of the diagnostic efficacy of ULD scans in Orthodontic and Orthognathic surgical treatment planning is indicated.

References

1. National Council on Radiation Protection and Measurements. Ionizing Radiation Exposure of the Population of the United States (Report No. 160), Bethesda, MD. 2009, The Council
2. Brenner DJ, Hall EJ. Computed tomography-an increasing source of radiation exposure. N Engl J Med. 2007;357:2277-84
3. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, Howe NL, Ronckers CM, Rajaraman P, W Craft AW, Parker L, Berrington de González A. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet 2012:380:499-505
4. Ludlow JB, Timothy R, Walker C, Hunter R, Benavides E, Samuelson DB, Scheske MJ. Effective Dose of Dental Cone Beam CT - a meta analysis of published data and additional data for 9 CBCT units. Dentomaxillofac Radiol. 2014;44:20140197
5. Ludlow JB, Ivanovic M. Comparative Dosimetry of Dental CBCT Devices and 64 row CT for Oral and Maxillofacial Radiology Oral Surg Oral Med Oral Pathol Oral Radiol Endodont 2008;106:930-938.
6. Ludlow JB, Walker C. Assessment of phantom dosimetry and image quality of i-CAT FLX CBCT. American Journal of Orthodontics & Dentofacial Orthopedics 2013;144:802-17
7. Valentin J. The 2007 Recommendations of the International Commission on Radiological Protection. Publication 103. Ann ICRP 2007; 37: 1- 332

Acknowledements

- This research was supported in part by NIDCR grant 1R21DE022160-01
- C.O.I. An honorarium and travel expenses were received from Planmeca Oy, Finland