

Juvenile Dosimetry of Panoramic and CBCT Imaging for Visualizing Root Resorption

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Abstract

Background: No studies have been done to evaluate radiation exposure to a 10 year old juvenile CIRS phantom using OSL dot dosimetry in conjunction with leaded glasses and thyroid shield, utilizing two and three dimensional imaging for orthodontic purposes.

Methods: A juvenile anthropomorphic phantom corresponding to a 10 year old male was used for all exposures. Panoramic radiographs were taken on a Sirona Orthophos XG machine and CBCT scans were taken on a Carestream Kodak 9000 3D machine. The preset pediatric settings were used and with the CBCT, the field of view selected was to image the anterior maxilla, showing the canines and the surrounding area. The images were performed with and without leaded glasses and thyroid shield. Dosimetry was performed using Optically Stimulated Luminescent (OSL) dosimeters. The effective radiation dose was calculated for the organs of the head and neck. Organ fractions irradiated were determined from ICRP-89. Overall effective doses were calculated in micro-Sieverts for the results and were based on the ICRP-103 tissue weighting factors.

Results: The effective doses measured with the Panoramic images were significantly less when compared to the CBCT scans. The highest organ dose exposures were in the salivary glands, oral mucosa, and extrathoracic airway. The use of leaded glasses and thyroid shield resulted in a dose reduction of 25% with both the Sirona Orthophos XG and the Kodak 9000 3D machines.

Conclusion: This was the first study to evaluate radiation exposure to a 10 year old juvenile CIRS phantom using OSL dot dosimetry in conjunction with leaded glasses and thyroid shield, using two and three dimensional imaging for orthodontic purposes. Restricting field of view to the anterior maxillary region allows CBCT imaging to be used in specific clinical situations when three dimensional assessment of the presence and severity of root resorption is necessary.

Keywords: *Dosimetry; Panoramic; CBCT; Root Resorption*

Background

The permanent maxillary canine is considered to be a principal unit of the dentition. Ectopic eruption and impaction of the permanent maxillary canines represent a significant problem of dental development. The treatment of such poses a unique challenge to orthodontists, since successful management of impacted maxillary canines involves accurate diagnosis of the impaction along with proper timing of intervention [1-7].

Ectopic eruption of maxillary canines can result in serious sequelae to the dentition:

1. Labial or lingual malpositioning of the impacted tooth.
2. Migration of the neighboring teeth and loss of arch length.
3. Internal resorption.
4. Dentigerous cyst formation.
5. External root resorption of the impacted tooth as well as the adjacent teeth.
6. Infection with partial eruption
7. Referred pain.
8. A combination of all of the above.

The radiographic evaluation of impacted maxillary canines and associated root resorption can be determined in two ways. Conventional 2D radiography (intraoral periapical images or panoramic images) or 3D radiography (CT or CBCT). CBCT is an image acquisition technique where a multiplanar image is reconstructed from two dimensional projection views around an object. The CBCT gives three dimensional and multiplanar images from a single rotation. The advantages of CBCT are accessibility, affordability, rapid scan time, field of view, image accuracy, and multiplanar image. The disadvantages are higher radiation dose, artifacts, and limited soft tissue imaging. CBCT previously has been used to image impacted maxillary teeth.

Objectives

To measure and compare the radiation dose exposure to the structures of the head and neck for a pediatric patient using conventional 2D, periapical and panoramic imaging and various 3D CBCT imaging in a dental school clinic setting. Also to evaluate the reduction in radiation dose when leaded eye glasses and thyroid collar were utilized so that preliminary clinical recommendations might be established for orthodontists to use the proper radiographic protocol to accurately detect the presence and severity of root resorption associated with maxillary canine impaction.

Methods and Materials

A pediatric male anthropomorphic phantom (Model 705; Computerized Imaging Reference System, Norfolk, Va.) corresponding to an average 10 year old boy who is 140 cm in height and 32 kg in weight was used for all exposures. Optically stimulated luminescent Nanodot dosimeters (OSLs) were placed at 21 key head and neck organs in the phantom head. All radiographic images were taken in the Radiology Clinic at Stony Brook School of Dental Medicine.

Traditional two-dimensional radiographs (periapical and panoramic) and multiple three-dimensional CBCT scans were obtained for this study. Two dimensional radiographs were taken on a Sirona Orthophos XG, (Sirona, Bensheim, Germany) for panoramic and on a Gendex Expert DC (Gendex Dental Systems, Hatfield, Pennsylvania) for periapical radiographs. The three - dimensional 3D scans were taken on a Carestream Kodak 9000 (Kodak Dental Systems, Carestream Health, Rochester , New York), an i-Cat Platinum (Imaging Sciences International, Hatfield, Pennsylvania) and a Instrumentarium Orthopantomograph OP300 (Instrumentarium Dental, Tuusula, Finland). Table 1 shows all the exposure times, kVp, and mA. For all the scans performed on the five machines, the various preset pediatric scan settings used typically for orthodontic imaging were used. The field of view for the CBCTs was selected to image the anterior maxilla, showing the area of the maxillary canines and its neighboring teeth. The scans were performed with and without the leaded glasses and thyroid collar. A scout image without the dosimeters in place was taken before the CBCT imaging to confirm that the region of interest (anterior maxilla) was within the field of view.

Imaging Unit	Tube Voltage	Ma	Exposure Time	S Fov (cm X cm)
Sirona Orthophos XG	62	8	14.1	X
Gendex DC	70	7	0.063	X
Carestream Kodak 9000 3D	75	8.0	10.8	4 x 4
i-Cat Platinum	120	5.0	26.9	16 x16
Instrumentarium Orthopantomograph OP300 Maxio Standard resolution	90	6.3	2.3	5 x 5
Instrumentarium Orthopantomograph OP300 Maxio High resolution	90	5.0	6.1	5 x 5

Table 1: Imaging Units Used.

The phantom head was exposed three times for each protocol and the exposure to the OSLs were read three times and the results averaged. All dosimeters were calibrated and data analysis was performed using Microsoft Excel (Redmond, Washington). Equivalent doses were calculated using the ICRP 2007 recommendations. Organ equivalent doses and overall effective doses were calculated using values from ICRP-89 and ICRP-103.

Results

The calculated effective doses were lowest for the panoramic radiograph, followed by the periapical series and the CBCT scans (Table 2). The exception was the effective dose of the Instrumentarium at standard resolution with shielding was measured at 34µSv, which was lower than the values found for the periapical series. The highest organ dose exposures were measured in the salivary glands, mandible, oral mucosa and extrathoracic airway (Table 3). Considering thyroid absorbed dose, it was observed that the values were consistently lower for the experimental runs performed with the protective radiation equipment, This was true except for the CBCT scans taken with the Instrumentarium at high resolution (Table 4).

Organ/Tissue	Gendex Export DC		Sirona Orthophos XG		Kodak 9000 3D		i-Cat Platinum		Instrumentarium OP300 Standard resolution		Instrumentarium OP300 High resolution	
	W/S	W/O	W/S	W/O	W/S	W/O	W/S	W/O	W/S	W/O	W/S	W/O
Effective Dose (µSv)	40	40	12	16	45	60	232	174	24	45	106	104

Table 2: Effective Dose For each imaging unit with and without thyroid shield and leaded glasses.

W/S: With Thyroid Shield and Leaded Glasses; W/O: Without Thyroid Shield and Leaded Glasses

ORGAN	Gendex DC		Sirona		Kodak		I-Cat Platinum		Instrumentarium Standard resolution		Instrumentarium High resolution	
Average organ Dose (µGy)	W/S	W/O	W/S	W/O	W/S	W/O	W/S	W/O	W/S	W/O	W/S	W/O
Mandible	365	267	72	98	296	396	2088	1481	287	315	915	887
Salivary Glands	1329	972	261	342	1431	1914	7608	5394	1047	1329	3333	3231
Parotid	443	324	87	114	477	638	2536	1798	349	443	1111	1077
Submandible	443	324	87	114	477	638	2536	1798	349	443	1111	1077
Sublingual	443	324	87	114	477	638	2536	1798	349	443	1111	1077
Remainder												
Extrathoracic Airway	165	160	53	67	198	262	974	745	144	185	460	445
Oral Mucosa	493	324	87	114	477	638	2536	1798	349	443	1111	1077

Table 3: Organ dose in micrograys.

ORGAN	Gendex DC		Sirona		Kodak		I-Cat Platinum		Instrumentarium Standard resolution		Instrumentarium High resolution	
	W/S	W/O	W/SW/O		W/S	W/O	W/S	W/O	W/S	W/O	W/S	W/O
Average organ Dose (μGy)												
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Table 3: Organ dose in micrograys.

Imaging Unit	Thyroid Organ Dose (μGy)	Thyroid Organ Dose (μGy)
	With thyroid shield and Leaded Glasses	Without thyroid shield and Leaded Glasses
Sirona Orthophos XG	54	235
Gendex DC	91	114
i-Cat Platinum	235	305
Kodak 9000 3D	90	143
Instrumentarium OP300 Maxio, Standard Resolution	68	123
Instrumentarium OP300 Maxio, High Resolution	208	190

Table 4: Thyroid dose comparison for all imaging units.

The use of leaded glasses and thyroid collar resulted in a dose reduction for the panoramic radiograph and selective CBCT scans. For the panoramic and Kodak 9000 CBCT machines the reduction was 25% and the reduction for the Instrumentarium was 24.4% (Table 5). There was no dose reduction with the periapical series taken with the Gendex machine and an increase in the dose with the i-cat at high resolution.

Organ/Tissue	Dose Reduction					
	Sirona		Kodak		Instrumentarium	
	W/S	W/O	W/S	W/O	W/S	W/O
Effective Dose (μSv)	12	16	45	60	34	45
Dose Reduction	25%		25%		24.4%	

Table 5: Percentage dose reduction using thyroid shield and leaded glasses.

Discussion

This was the first study to quantitatively measure radiation exposure to a 10 year old CIRS phantom using OSL dot dosimetry in conjunction with leaded glasses and thyroid shield utilizing two and three dimensional imaging for orthodontic purposes of visualizing impact-

ed maxillary canines and associated root resorption. The study mainly sought to measure absorbed organ doses for various radiosensitive tissues and organs of the head and neck. The rationale was to compare various pre-set scanning modes of multiple CBCT machines with each other as well as with conventional digital radiographs. CIRS phantoms are fabricated using materials that are superior in their imaging properties and may more accurately simulate the radiation absorption characteristics of actual organs and tissues compared to the Rando phantom. OSLs are based on a more recent technology for measuring absorbed radiation and recent studies appear to indicate that they have a higher sensitivity in the low radiation range [8]. This study demonstrated that CBCT imaging had higher levels of radiation than conventional two-dimensional radiography. The highest effective dose among the CBCT machines was seen with the i-Cat Platinum. The higher effective dose value seen with the i-Cat in our study may be explained by the positioning of the phantom during exposure, allowing greater radiation directly absorbed by the salivary and mandible, which in turn contributed to the overall higher effective dose.

In general, the highest amount of radiation was seen in the salivary gland tissues, since the salivary glands are centrally located within the imaging field. They are directly exposed to radiation throughout the physical rotation of the CBCT. The highest organ dose was 2,536 μGy seen with the salivary glands when exposed with the i-Cat Platinum machine. This dose is considerably lower than the threshold dose found to induce deterministic effects. 2000mGy is considered by the ICRP to be the threshold for deterministic effects in medical imaging [9].

Conclusions

CBCT imaging exposes patients to higher levels of radiation than conventional two-dimensional digital radiography.

When seeking to radiographically diagnose and evaluate root resorption associated with impacted canines, the orthodontist must weigh the benefits of the selected radiographic modality against the risks to which the patient is exposed.

Following the ALARA principle, restricting the field of view to the anterior maxilla should allow CBCT imaging to be used in certain justified clinical situations when three-dimensional assessment of the presence and severity of root resorption is necessary. A narrow field CBCT with proper pediatric settings and shielding is appropriate.

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