DOSIMETRY OF THREE INTRAORAL IMAGING COLLIMATORS AND TECHNICAL PERFORMANCE USING TWO INTRAORAL DEVICE/COLLIMATOR COMBINATIONS

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ABSTRACT

K. BRANDON JOHNSON: Dosimetry of Three Intraoral Imaging Collimators and Technical Performance using Two Intraoral Device/Collimator Combinations
(Under the direction of SM Mauriello)

Using optical stimulated luminescent dosimetry, FMX effective dose (E) was calculated for 18-projection adult and 12-projection child anthropomorphic phantom examinations using circular and Rinn® (Standard) and Tru-Align™ (Test) rectangular collimators. Technical performance was assessed for rectangular devices using paired FMXs made on DXTTR phantoms by 17 senior dental hygiene students. Image errors, time/motion effort, and collimator preference were evaluated. Adult FMX E was 95µSv circular, 76µSv Test, 60µSv Standard (p=0.001). Child doses were 80µSv circular, 70µSv Test, 48µSv Standard. Child thyroid-shielding produced significant reductions in effective dose for Standard (p=0.004). A lower mean number of errors occurred with the Test compared to the Standard (p=0.048); however, major errors requiring retakes were not statistically different for the two systems. Subjects preferred the Test device which produced FMXs in less time. The Test device produced diagnostically acceptable radiographs more efficiently with fewer cone-centering errors, but at the expense of patient dose.

ACKNOWLEDGEMENTS

I would like to sincerely express my gratitude for the direction provided to me under the expertise of my thesis committee members, Dr. Sally Mauriello, Dr. John Ludlow and Dr. Enrique Platin.

DEDICATION

I dedicate my thesis work to my loving mother, Dr. Karen Bremer, who has provided endless encouragement and support for all of my endeavors.

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LIST OF ABBREVIATIONS AND SYMBOLS

ADA – American Dental Association

BWX – Bitewing projection

CC – Cone Centering

CIRS ATOM Max – Computerized Imaging Reference Systems, Inc. Diagnostic Head Phantom

DXTTR – Dental X-ray Technique Training Replica

E – Effective Dose

FMX – Full Mouth Series

Adult: (18 intraoral projections=14 periapicals and 4 bitewings)

Child: (12: intraoral projections = 10 periapicals and 2 bitewings)

H- Horizontal Angulation

ICRP – International Commission on Radiation Protection

IDI – Interactive Diagnostic Imaging

kVcp – Kilovoltage Constant Potential

mA – milliAmperage

NCRP – National Commission on Radiation Protection

OSLD – Optically Stimulated Luminescent Dosimeter

P – Packet (sensor/receptor) placement

PA – Periapical Projection

PID – Position Indication Device

PSP – Photostimulable Phosphor

RINN – American dental equipment manufacturer

SCED – Source-to-end-distance from the focal spot to the terminal end of the collimator

TEPR – Training Electronic Patient Record

V – Vertical Angulation

XCP – Extension Cone Paralleling (Instrument)

µ - micro

µGy – micrograys

µSv – microsieverts

CHAPTER I

INTRODUCTION

The detrimental effects of ionizing radiation on human tissues to patients and operators have been studied extensively. As a result, dentistry has made strides to minimize patient dose through the use of faster receptors, protective patient shielding, digital imaging, collimation of the x-ray beam and beam alignment devices.[1-3] Collimators that have been designed to mimic the shape and size of the receptor have demonstrated a lower effective dose to the patient but have been blamed to result in a higher number of image quality errors[4-6].

Producing diagnostic images and reducing the dose to the patient are primary goals for the dental radiographer.[1-5] The IDI Tru-align™ system is a radiologic collimation device that is reported to produce better quality images, increase safety to patients and save time during exposures.[7] In addition, time efficiency for exposing intraoral images is reported to be improved due to its laser guided and magnetic positioning and alignment system. This enhanced device composed of a magnetic alignment ring and a positioning-indicator laser beam with a visual light and audible signal was designed to eliminate technical errors (cone cuts) and retakes. Other beam alignment devices on the market do not provide these enhancement features. The authors of a previous study (2011) recommended modifications to optimize the diagnostic quality of the image.[6] Modifications were made to the device based on these findings to improve image characteristics and device adaptability.[8] No studies have evaluated effective dose or technical performance of the device since it was modified.

Therefore, the purpose of this study was to evaluate the Tru-align™ system when comparing the device to a universal rectangular collimator insert. Our goal was to determine and compare the efficacy of dose reduction using three different intraoral collimators and to compare the technical accuracy and time efficiency between two rectangular collimator devices. Specific research objectives were:

1. To measure effective dose (E) using adult and child phantoms with circular, rectangular, and enhanced intraoral rectangular collimators
2. To assess the efficiency of dose reduction with the addition of thyroid shielding of the child phantom for the three collimators.
3. To compare the number and type of technical errors between the two rectangular collimators.
4. To compare the diagnostic acceptability of the two rectangular collimators.
5. To compare the time efficiency and user acceptability of the two collimator devices.

CHAPTER II

REVIEW OF LITERATURE

In 2007, the International Commission on Radiation Protection (ICRP) updated their previous 1990 recommendations on radiation protection, revising the calculation of effective dose and estimation of risk of cancer for tissues in the maxillofacial area.[1, 4] The National Commission on Radiation Protection (NCRP) has emphasized that dental professionals make every attempt to lower the radiation exposure to staff and patients as they have a professional, moral, and legal obligation to keep radiation exposure to patients and staff as low as reasonably achievable. Multiple techniques are available for reducing radiation exposure to patients. Among these techniques are the availability of faster receptors, digital imaging, leaded aprons, thyroid collars, beam alignment devices, longer source to receptor distances and collimation of the of the x-ray beam.[1,3,5] Restriction of the primary beam by collimation has shown to be one of the simplest and most effective ways to reduce patient exposure from intraoral x-ray projections.[1, 6]

Two shapes of open ended collimators are available for intraoral radiography: circular and rectangular.[1-3,5,6,9-11] Rectangular collimation has been proven effective in reducing radiation received by the patient when compared to round collimation. The incident beam and irradiated region on the patient's face corresponds more to the size and shape of the rectangular image receptor. Collimation by definition restricts and shapes the x-ray beam, limiting the amount of both primary and scatter radiation to which the patient is exposed.[3] While dose reduction is a primary concern in dental radiography, rectangular collimation is not as widely used as circular collimation.[1, 9] This may be

attributed to the increased chance of image errors due to the more restricted x-ray beam. Elevated margin for error results in increased amounts of technical errors such as cone cuts, horizontal and vertical alignment errors, and ultimately the necessity for retakes.[5,9,10] Regardless of collimation, inability to produce a quality diagnostic and error free image may lead to increased patient exposure due to retakes.[9] It is arguable that too many retakes may defeat the purpose of reduced radiation from rectangular collimation. [4-6, 9] However, with today's medical technology and innovation, using round collimation with its larger beam area is an easy but ethically questionable way to solve the problem of retakes as it has been shown to expose patients to more than four times the amount of radiation as compared to rectangular collimation.[1, 2]

The ADA, ICRP, and NCRP strongly recommend the use of rectangular collimation with intraoral imaging.[1-6] A current guideline established by the NCRP states that the x-ray beam should not exceed the minimum coverage necessary, and each dimension of the beam should be collimated so that the beam does not exceed the receptor by more than 2 percent of the source-to-image receptor distance. Radiographic equipment is either manufactured to incorporate rectangular collimation or universal adapters are available to retrofit existing circularly collimated equipment.[5, 11] Continuing concern about long-term and cumulative risks of cancer development from low doses of ionizing radiation has increased interest in the implementation of rectangular collimation.[1]

The evolution of faster speed films and subsequently the introduction of digital radiography continues to lower the amount of radiation necessary to expose diagnostic images.[1] While these technologies convert x-rays into images more efficiently than slower film technology, they have had to overcome concerns that reduced exposure may result in reduced diagnostic quality. Rectangular collimation functions by reducing the area of exposure and does not require any alteration of exposure factors or image receptors. However concerns have been voiced regarding the increased risk of missing anatomy of interest through cone cuts due to beam aiming errors.[5, 6, 9, 10]

Innovative positioning devices aim to reduce some of the chances of cone-cutting and technical errors of the resulting images. In the 1960's DENTSPLY/RINN® introduced XCP®

instruments designed for use with the paralleling technique to reduce retakes and improve diagnostic acceptability of intraoral images. The RINN XCP® intraoral beam indicating device has become a standard for acquiring intraoral images using the paralleling technique and can be used with rectangular collimation.[10] The Tru-Align™ manufactured by Interactive Diagnostic Imaging, facilitates operator alignment of the x-ray beam with XCP® type receptor holders and claims to make the task of taking quality radiographs with a rectangular collimator nearly flawless.[7]

This intraoral rectangular collimator device composed of a magnetic alignment ring and a positioning-indicator laser beam with a visual light and audible signal was designed to eliminate technical errors (cone cuts) and retakes[7]. The test device incorporates a rectangular collimator shape and a housing that will retrofit over most existing X-ray round cones. Attached to the end of the rectangular opening is a magnetized ring that locks on to the holder when it is aligned properly. When the beam is perfectly aligned with the acquisition device, the unit beeps and/or a light flashes indicating perfect alignment. The device can be used with film, digital sensors, or phosphor plates, and works with most standard film/sensor holders.[5, 6, 7]

Even though rectangular collimation substantially reduces radiation exposure to the patient and can create better quality images, the increased prevalence of cone cuts has caused dentists to shy away from its implementation.[1,5, 9] Many dental schools include rectangular collimation in their student teaching and training courses. Even with training, cone cutting with subsequent loss of diagnostic information and need for retakes continues to be a major issue.[9] While limited scientific literature exists, two studies have evaluated the Tru-Align™ device, measuring dosimetry, technical accuracy and time efficiency.[5, 6] Based on early studies of the device, modifications were suggested and incorporated in the design and the device was remarketed. No studies as yet have evaluated the effect of design changes on examination dose or technical error rate.[4, 5, 8]

CHAPTER III

METHODS

This study was designed to compare circular and two rectangular collimator devices that are currently being used in dental radiographic practice. When exposing radiographs, it is important to produce a diagnostic image while keeping the dose as low as reasonably achievable (ALARA). Therefore the design of this study included a dosimetry component and a technical component.

A. Methods for Dosimetry Component

1. X-ray Equipment and Collimation Devices

Dose associated with three collimator modalities was measured. A 6 cm diameter circular collimator with a 30 cm source-to-end distance was utilized for circular techniques (Figure 3.1). The RINN® universal rectangular collimator insert (RINN® Corp, Elgin, IL) hereafter referred to as "Standard" was fitted over the circular collimator end resulting in a 33 cm source-to-end distance (Figure 3.2). The IDI Tru-Align™ (Interactive Diagnostic Imaging, LLC) intraoral rectangular collimating device, hereafter referred to as "Test", was fitted on the opening of the tube head producing a 30 cm source-to-end distance (Figure 3.3). All exposures were made using the same Planmeca Prostyle Intraoral unit (Planmeca USA, Roselle, IL) with the following exposure factors, 70 kVp, 8 mA (adult: .20 & .32; child: .16 & .25) The matrix for this study is found in Table 3.1.

2. Phantoms

Adult dosimetry was acquired using an average adult tissue-equivalent phantom (ATOMmax Model 711HN – CIRS Inc., Norfolk, VA) (Figure 3.4). The phantom was sectioned in 25 mm thick axially oriented slices which permitted access to specific tissues and anatomical locations of interest. Slices were modified to accept nanodot dosimeters at these internal and external sites (Appendix A). During the imaging process, the phantom was oriented so that the section planes were approximately parallel to the floor. Dosimeters were positioned at 24 anatomical locations corresponding to tissues of interest seen in Appendix B.

Child dosimetry was acquired using a tissue equivalent phantom simulating the anatomy of a 10-year old child (Model 706 HN, CIRS Inc., Norfolk, VA) seen in Figure 3.5. The child phantom was divided into 25 mm thick axially oriented layers and dosimeters were positioned at 24 anatomical locations corresponding to tissues of interest (Appendix B).

3. Dosimeters and Reader

Dosimetry was recorded using optically stimulated luminescence (OSL) dosimeters (Figure 3.6). Optically stimulated luminescent dosimeters (Nanodot, Landauer, Inc., Glenwood, IL) respond to ionizing radiation by storing energy proportional to the amount of x-ray energy in the exposure. Each dosimeter is encased in a light-tight plastic holder measuring approximately 1 mm x 10 mm x 10 mm. This case prevented loss of energy through stimulation by ambient light. Sets of 24 dosimeters were grouped and coded for identification. Multiple dosimeter sets were used during this study. Each set was cleared of stored energy using a florescent light source (x-ray film view box) for a minimum of twenty-four hours prior to establishing baseline reading.

Dosimeters used in this study were read with a portable reader (MicroStar, Landauer, Inc., Glenwood, IL) (Appendix C). The reader was calibrated initially with a set of dosimeters supplied by the manufacturer that had been exposed to known amounts of energy from an 80 kVp x-ray source.

Reader performance was checked before each use. Photon counts were converted to dose using an energy specific conversion factor reflecting the 70 kVp source that was used throughout the study.

4. Adult Dosimetry Procedure

Eighteen projections simulating an adult Full Mouth Series (FMX) were exposed using each modality on the adult ATOMmax phantom. For each dosimeter run, the simulated FMX was repeated 10 times (180 exposures) to provide a more reliable measure of energy in the dosimeters at the peripheries of the exposure areas. Dosimeter readings were then divided by 10 to determine the dose per single FMX series. Each dosimetry run was repeated 3 times with the same device to determine variability and the average dose of the 3 runs was calculated for each modality.

5. Child Dosimetry Procedure

To measure child dosimetry the adult procedure was repeated with a child ATOMmax phantom utilizing a simulated 12 projection FMX and reduced exposure setting ; 70 kVp, 8 mA (adult: .20 & .32; child: .16 & .25). Additional dosimetry data were collected for the child phantom with thyroid shielding (Figure 3.7). One dosimeter run for each of the collimators was acquired using the child phantom with thyroid collar shielding. Each run included ten FMX exposure sets (120 exposures). The matrix for this study is found in Table 3.1. Exposure parameters for the adult and child FMX sequences are seen in Table 3.2.

6. Dose Calculations and Adjustments:

Effective dose was the primary outcome variable of this study. It is arrived at only by calculation and its value expresses the relative risk of human tissue detriment from ionizing radiation. Doses from OSL dosimeters at specific locations within the tissue or organ were averaged to express the average tissue-absorbed dose in micrograys (μGy). The products of these values and the estimated percentages of tissue or organ irradiated in an FMX were used to calculate the equivalent dose

(Appendix E). Effective dose, expressed in μSv, was calculated by using the equation $E = \Sigma\, w\mathrm{T} \times H\mathrm{T}$ and applying 2007 ICRP tissue weighting factors,[4] where effective dose (E) is the sum of the products of the tissue-weighting factor (wT), (Appendix D) and the equivalent doses (HT).[1,4]

Exposure settings used in this study were optimized for E/F speed film (Insight, Kodak) and a 33 cm source PID end distance. Doses for the Circular and Test device doses were corrected for the shorter source - PID end distance (both 30 cm) using the inverse square law. This resulted in a 20% reduction in dose readings for Circular and Test devices. (Appendix F)

7. Statistical Analysis

Effective dose (μSv) was analyzed using ANOVA and Tukey Honestly Significant Difference (HSD) test when significant differences were present. Overall percentages of dose attributed to each rectangular device were expressed as a percentage of circular dose.

B. Methods for Technical Performance Component

1. Study Population

The study population consisted of 33 senior dental hygiene students at the University of North Carolina at Chapel Hill School of Dentistry. Criteria for inclusion in the study were successful completion of the preclinical radiology course and two semesters of clinical radiology experience prior to enrolling to participate. All participants enrolled voluntarily in the study and signed consent forms. Examples of the recruitment email and consent form are included in Appendix G and Appendix H. This study was approved by the UNC Institutional Review Board.

2. Devices

Two device/collimator combinations were used to test for technical performance and diagnostic acceptability. Both device combinations were designed to be used with the RINN XCP®

receptor holding device, although the method for alignment varied depending on the device. The standard device was fitted over the 6 cm diameter position-indicating device extension (circular) with a 33 cm source-to-end distance (Figure 3.8). The Tru-Align™ device was fitted to the tube head without the circular extension with 30 cm source-to-end distance (Figure 3.9). The RINN® universal rectangular collimator insert (standard) was used with the RINN XCP® receptor holding device in its entirety. For Tru-align™ techniques, the RINN XCP® ring was replaced by a ring specifically designed to be used with the test device. The unique Tru-Align™ alignment ring that replaces the RINN XCP® ring is square in shape and has two arms of different lengths (Figure 3.10). The longer arm adapts to the XCP® bar for anterior and bitewing projections while the shorter arm adapts to the bar for posterior periapical projections. The alignment ring is affixed with multiple round flush mounted magnets.

3. Receptors

All projections were exposed using DenOptix® Photostimulable Phosphor Plate (PSP) receptors for each FMX (Figure 3.11). Size 1 receptors were used for lateral/canine periapical projections (n=4) and Size 2 receptors were used for central (n=2), premolar (n=4), and molar (n=4) periapical projections and premolar (n=2) and molar (n=2) bitewing projections. A total of 18 projections constituted an FMX for the technical performance segment of this study.

4. Equipment

All exposures with both standard and test collimator devices where made using an intraoral Planmeca Prostyle x-ray unit (Intra, Planmeca USA, Roselle, IL). A constant potential (kVcp) of 70 was used with 8 milliamperes (mA). Exposure times were .20 seconds for anterior projections and .32 seconds for posterior projections. Two Dental X-ray Teaching and Training Replicas (DXTTRs) were identified for use in the study (Figures 3.8 and 3.9). Each DXTTR was designed with natural

teeth and human skulls. Selection of the DXTTRs was based on optimal, mechanical and operational conditions.

5. Evaluator Criteria and Image Assessment

The evaluator was experienced in assessing radiographic projections for technical and diagnostic quality. Intra-rater reliability was assessed during the evaluation process. Images were scanned and stored in the Training Electronic Patient Record student system (TEPR). Each projection was viewed in a low lit room on a 22" Lenovo monitor with a resolution of 1680 x 1050 dpi. All projections were evaluated over a three hour time frame with periodic (two 10 minute) breaks. Data were collected using a direct data entry system using an EXCEL statistical application. A sample page of the worksheet is included in Appendix I.

All study images were blinded to the evaluator based on device/collimator combination and radiographer. The images were evaluated based on predetermined criteria. Minor errors were represented by the presence of the error, but the anatomic structure is displayed in the projection. A major error in diagnostic quality was based on the absence of specified anatomic structures. Minor errors involving packet placement, horizontal angulation, vertical angulation, and cone centering constituted a deduction of one point per error with four points being the greatest deduction. Major errors involving any of the four criteria were deemed non-diagnostic and automatically resulted in a four point deduction for that image. Each of the 18 images of the FMX was graded and an overall score given for that set of images. The criteria and evaluation form used to assess the technical quality of the projections are included in Appendix J and K.

6: Post-participation Survey

Subjects completed a five item survey instrument immediately following their participation in the study. The survey instrument is shown in Appendix L. The survey was designed to solicit

information from the subjects regarding their experience using the test device, assessing strengths, weaknesses and preferred device.

7: Technical Performance Procedure

All study subjects chose a block of time to participate. No more than two subjects could participate at the same time. Once a time for participation was established, each subject was required to consent by reading and signing the IRB approved study participation consent form. Upon arrival, subjects were given a brief review on the proper usage of each of the two devices and their task. Prior to arrival, the principal investigator set up DXTTR manikins, laid sensors out with a corresponding FMX template, and installed both standard and test devices to be ready for use. Each subject was randomly assigned to an operatory, DXXTR manikin and one of two study devices, (Appendix M). When ready to begin, consented subjects exposed one FMX using either the standard device or the test device. The principal investigator recorded start and stop times for each study subject during testing of each device. Upon completion of the first FMX with either device, the principal investigator gathered exposed sensors and scanned images into the TEPR. All images were coded to blind the evaluator to the subject and device used. The principal investigator removed the first of the two devices tested and installed the remaining device for subject use and start and stop times were again recorded. Subjects were allowed unlimited time to complete the FMX's but were encouraged to treat the radiographs as if they were dealing with a live patient. Both FMX's were exposed using PSP digital sensors on a DXTTR manikin. At the end of their task each subject completed and immediately returned the post participation survey to the principal investigator. A copy of the survey is included in Appendix L.

8: Statistical Analysis

Data were analyzed using frequencies, ANOVA and least squares means using a general linear model. A general linear model was used to analyze mean numbers of errors between the two

devices. ANOVA was used to assess error differences due to location in the mouth (Anterior, Posterior and Bitewing). A paired t-test was used to evaluate the mean time/effort between the two devices.

CHAPTER III FIGURES

Figure 3.1: Circular Collimator

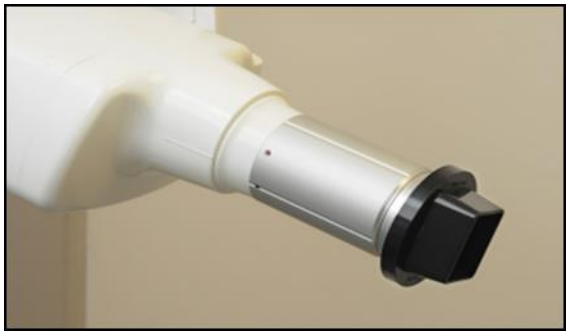


Figure 3.2: Standard Collimator

Figure 3.3: Test Collimator

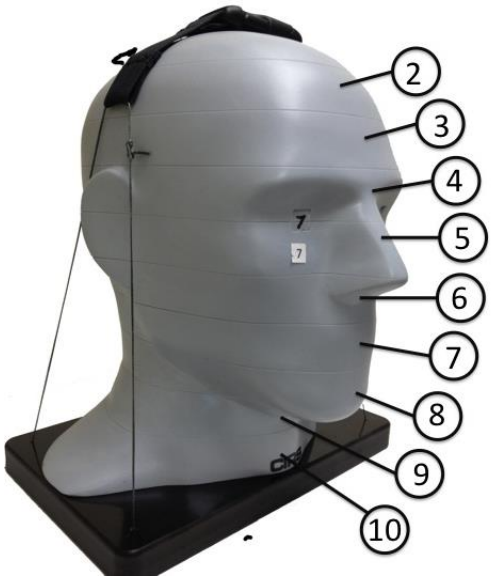


Figure 3.4: Average Adult Tissue-Equivalent Phantom
(ATOMmax Model 711HN - CIRS Inc, Norfolk, VA)

Figure 3.5: Child Tissue-Equivalent Phantom.
(ATOMmax Model 706 HN, CIRS Inc., Norfolk, VA)

Figure 3.6: Nanodot OSL Dosimeters

Figure 3.7: Child Tissue-Equivalent Phantom (w/Thyroid collar)
(ATOMmax Model 706 HN, CIRS Inc., Norfolk, VA)

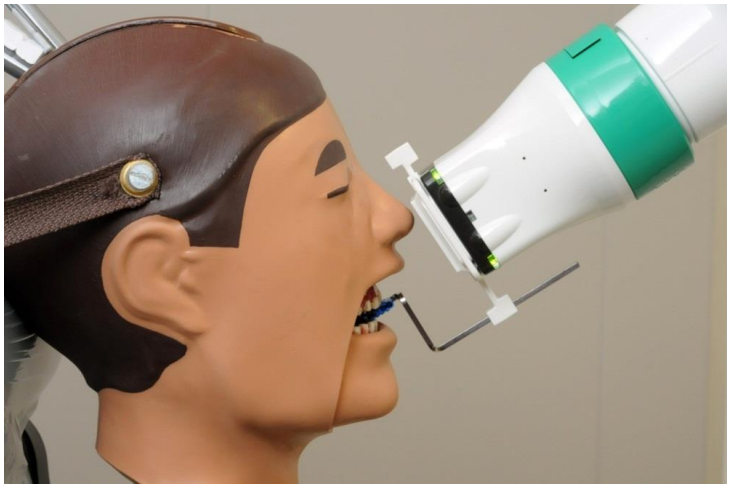


Figure 3.8: Test Collimator Device (DXTTR Manikin)

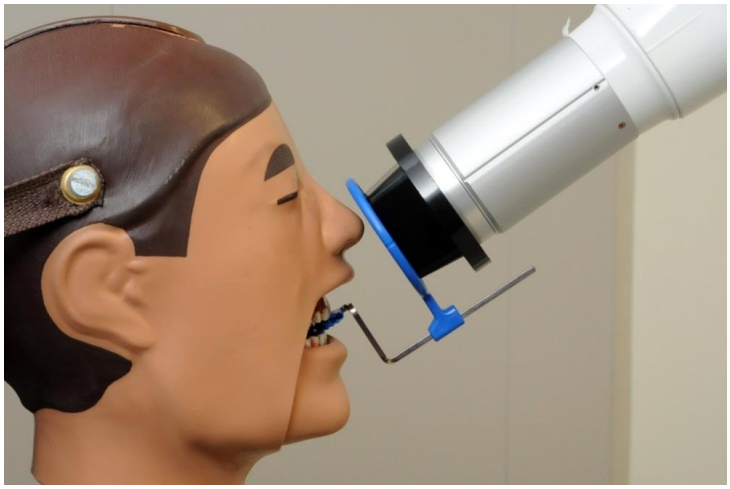


Figure 3.9: Standard Collimator Device (DXTTR Manikin)

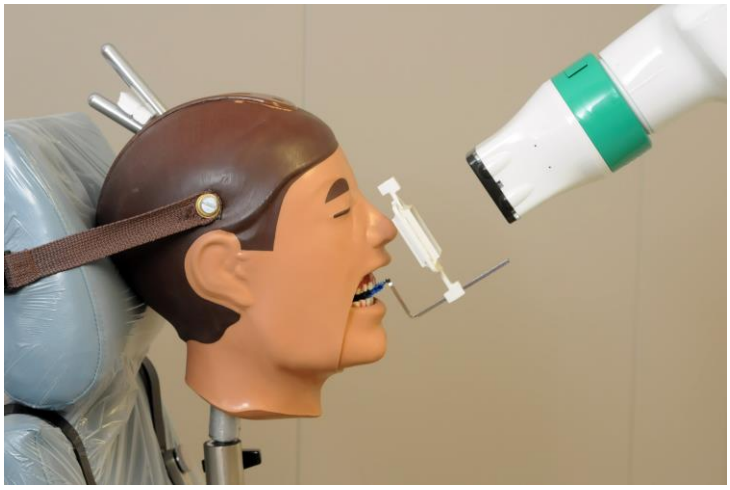


Figure 3.10: Test Collimator Beam Alignment Ring

Figure 3.11: DenOptix® Photostimulable Phosphor Plate (PSP) receptors (Size 2 example)

CHAPTER III TABLES

Dosimetry Acquisition Study Matrix
Modalities (3): Tru-Align (rectangular), Rinn collimator insert (rectangular), open cylinder (circular)
Phantom sizes (2): adult, 10-year-old child
Repetitions of dosimeter runs: 3
Total dosimeter runs: 18
Adult FMX – 18 image series: 6 vertical anterior PAs, 8 horizontal posterior PAs, 4 PBWs
Child FMX – 12 image series: 6 vertical anterior PAs, 4 horizontal posterior PAs, 2 PBWs
FMX Exposures per dosimeter run: 10
Total FMXs for project: 180
Total exposures: 2520
ANOVA model: Outcome variable – Effective dose
Experimental variables: Modality, Phantom, Repetition, incorporation of thyroid shield

Table 3.1 Dosimetry Acquisition Study Matrix

Intraoral Imaging Study Parameters					
Image Type	Area	Vertical	Horizontal	Exposure time (sec)	No. of Images (child)
PA maxillary	Molar	25º	80º	0.32	2 (0)
PA maxillary	Premolar	25º	75º	0.32	2 (2)
PA maxillary	Canine-lateral	45º	25º	0.20	2 (2)
PA maxillary	Centrals	45º	0º	0.20	1 (1)
PA mandibular	Molar	0º	80º	0.32	2 (0)
PA mandibular	Premolar	-15º	75º	0.32	2 (2)
PA mandibular	Canine-lateral	-20º	25º	0.20	2 (2)
PA mandibular	Centrals	-20º	0º	0.20	1 (1)
BW	Molar	10º	80º	0.32	2 (0)
BW	Premolar	10º	75º	0.32	2 (2)

Table 3.2 Exposure Parameters for the Adult and Child FMX Sequences

CHAPTER IV

RESULTS

A. Results of Dosimetry Component

Table 4.1 displays a summary of effective doses for the adult, child, and child with thyroid collar phantoms from each of the three collimator modalities. The lowest dose was achieved using the Standard collimator. This finding was true for each of the three phantom conditions. Adult mean effective dose was found to be significantly different ($p=0.001$) among the three collimator modalities; Circular (95μSv), Test (75μSv) and Standard (60μSv). Child doses were significantly lower ($p=0.0005$) with the Standard device (48μSv) when compared to the Test (70μSv) or Circular (80μSv) collimator. A statistically significant difference in effective dose was not present between the Test and Circular devices. This statistical pattern was also seen when the thyroid collar was added to the child phantom.

Figure 4.1 shows the percent reductions in average effective dose as well as percent reductions in surface area exposure that was achieved by each of the two rectangular devices when compared to the circular collimator. Compared with circular, percent effective dose reduction for the Adult was 20% with the Test and 37% with Standard collimator. When compared to the circular collimator, percent dose reductions for the Child were 14% with the Test and 40% with the Standard.

Figure 4.2 shows a comparison of the actual surface area exposure fields from the three collimator modalities. It was determined that the Test device yields a surface area exposure that is 82% of the surface exposure area produced by the circular device, while the Standard device produces a exposure area that is 53% of the exposure area from circular.

Table 4.2 shows a comparison of equivalent thyroid tissue dose in the child phantom with and without Shielding as a function of the three collimator modalities. Unshielded child thyroid tissue doses followed the same trends as with overall child effective doses where dose was significantly lower (p=0.0005) with the Standard device (368μGy) when compared to Circular (822μGy) and Test (769μGy). Thyroid shielding reduced equivalent dose to thyroid tissue by 32% with circular collimation (558μGy), 33% with Test rectangular collimation (519μGy), and 26% with Standard rectangular collimation (271μGy).

B. Results of Technical Performance Component

Seventeen subjects were enrolled in the study from a population of 33 senior dental hygiene students (51.5%). All subjects completed the technical component of the study and the written survey.

Figures 4.3 and 4.4 present the findings of all errors by number and error type. Figure 4.3 displays the average number of technique errors (PP, V, H, and CC) per FMX by device (standard vs. test). A statistically significant (p=0.048) lower number of mean errors occurred when using the test device ($\bar{x}$=9.7) compared to the standard device ($\bar{x}$=12.1). When specific types of technique errors were investigated, cone centering (CC) errors occurred almost 2.5 times more often with the Standard device (Standard device: $\bar{x}$=3.6 vs. Test device: $\bar{x}$=1.1) as shown in Figure 4.4.

Figure 4.5 presents the findings based on error severity (major or minor) displaying the average number of errors (PP, V, H, and CC) per FMX. An error scored as a major error indicated that the image did not offer diagnostic value. A minor error indicated that the error was present but did not compromise the diagnostic quality of the image. The mean number of diagnostically unacceptable errors per full mouth series was similar between devices (Standard device: $\bar{x}$=3.2 vs. Test device: $\bar{x}$=2.9). A greater difference was seen in the reported mean number of minor errors between the two devices (Standard device: $\bar{x}$=8.9 vs. Test device: $\bar{x}$=6.8). The average number of minor technique errors per full mouth series by error type (PP, V, H, and CC) is displayed in Figure

4.6. Minor cone centering errors occurred almost 1.5 times more often with the Standard device (Standard device: $\bar{x}$=3.5 vs. Test device: $\bar{x}$=1.1). There was no significant difference in the occurrence of (PP, V, H) minor errors between the Standard and Test devices. When the data were analyzed by the specific type of technique error by severity, the mean number of major errors was similar among error type (PP, V, H, CC). Figure 4.7 displays these data trends.

Figure 4.8 displays the average number of all errors that occurred based on location in the mouth (Anterior, Posterior, Bitewing) by device (Standard vs. Test). There was a significant difference in the average number of errors when comparing posterior to anterior locations (Standard device: $\bar{x}$=3.6 vs. Test device: $\bar{x}$=1.1 and posterior to bitewing locations ($p<0.0001$). There was not a significant difference when comparing anterior to bitewing locations.

Figure 4.9 displays the average number of major errors that occurred based on location between the Standard and Test devices. The standard device produced more major errors (not significant) in the Anterior and Bitewing locations while the Test device produced more major errors in the Posterior location. There were no significant differences in the amount of major errors that occurred between the two devices among the three locations.

Figure 4.10 displays the average number of minor errors that occurred based on location between the Standard and Test devices. More minor errors occurred while using the Standard device versus the Test device in the in all locations (Anterior, Posterior, Bitewing).

Figure 4.11 displays the average number of errors (PP, V, H, and CC) per FMX by device (standard vs. test) that occurred during anterior projections. More (PP) and (CC) errors occurred with the standard device while more (V) and (H) errors occurred with the test device. There was no significant difference in average number of errors produced between the two devices during anterior projections.

Figure 4.12 displays the average number of errors (PP, V, H, and CC) per FMX by device (standard vs. test) that occurred during posterior projections. More (CC) errors occurred with the

standard device while more (PP, H, V) errors occurred with the test device. There was no significant difference in average number of errors produced between the two devices during projections.

Figure 4.13 displays the average number of errors (PP, V, H, and CC) per FMX by device (standard vs. test) that occurred during bitewing projections. More (PP, H, CC) errors occurred with the standard device while more (V) errors occurred with the test device. There was no significant difference in average number of errors produced between the two devices during bitewing projections.

Figure 4.14 displays the average time required to complete a FMX by device. Average time required to complete an FMX using the standard and test device was 21 minutes and 17 minutes respectively. Significantly less time was needed to expose a FMX when using the Test device ($p=0.0001$).

Table 4.3 displays the subject responses to each of the five questions of the post-participation survey. Question #1 asked the subjects (n=17) to state any complications/malfunctions of the device/collimator combinations that were experienced when exposing the projections. Regarding the standard device, four subjects (24%) reported x-ray unit tube head instability or drifting and one subject (<1%) reported experiencing a malfunction with the collimator. Regarding the test device, 8 subjects (47%) reported that the weight of the device was an issue and 6 subjects (35%) reported that the lighted signal feature produced inaccuracies.

Question #2 asked the subjects (n=17) to list which enhancement features (audible and visual signals, magnetic ring), if any, were helpful to them as the operator. Eighty-two percent chose the visual (lighted) signal, seventy-one percent listed the magnetic positioning ring, and thirty-five percent listed the audible signal as being helpful to them during exposures.

Questions 3 and 4 explored the choices of subjects regarding impact on image quality and ease of use. Responses to Question 3 indicated that fifteen subjects felt that using the test device would produce better quality images. One subject chose the standard device and one subject remained undecided. Question 4 asked the subjects (n=17) to make a choice as to which of the two

devices they found easier to use. Sixteen chose the test device while one remained undecided. No subjects chose the standard device.

Question 5 asked the subjects (n=17) to choose a device based on their overall preference and to elaborate as to why. Sixteen responses were in favor of the test device while one subject preferred the standard device.

A general linear model with correlated errors was fit to the doubly repeated design where each student used both devices and took x-rays of the anterior, posterior, and bitewing locations using each device.[12] The covariance matrix was assumed to be of direct product form with unstructured covariance matrices specified for both device and location; this was estimated using the "repeated location device/ type=UN@UN subject=patid" statement in SAS PROC MIXED).[13] In an initial model, interactions between the fixed effects of location and device were not statistically significant (Wald F=0.52, 2 d.f., p=0.60). Subsequently, the main effects model with location and device was fitted. With regards to device, there was a statistically significant difference between the two devices standard pop-in collimator and Tru-Align™ collimator (p=0.0478). The model-predicted least squares means (standard errors) for device were as follows: standard pop-in collimator, mean=4.04 (se 0.34); Tru-Align™ collimator, mean=3.24 (se 0.24).

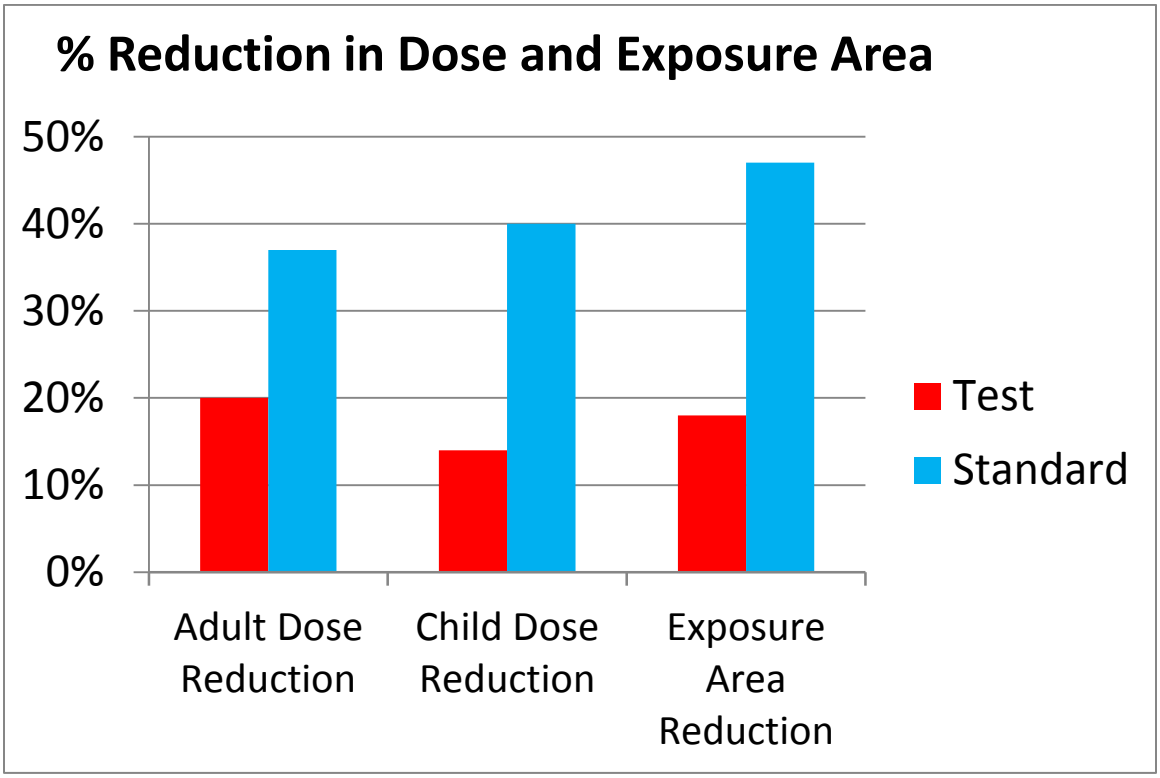


Figure 4.1: Percent Reduction in Exposure Area and Dose When Compared to Circular

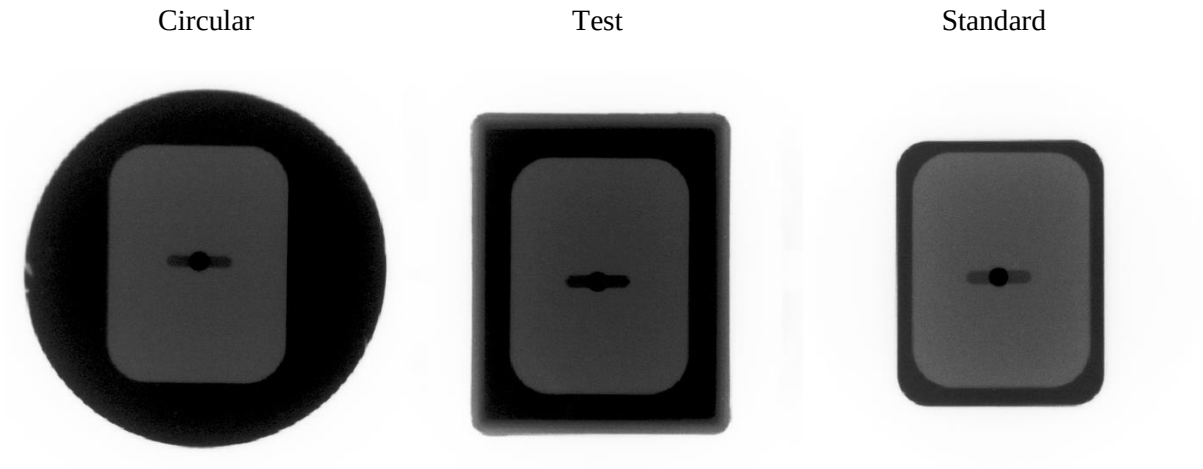


Figure 4.2: Clinical Surface Area Exposures from Circular, Test and Standard Collimators with Size 2 PSP Receptor Centered.

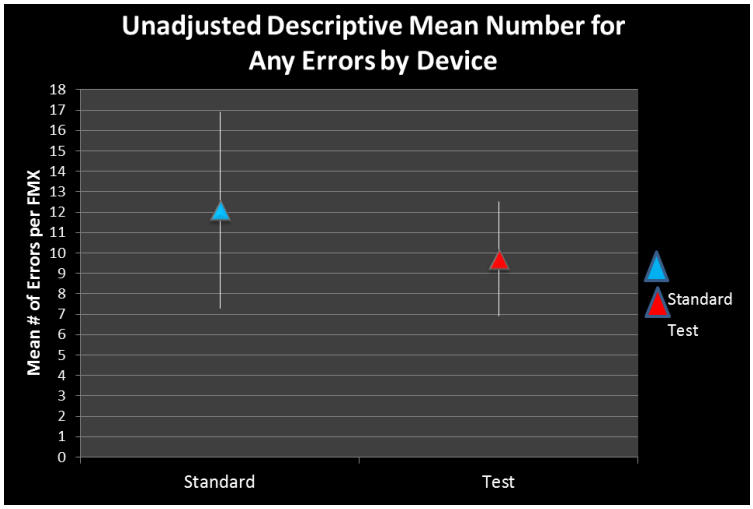


Figure 4.3: Unadjusted Descriptive Mean Number for All Errors by device

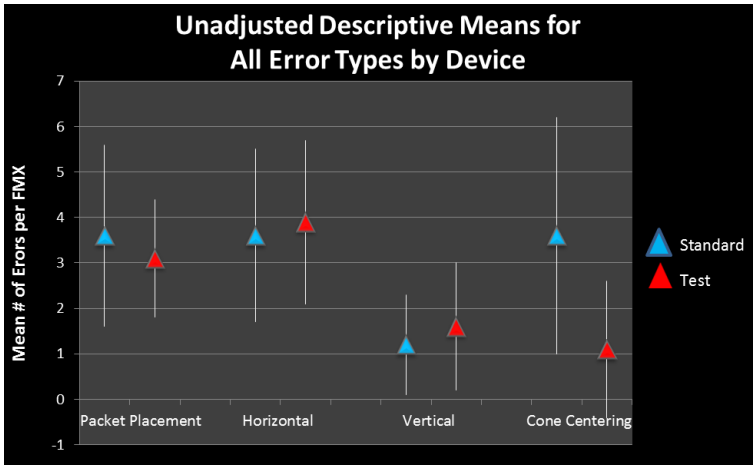


Figure 4.4: Unadjusted Descriptive Mean Number for All Error Types by Device

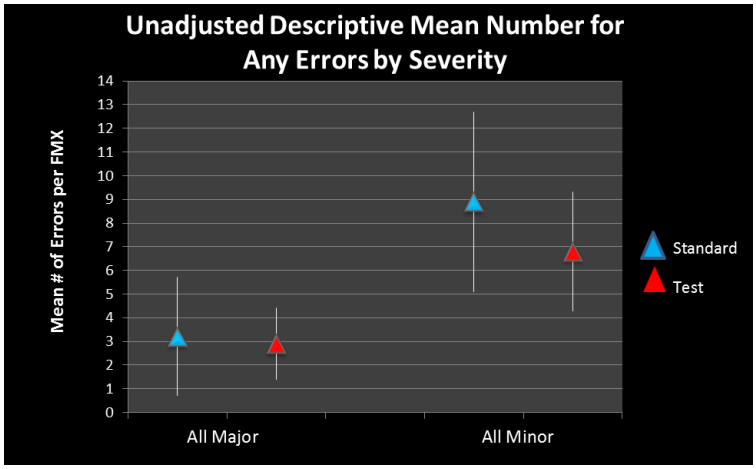


Figure 4.5: Unadjusted Descriptive Mean Number for All Error by Severity

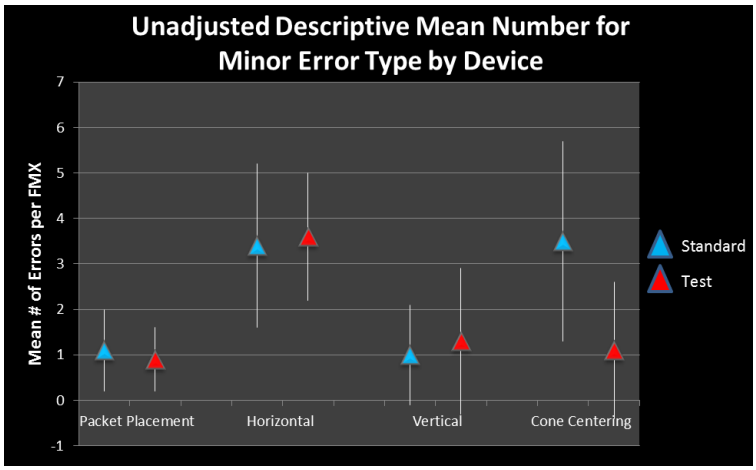


Figure 4.6: Unadjusted Descriptive Mean Number for Minor Error Type by Device

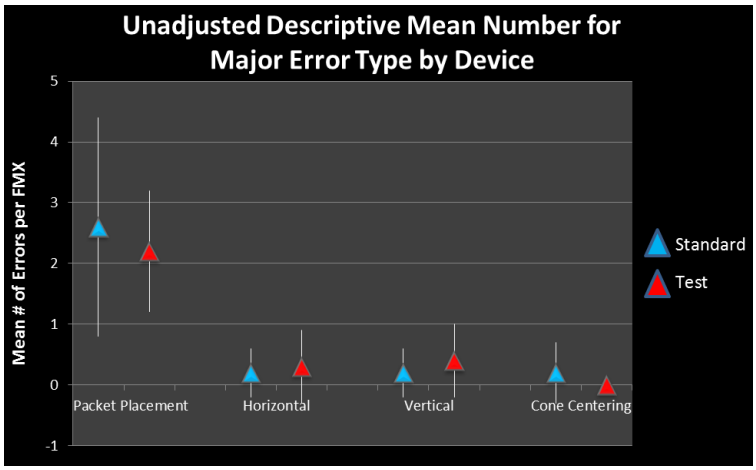


Figure 4.7: Unadjusted Descriptive Mean Number for Major Error Type by Device

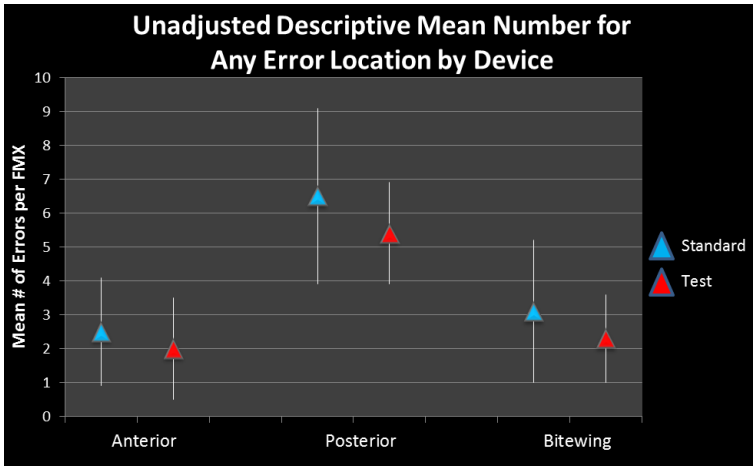


Figure 4.8: Unadjusted Descriptive Mean Number for Any Error Location by Device

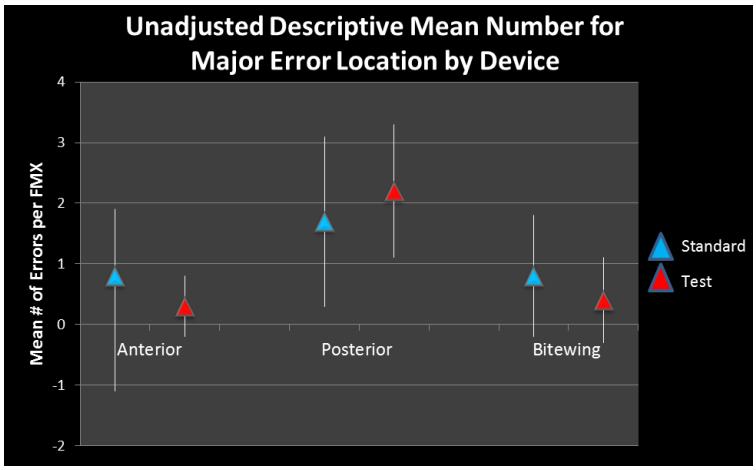


Figure 4.9: Unadjusted Descriptive Mean Number for Major Error Location by Device

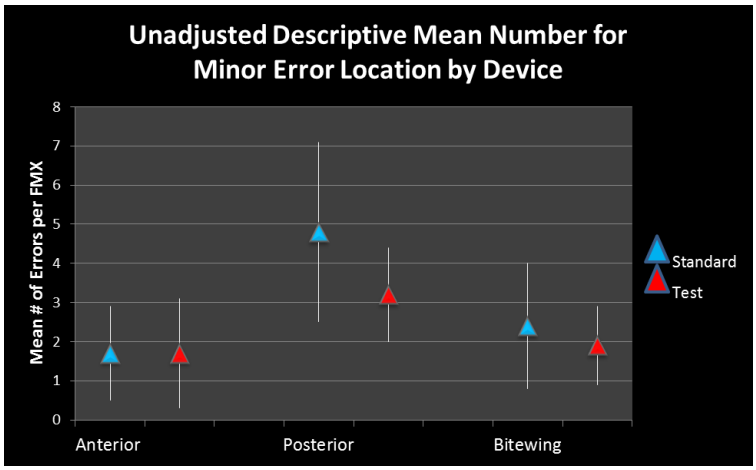


Figure 4.10: Unadjusted Descriptive Mean Number for Minor Error Location by Device

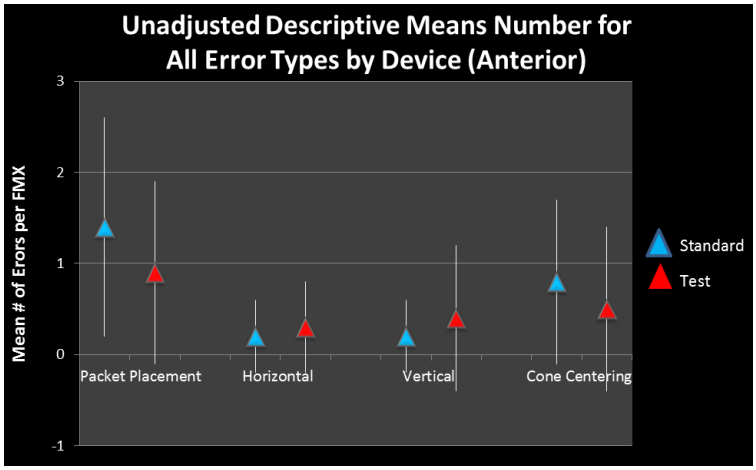


Figure 4.11: Unadjusted Descriptive Mean Number for All Error Types by Device (Anterior)

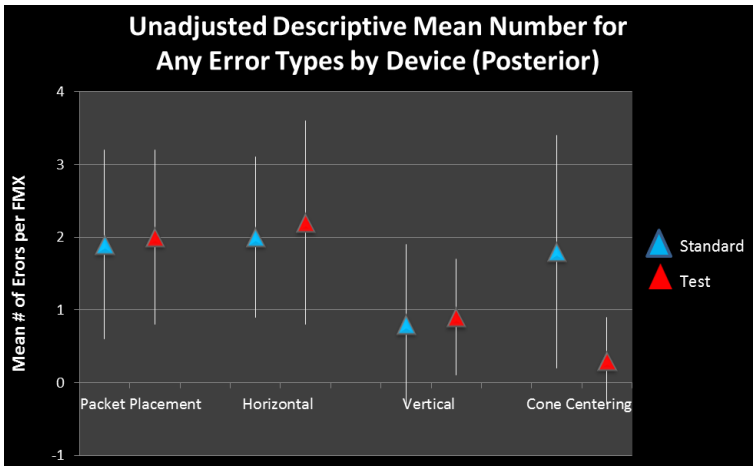


Figure 4.12: Unadjusted Descriptive Mean Number for All Error Types by Device (Posterior)

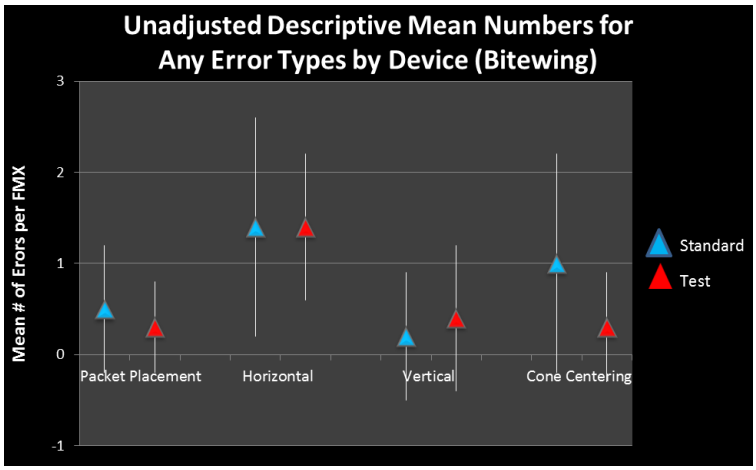


Figure 4.13: Unadjusted Descriptive Mean Number for All Error Types by Device (Bitewing)

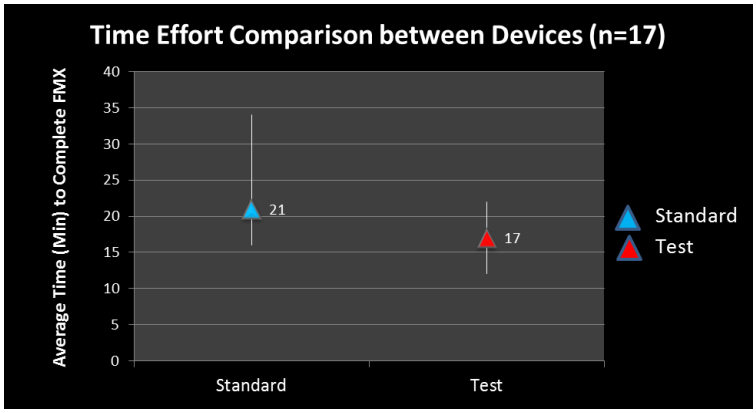


Figure 4.14: Time Effort Comparison between Devices

Effective Doses (μSv) for Standard FMX Exams E/F-Speed Film Settings			
	Circular μSv (SD)	**Test** μSv (SD)	**Standard** μSv (SD)
Adult	**95** (2.3)	**76** (8.9)	**60** (7.4)
Child	**80** (13)	**70** (8.2)	**48** (0.9)
Child w/ Thyroid Collar	**71***	**67***	**46***

* No standard deviations for Child w/Thyroid Collar Doses

Table 4.1: Effective Doses (ED) for Standard FMX Exams

Equivalent Thyroid Dose in Child Phantom with and without Thyroid Collar E/F-Speed Film Settings			
	Circular	**Test**	**Standard**
No shielding	822 μGy	769 μGy	368 μGy
Thyroid collar	558 μGy	519 μGy	271 μGy
Dose reduction	**32%**	**33%**	**26%**

Table 4.2: Thyroid Equivalent Dose in Child Phantom with and without Thyroid Collar

SURVEY QUESTION	SURVEY RESPONSES	n (%)
1. State any complications/malfunctions of the device/collimator combinations that you experienced when exposing the projections?	• Weight of test device • Inaccurate light activation • Tube head instability with standard device • Standard device malfunction	8 (47) 6 (35) 4 (24) 1 (<1)
2. Which enhancement features (audible and visual signals, magnetic ring), if any, were helpful to the operator?	• Visual light • Magnetic ring • Audible beep	14 (82) 12 (71) 6 (35)
3. Which device did you perceive provided the best diagnostic images?	• Standard • Test • Undecided	1 (6) 15 (88) 1 (6)
4. In general, which device did you find to be easier to use as the provider?	• Standard • Test • Undecided	0 (0) 16 (94) 1 (6)
5. Please tell us your overall device preference and why.	• Standard • Test	1 (6) 16 (94)

Table 4.3: Post-Participation Survey Responses

CHAPTER V

DISCUSSION

A primary goal of radiography is to render a diagnostic image while keeping the dose to the patient as low as reasonably achievable. This study evaluated the effective dose and technical performance of collimators commercially available for use in dental practice. The dosimetry component of the study evaluated three intraoral radiographic collimators (circular and two rectangular) using adult and child anthropomorphic phantoms. The technical component compared the performance of two rectangular collimators: one with technique enhancement features that attached to the tube head and one that inserted into a circular collimator. Additional outcome measures were subject feedback on the use and preference of the collimators and a comparison of time/effort between the two devices. Issues to be discussed pertain to collimator shape and its' impact on patient dose, the importance of assessing technical quality, and author recommendations for use in clinical practice.

Based on the findings of this study, the effective dose differences are related to the size of the collimator field rather than the shape of the field. The lowest dose was consistently achieved when using the Standard collimator which had a smaller field of exposure. In the adult, the Test device produced a significant reduction in dose compared to the Circular collimator. However, significant additional dose reduction was achieved with the addition of a universal rectangular collimator (Standard). Although child effective dose was slightly lower with the Test collimator as compared to circular, no statistical significance in dose differences could be identified between the two devices. Child effective dose from the Standard collimator was significantly lower than from the other two

devices. The dose difference is of particular importance when considering the increased sensitivity of child thyroid tissues as compared to thyroid tissues in an adult. This study found that equivalent thyroid tissues in the child received an increased dose when compared to the adult. As shown in Appendix N, the increased exposure is most likely related to the distance of the thyroid gland from the dento-alveolar area. This closer proximity of the thyroid organ to the perioral tissues in the child permits a higher intensity of scatter radiation to the thyroid tissue when compared to an adult. Dose reductions were attained using thyroid shielding thus demonstrating the importance of using a thyroid shield on a child. We found that child equivalent thyroid dose was more than halved from the minimal modification of insertion of a rectangular collimator into the circular end. Indeed, use of the standard rectangular collimator alone resulted in greater reduction of exposure to the thyroid gland than did use of a thyroid shield with circular collimation technique. While dose to thyroid was considerably lower with the Standard rectangular collimator, an additional 26 to 33 percent reduction in specific thyroid tissue dose was achieved by the use of a patient thyroid shield. These findings support those of Kircos et al. who concluded that dose to thyroid tissues with rectangular collimation could be further reduced by approximately one-third using shielding.[14] These data reinforce the ADA's strong recommendation for the use of thyroid shielding and the NCRP's statement that thyroid shielding *shall* be used during child intraoral periapical and bitewing exposures.[2, 3]

Dose reductions as the result of utilizing rectangular collimation as compared to circular have been reported in varying numbers.[1,6,11,14] This study found dose reductions as great as 40% for rectangular collimation compared to circular collimation while similar studies reported reductions of 60-80% with rectangular collimation.[5, 6, 15] Cederberg et al. showed that rectangular collimation provided a 72% to 80% reduction in effective dose when compared to a 6.67 cm diameter ($34.92cm^2$) circular position indicating device.[15] As this study's findings show, collimator dimensions effect dose. This study employed the use of a six centimeter diameter ($28.27cm^2$) PID for circular exposures compared to a larger diameter. A seven centimeter diameter circular ($38.48cm^2$) PID is still widely used.[14,15, 16] As an increase in diameter of the beam field relates to increased exposure, this additional

one cm difference in diameter contributes to a 25 percent increase in surface area exposed. This would explain dose differences among the various studies.

Exposures used in this study are reflective of E/F-speed (Insight by Kodak) film settings. F-speed is the fastest speed film emulsion that is currently available and recommended by the ADA, FDA and NCRP.[2,3,17] Still today the most commonly practiced technique for completing an FMX involves circular collimation with D-speed film.[1] Use of D-speed rather than E/F-speed film regardless of circular or rectangular collimation use increases the dose to the patient by approximately two and one half times. PSP receptor exposure can be half of F-speed, while CCD sensors require even less. According to Ludlow et al., using the ICRP's 2007 recommendations for calculating effective dose, patient's receiving an FMX using high speed receptors (F-speed film or PSP receptor) with typical circular collimation rather than optimal rectangular will increase their chances of fatal cancer as a result by nearly 5 times.[1] The technique of D-speed film in combination with circular collimation instead of a high speed receptor along with optimal rectangular collimation increases that patients' probability of death from cancer by tenfold.[1] Although, practitioners report continued use of slow speed film due to better image quality, studies have shown that the faster speed film and digital receptors yield comparable diagnostic information.[18,19]

The NCRP Report No. 145 states that rectangular collimation *shall* be used for intraoral periapical projections.[2] The guideline set forth states that each dimension of the beam, measured in the plane of the image receptor, *should* not exceed the dimension of the image receptor by more than two percent of source-to-image receptor distance.[2] This study finds, within the limits of measurement, the Test device to be non-conforming with an average of four percent excess beam in each dimension of the receptor (ANSI Size 2) compared to one percent with the Standard. This four percent excess is double the two percent limit, thus most of the exposure reduction possible with the rectangular format has been lost (Table 5.1).

When the devices were compared based on technical performance there was not a consistent pattern seen where one device outperformed the other with respect to packet placement, vertical

angulation or horizontal angulation errors. However, the Test device produced significantly fewer overall errors when compared to the Standard device. The type of error that was primarily reduced with the Test device was cone cutting. Interestingly, there was minimal difference between the devices in the number of errors requiring a retake to render a diagnostic image. Thus, most of the cone centering errors that were made did not influence the diagnostic quality of the image. Parks reported the same findings as this study regarding the production of more cone cutting errors when devices were used to collimate the beam to the size of the receptor. [20] In contrast to this study's results, Parks found the Rinn® Snap-on rectangular collimating device resulted in a statistically higher number of retakes when compared to other devices. Additionally this study found that more errors occurred in posterior projections compared to anterior and bitewing projections regardless of the device used.

One of the major challenges in dentistry regarding adoption of dose reduction techniques is whether the user feels that the device helps them to achieve diagnostic images with good image quality. The survey data indicated that the majority of subjects liked the enhancement features of the Test device and that the Test device rendered a better diagnostic image. Subjects were able to work faster with the Test device and reported preference for the Test device.

It appears that the Test device's enhancement features could have played a part in the reduction of cone centering errors when compared to the Standard device. This study found that the newly modified Test device produced fewer cone centering errors than the freely adjustable Standard rectangular device. These findings contradict the previous study findings using the original (unmodified) test device.[5] It was reported that the original device produced almost four times the number of cone centering errors as the standard.[5] The larger collimator field of the test device compared to the originally tested Test device may be the reason for this finding. Based on image quality, there appeared to be slightly fewer errors with the use of the Test device but the reduced errors were not errors that minimized the number of retake projections. Given the superior dose

reduction with the Standard device, the Test device cannot be recommended over the Standard alternative.

When interpreting the results of this study, it is important to recognize the limitations of the study design. First, the images from the technical performance component of this study were exposed on DXTTR manikins. Tongue movement and patient cooperation, factors that often influence image acceptability, were not able to be factored in when determining the technical performance of the collimators. Thus, the number and types of errors seen with DXTTRs may be different from live patients. Second, only about half of the study population chose to participate in the study. This may have introduced a subject bias. Thus, a comparison of non-participants with study participants would have helped to determine if differences in groups existed. Although comparisons between groups were not done, attempts were made to standardize a minimum competency level for all subjects. For example, all subjects had passed their preclinical competency and participated in two semesters of radiographic clinical practice. Third, technical differences between the two collimators were based on the radiographic performance skills of the subjects. As mentioned, the subjects had limited clinical experience. Performance results of the devices may have been different if they were used by experienced clinicians. Presumably, experienced clinicians are more likely to identify and problem solve incorrect placement of devices. Lastly, the study design included the comparison of two rectangular collimators. The application of study findings to clinical practice would be stronger if the study design had included circular collimation. A large number of clinicians have continued to use circular collimation even though rectangular collimation is strongly recommended by the American Dental Association.[1, 3]

While the effects of high-dose radiation are well known, the risks from low doses have been estimated by extrapolation from the existing high-dose data.[4] Thus there remains uncertainty in the risk of harmful effects from very low doses as encountered in intraoral radiography.[4] Assuming that intraoral dental radiographs are the most frequent x-ray examinations performed, the significance level is elevated. Therefore the challenge to us as educators and radiology clinicians is how to initiate

change in clinical practice theory while adhering to the ALARA principle using these simple and effective means. Change may be increased through the following means. First, modification of current dental, dental hygiene and dental assisting curricula is crucial. The likelihood that clinical providers would promote and adhere to simple dose reduction techniques in intraoral radiography as a continuation of their formal training is highly probable. In 2002, Geist et al. determined that rectangular collimation is used in addition to circular PID's at 21 dental schools (32%) in North America and is used exclusively by 10 (15%).[16] Geist showed a majority of the schools that implemented rectangular collimation did so only in the main radiology clinic while other various clinic operatories did not use rectangular collimation solely for fear of excessive technical error rates.[16] These reported numbers demonstrate the overwhelmingly low acceptance of this technique as a fundamental approach to dose reduction. Second, the behavior of practicing clinicians may be changed through reinforcement of effective state of the art strategies by consistent exposure to formal continuing education programs. For example, new devices/techniques and patient protection information regarding dose can be provided to help clinicians make knowledgeable decisions. Third, it is important to develop devices or techniques that make the transition to dose limiting procedures easy. Innovations like the Test device used in this study may be an example of a step in the right direction. Subject responses showed an overwhelming preference for the device with enhancement features. While adjustments may need to be made for devices to conform to NCRP guidelines, dental radiography equipment with enhancement features that promote dose reduction and strengthen technical accuracy can inspire enthusiasm and willingness of clinicians to abide by and promote the ALARA principle.

In conclusion, this study assessed both radiation dose and technical performance of two rectangular collimators currently used in dental practice. The study results confirm that reductions in x-ray exposure by collimation of the x-ray beam and the addition of thyroid shielding can significantly reduce patient risk from intraoral imaging. Additionally, adjustments in radiographic procedures can significantly impact image quality. Thus, the health and safety of the clinician,

patient, and public can easily be improved through the use of rectangular collimation and thyroid protection. Therefore to optimally adhere to the ALARA principle, the authors make the following recommendations:

- Radiographers should not only implement rectangular collimation, but should consider the size of the area of the exposure produced by the collimator.
- In combination with rectangular collimation, clinicians should use F-speed film or faster receptors (PSP, CCD) for intraoral imaging.
- Where possible, radiographers should use thyroid shielding. This is especially beneficial for children.
- Emphasis should be placed on quality training and consistent continuing education to reinforce the use of state of the art techniques and skills involved in imaging optimal intraoral projections.

Uncertainty remains regarding the cumulative effects of long term exposure to low doses of ionizing radiation with respect to risks for cancer development. Therefore, implementation of these recommendations will help insure the safe use of ionizing radiation in dental practice.

CHAPTER V FIGURES

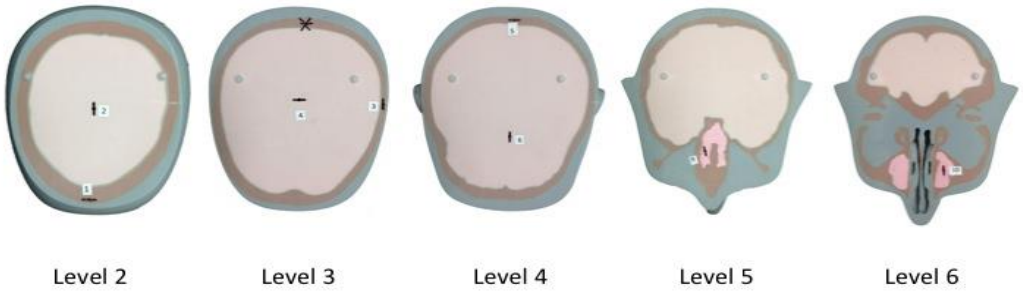
Tru-Align and RINN Rectangular Collimator Dimensions 2007 NCRP Guidelines		
	dimension (mm)	
	Tru-Align	RINN Universal
Source-collimator end	314	343
Source-receptor	339	368
2% limit	6.8	7.4
ANSI No. 2 receptor - Long	41	41
ANSI No. 2 receptor - Short	31	31
Long + 2% limit	47.8	48.4
Short + 2% limit	37.8	38.4
Actual beam – Long	56	46
Actual beam – Short	45	36
Excess beam dimension - Short	8.2	-2.4
Excess beam dimension - Long	7.2	-2.4
Rounding		
Long % of Source-receptor	4%	1%
Short % of Source-receptor	4%	1%
Average	**4%**	**1%**

Table 5.1: Tru-Align and RINN Rectangular Collimator Dimensions 2007 NCRP Guidelines

APPENDIX A:

ATOMmax Phantom Levels for Dosimeter Locations (Adult and Child)

CIRS ATOM Max 711-HN adult phantom levels for dosimeter locations



Level 2 Level 3 Level 4 Level 5 Level 6

CIRS adult phantom

Level 7 Level 8 Level 9 Level 10

CIRS 10 year-old child phantom levels for dosimeter locations

Level 2 Level 3 Level 4 Level 5

CIRS 10 year-old child phantom

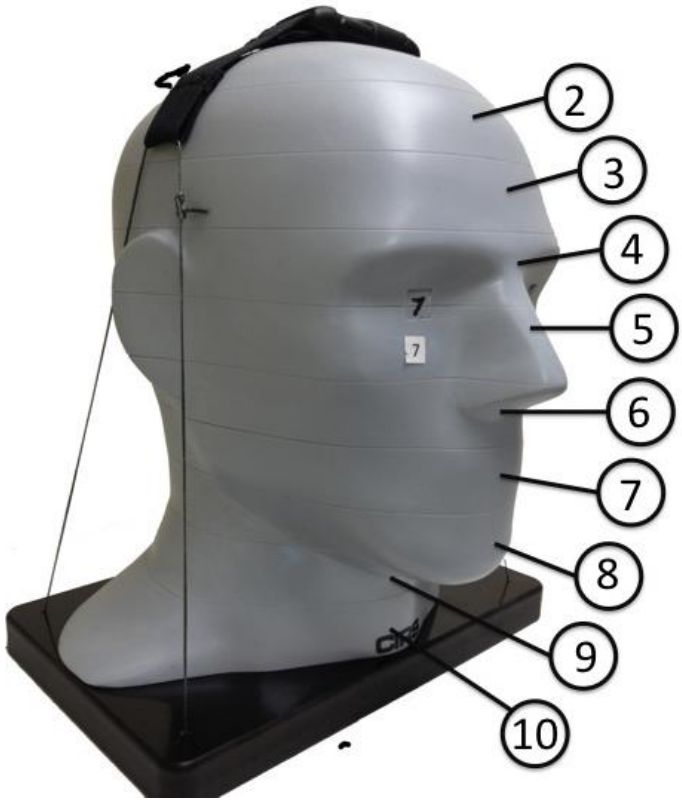
Level 6 Level 7 Level 8 Level 9

APPENDIX B

CIRS Phantom OSL Dosimeter Locations (Adult and Child)

OSL ID	CIRS Adult Phantom Location (level of OSLD location)
1	Calvarium anterior (2)
2	Mid brain (2)
3	Calvarium left (3)
4	Mid brain (3)
5	Calvarium posterior (4)
6	Pituitary (4)
7	Right lens of eye (4-5)
8	Left lens of eye (4-5)
9	Right ethmoid (5
10	Left maxillary sinus (6)
11	Oropharyngeal airway (7)
12	Right parotid (7)
13	Left parotid (7)
14	Right ramus (7)
15	Left ramus (7)
16	Left back of neck (8)
17	Right submandibular gland (8)
18	Left submandibular gland (8)
19	Center sublingual gland (8)
20	Center C spine (8)
21	Lateral neck–left (9)
22	Thyroid – left (10)
23	Thyroid - right (10)
24	Esophagus (10)

Phantom Levels



APPENDIX B
(continued)

CIRS Phantom OSL Dosimeter Locations

OSL ID	Child Phantom Location (level of OSLD location)
1	Calvarium anterior (2)
2	Calvarium left (2)
3	Calvarium posterior (2)
4	Mid brain (2)
5	Mid brain (3)
6	Pituitary (4)
7	Right orbit (4)
8	Right lens of eye (4-5)
9	Left lens of eye (4-5)
10	Right maxillary sinus (5)
11	Left nasal airway (5)
12	Right parotid (6)
13	Left parotid (6)
14	Left back of neck (6)
15	Right ramus (7)
16	Left ramus (7)
17	Right submandibular gland (7)
18	Left submandibular gland (7)
19	Center sublingual gland (7)
20	Center C spine (8)
21	Thyroid superior–left (8)
22	Thyroid – left (9)
23	Thyroid - right (9)
24	Esophagus (9)

APPENDIX C

Dosimeter Reader (MicroStar, Landauer, Inc., Glenwood, IL)

APPENDIX D

Tissue Weighting Factors for Calculation of Effective Dose – ICRP 2007 Recommendations

Tissue Weighting Factors for Calculation of Effective Dose ICRP 2007 Recommendations	
Tissue	***2007*** w_T
Bone marrow	**0.12**
Breast	**0.12**
Colon	**0.12**
Lung	**0.12**
Stomach	**0.12**
Bladder	**0.04**
Esophagus	**0.04**
Gonads	**0.08**
Liver	**0.04**
Thyroid	**0.04**
Bone surface	**0.01**
Brain	**0.01**
Salivary glands	**0.01**
Skin	**0.01**
Remainder Tissues	**0.12†**

† Adrenals, *Extrathoracic region*, Gall bladder, Heart, Kidneys, *Lymphatic nodes*, *Muscle*, *Oral Mucosa*, Pancreas, Prostate, Small Intestine, Spleen, Thymus, and Uterus/cervix.

(*italicized text* represents remainder tissues used for calculation of maxillofacial dose)

APPENDIX E

Estimated Percent of Tissue Irradiated and OSL Locations for Adult and Child Phantom

Estimated % of Tissue Irradiated and OSL Locations for Adult Phantom		
	Fraction Irradiated	OSL ID
Bone Marrow	12.2%	
mandible	0.8%	14, 15
calvaria	7.7%	1, 3, 5
cervical spine	3.8%	20
Thyroid	100%	22, 23
Esophagus	10%	24
Skin	5%	7, 8, 16
Bone surface*	16.5%	
mandible	1.3%	14, 15
calvaria	11.8%	1, 3, 5
cervical spine	3.4%	20
Salivary glands	100%	
parotid	100%	12, 13
submandibular	100%	17, 18
sub-lingual	100%	19
Brain	100%	2, 4, 6
Remainder		
lymphatic nodes	5%	11-13, 17-19, 21-24
muscle	5%	11-13, 17-19, 21-24
extrathoracic airway‡	100%	9-13, 17-19, 21-24
oral mucosa	100%	11-13, 17-19

Estimated % of Tissue Irradiated and OSL Locations for Child Phantom		
	Fraction Irradiated	OSL ID
Bone Marrow	15.4%	
mandible	1.1%	15, 16
calvaria	11.6%	1, 2, 3
cervical spine	2.7%	20
thyroid	100%	21, 22, 23
esophagus	10%	24
skin	5%	8, 9, 14
Bone surface*	16.5%	
mandible	1.3%	15, 16
calvaria	11.8%	1, 2, 3
cervical spine	3.4%	20
Salivary glands	100%	
parotid	100%	12, 13
submandibular	100%	17, 18
sub-lingual	100%	19
Brain	100%	4, 5, 6
Remainder		
lymphatic nodes	5%	12-13, 17-19, 21-24
muscle	5%	12-13, 17-19, 21-24
extrathoracic airway‡	100%	10-13, 17-19, 21, 24
oral mucosa	100%	12-13, 17-19

APPENDIX F

Source-to-end Distances for Collimators and Adjustment Multiplier for Circular and Test

Source-to-End Distances for Collimators and Adjustment Multiplier			
	SCED (in)	SCED (cm)	Normalize to Standard (multiplier)
Circular (extension)	12.1	30	0.8
Standard (with extension)	13.5	33	1.0
Test (without circular extension)	12.4	30	0.8

APPENDIX G

Recruitment Email

To: All Senior Dental Hygiene Students, Class of 2012

I would like to invite each of you to be a participant in my research project. I have the opportunity to test a very new radiology collimation device that each of you will very likely come into contact with in your near future careers. The device is designed to minimize cone cuts and alignment errors.

The test system is a device that consists of a rectangular collimator that will retrofit over most existing X-ray round cones. Attached to the end of the rectangular cone is a magnetized ring that locks on to the holder when it is aligned properly. When the beam is perfectly aligned with the acquisition device, the unit beeps and/or a light flashes indicating perfect alignment. This device can be used with film, digital sensors, or phosphor plates, and works with most standard film/sensor holders.

The study would require you to take two full mouth series (18 projections) on DXXTR, one with your current armamentarium using the pop-in rectangular collimator and one using the test collimator device. I will be comparing cone cuts and other technique errors (horizontal, vertical, packet placement) between the two devices as well comparing differences in time effort between the two. There will be a brief five question survey to complete after you have used both devices to gather your feedback.

The more participants I have, the more data I can acquire which I will need for this study to be successful. I'd like to provide a pizza lunch with a quick presentation to you all and answer any questions. Additionally each study participant will receive a $5 gift card as a reward for participating.

If you have interest in participating please let me know by *(specified date)* via email,

brandon1@dentistry.unc.edu, or inquire at my office in room 3210 Old Dental Building.

Thank you for considering participation in this research project!

Brandon Johnson, RDH, BS
Dental Hygiene Education Program
UNC-CH School of Dentistry

APPENDIX H

IRB Consent Form

IRBIS ORIS
University of North Carolina-Chapel Hill
Consent to Participate in a Research Study
Adult Subjects
Biomedical Form

IRB Study #12-0463
Consent Form Version Date: March 15, 2012

Title of Study: Technical performance and dosimetry using two intraoral radiologic device/collimator combinations

Principal Investigator: Brandon Johnson
UNC-Chapel Hill Department: Dental Ecology
UNC-Chapel Hill Phone number: 919-966-2800
Faculty Advisor: Sally M. Mauriello

Study Contact telephone number: 919-966-2800
Study Contact email: brandon1@dentistry.unc.edu

What are some general things you should know about research studies?
You are being asked to take part in a research study. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason.

Research studies are designed to obtain new knowledge that may help other people in the future. You may not receive any direct benefit from being in the research study. There also may be risks to being in research studies.

Deciding not to be in the study or leaving the study before it is done will not affect your relationship with the researcher, your health care provider, or the University of North Carolina-Chapel Hill. If you are a patient with an illness, you do not have to be in the research study in order to receive health care.

Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about being in this research study. You will be given a copy of this consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.

What is the purpose of this study?
In order to conform to the American Dental Association recommendation of keeping the

patient dose "as low as reasonably achievable" (ALARA), dental manufacturers have developed collimators (devices that align the x-ray beam) that are shaped to the size of the x-ray receptor. As a result, the dose to the patient is decreased but the number of radiographic images with technique errors increases due to the closely sized beam. A relatively new device has been commercially sold to dental offices to help dental professionals take x-ray images without alignment errors.

The main aims of the study are:

- to compare the number and type of technical errors between the two systems (test and standard).
- to compare the diagnostic acceptability of the two systems.
- to compare the time efficiency and user acceptability of the two systems.

The purpose of this research study is to learn about the technical performance of a radiologic receptor holding device that is designed to reduce technique errors that occur when using rectangular collimation.

You are being asked to be in the study because you are a senior dental hygiene student at the University of North Carolina.

You should not participate if you are pregnant or believe you might be pregnant.

How many people will take part in this study?

If you decide to be in this study, you will be one of approximately 33 people in this research study.

How long will your part in this study last?

If you chose to participate in this study, the total length of time of your involvement will be approximately 2-3 hours. The recruitment presentation and study consent will be about 30-45 minutes and the actual exposure of radiographs and completion of the survey will be 1-2 hours. There will not be any follow-up after the completion of the radiographs and survey.

What will happen if you take part in the study?

If you are interested in participating in this study, you will attend a recruitment presentation that will describe your involvement in the study, the device to be tested, and sign a consent form. Once enrolled in the study, you will:

- sign up for a time to expose the two full mouth series (18 exposures per full mouth),
- at the assigned time, you will expose one full mouth series using the test system and one full mouth series using the standard system in the UNC Radiology clinic,
- at the completion of the two full series, you will complete a short survey.

The study survey has five questions that ask you which device system you preferred to use, any problems using the two systems, and the length of time it took for you to take each full series. You may choose to leave blank any questions that you do not want to answer.

The device system to be used first, the DXTTR manikin, and operatory will be decided by chance, like flipping a coin.

What are the possible benefits from being in this study?
Research is designed to benefit society by gaining new knowledge. You are not likely to benefit from participation in this research other than a onetime exposure to a new device.

What are the possible risks or discomforts involved with being in this study?
There is a small risk associated with minimal exposure to radiation. The x-ray beam is shaped in a rectangle and the same exposure times will be used as the standard of practice used in the UNC Radiology clinic. The amount of radiation to the patient would be 1.8 mR per full mouth series. Operator exposure is lower due to the positioning outside of the operatory to depress the exposure switch. Although minimal, the effects of radiation exposure are cumulative. Thus, any additional radiation exposure that may occur would be in addition to that you normally would receive as part of your educational program and any medical radiation received.

There may be uncommon or previously unknown risks that might occur when using ionizing radiation. You should report any problems to the researchers.

What if we learn about new findings or information during the study?
You will be given any new information gained during the course of the study that might affect your willingness to continue your participation.

How will your privacy be protected?
Survey data will be protected by being stored in a locked office at the UNC School of Dentistry. Data will be entered into a password protected desktop computer in the locked office. Only research investigators will have access to the data. Radiographic images of the manikins will be stored on the password protected electronic patient record under the unique ID number. There is no linkage file identifying you by name.

No subjects will be identified in any report or publication about this study. Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, UNC-Chapel Hill will take steps allowable by law to protect the privacy of personal information. In some cases, your information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies (for example, the FDA) for purposes such as quality control or safety.

What will happen if you are injured by this research?
All research involves a chance that something bad might happen to you. This may include

the risk of personal injury. In spite of all safety measures, you might develop a reaction or injury from being in this study. If such problems occur, the researchers will help you get medical care, but any costs for the medical care will be billed to you and/or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay you for any such reactions or injuries, or for the related medical care. However, by signing this form, you do not give up any of your legal rights.

What if you want to stop before your part in the study is complete?
You can withdraw from this study at any time, without penalty.

Will you receive anything for being in this study?

You will receive a free pizza lunch for attending the recruitment presentation. If you complete the study, you will be receiving a $5 gift card for taking part in this study. If you choose to withdraw prior to completion of the study, then you will only receive the free pizza lunch at the recruitment presentation.

Will it cost you anything to be in this study?
It will not cost anything to participate in the study.

What if you are a UNC student?
You may choose not to be in the study or to stop being in the study before it is over at any time. This will not affect your class standing or grades at UNC-Chapel Hill. You will not be offered or receive any special consideration if you take part in this research.

Who is sponsoring this study?
This research is not being funded by any sponsor. The company that markets the radiologic device being tested (Tru-Align™ Systems x-ray device, Interactive Diagnostic Imaging X-ray Company) is providing the $5 gift card as incentive to participate in the study. The researchers do not, however, have a direct financial interest with the company. The researchers will be responsible for the reporting of the study results.

What if you have questions about this study?
You have the right to ask, and have answered, any questions you may have about this research. If you have questions, complaints, concerns, or if a research-related injury occurs, you should contact the researchers listed on the first page of this form.

What if you have questions about your rights as a research subject?
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject, or if you would like to obtain information or offer input, you may contact the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

- -

Title of Study: Technical performance and dosimetry using two intraoral radiologic device/collimator combinations

Principal Investigator: Brandon Johnson

Subject's Agreement:

I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree to participate in this research study.

_____ _____
Signature of Research Subject Date

_____
Printed Name of Research Subject

_____ _____
Signature of Research Team Member Obtaining Consent Date

_____
Printed Name of Research Team Member Obtaining Consent

APPENDIX H

(Continued)

IRB Approval Letter

To: Brandon Johnson
Dental Ecology

From: Biomedical IRB

Approval Date: 1/25/2013
Expiration Date of Approval: 1/24/2014

RE: Notice of IRB Approval by Expedited Review (under 45 CFR 46.110)
Submission Type: Renewal
Expedited Category: 7.Surveys/interviews/focus groups
Study #: 12-0463

Study Title: Technical performance and dosimetry using two intraoral radiologic device/collimator combinations

This submission has been approved by the IRB for the period indicated.

Study Description:

Purpose: The purpose of this study was to compare the dose, number and type of technical errors, and time effort between the IDI Tru-Align (test) collimator in combination with the XCP® standard beam alignment device and the Rinn® universal rectangular collimator with the XCP® standard beam alignment device.

Participants: Thirty three senior dental hygiene students were invited to participate in the study. Seventeen were consented to participate in the study.

Procedures (methods): Each student exposed a full- mouth series on a Dental X-ray Trainer (DXTTR) using each test device with the test collimator and a full mouth series was exposed with the standard device and universal collimator. Technical quality was assessed by evaluating each projection based on packet placement, horizontal angulation, vertical angulation, and cone centering. An experienced evaluator, co-investigator, was blinded and assessed the images and recorded errors. Dosimetry was measured by simulating a full series using each device on an ATOMMAX Phantom using optical luminescent (OSL) dosimetry chips to evaluate the absorbed

dose at various anatomic sites. Dosimetry measures were completed by the principal investigator. At the completion of the study, each subject responded to a five question survey assessing device preference, user-friendliness of the device, time effort, device complications, and learning curve. Data were analyzed using a paired student t-test, analysis of variance (ANOVA), and frequencies.

Regulatory and other findings:

This research is closed to enrollment and remains open for data analysis only.

Investigator's Responsibilities:

Federal regulations require that all research be reviewed at least annually. It is the Principal Investigator's responsibility to submit for renewal and obtain approval before the expiration date. You may not continue any research activity beyond the expiration date without IRB approval. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.

Your approved consent forms and other documents are available online at http://apps.research.unc.edu/irb/irb_event.cfm?actn=info&irbid=12-0463.

You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented. Any unanticipated problem involving risks to subjects or others (including adverse events reportable under UNC-Chapel Hill policy) should be reported to the IRB using the web portal at http://irbis.unc.edu.

This study was reviewed in accordance with federal regulations governing human subjects research, including those found at 45 CFR 46 (Common Rule), 45 CFR 164 (HIPAA), 21 CFR 50 & 56 (FDA), and 40CFR 26 (EPA), where applicable.

CC:
Sally Mauriello, Dental Ecology

APPENDIX I

Sample Excel Data Entry Worksheet

Projection 1 Right Maxillary Molar			
PP	H	V	CC
1	2	1	3

Code:

1 = No error present

2 = Presence minor error

3 = Presence major error

APPENDIX J

Criteria Used to Assess the Technical Quality of the Projections

PERFORMANCE CRITERIA FOR INTRAORAL RADIOLOGY

Periapical Examinations

A. General Considerations- All periapical views should demonstrate:

1. 1/4 inch of alveolar bone visible beyond the apex of each tooth.
2. 1/16 - 1/8 inch margin between the crowns of the teeth and the edge of the film.
3. Occlusal plane should be straight or slightly curved upward toward the distal.

B. Specific Views

1. Maxillary Centrals- #2 vertical

   The central/central interproximal space is centered on the film. Demonstrate the central incisors, lateral incisors, the proximal portion of canines, incisive foramen, and nasal fossa. Interproximal spaces open with emphasis between the central incisors.

2. Maxillary Lateral/Canine- #1 vertical

   The lateral/canine interproximal space is centered on the film. Demonstrate the entire lateral and canine, the distal portion of the central incisor, and mesial portion of the premolar. Interproximal spaces open with emphasis between the lateral and canine (the canine and the premolar will appear overlapped; this is a result of the transition to a double row of cusps and the normal curvature of the arch).

3. Maxillary Premolar- #2 horizontal

   Demonstrate no less than the distal portion of canine; the entire first premolar, second premolar, and first molar, and the mesial of the second molar. Interproximal space open with emphasis on the canine/first premolar and the first premolar/second premolar areas.

4. Maxillary Molar- #2 horizontal

   Demonstrate the entire first molar, second molar, and third molar or most distal tooth present. Interproximal spaces open with emphasis between the first and second molar.

5. Mandibular Centrals- #1 vertical

Demonstrate the central/central interproximal space centered on the film. Demonstrate the central incisors, lateral incisors, and the proximal portion of canines. Interproximal spaces open with emphasis between central incisors.

6. Mandibular Lateral/Canine- #1 vertical

Demonstrate the lateral/canine interproximal space centered on the film. Demonstrate the entire lateral incisor and canine, the distal portion of the central incisor and mesial portion of the premolar. Interproximal spaces open with emphasis between lateral and canine (the canine and the premolar will appear overlapped; this is the result of the transition to a double row of cusps and the normal curvature of the arch).

7. Mandibular Premolar- #2 horizontal

Demonstrate no less than the distal portion of the canine; the entire first premolar, second premolar, first molar, and the mesial of the second molar. Interproximal spaces open with emphasis on the canine/first premolar and the first premolar/second premolar areas.

8. Mandibular Molar- #2 horizontal

Demonstrate the entire first molar, second molar, and third molar or most distal tooth. Interproximal spaces open with emphasis between the first molar and the second molar.

Interproximal (Bitewing) Examinations

A. General Considerations- All interproximal (bitewing) views:

1. Occlusal plane should be straight or slightly curved upward toward the distal.
2. Equal distribution (demonstration) of maxillary and mandibular crowns, and maxillary alveolar crests.

B. Specific Views

HORIZONTAL BITEWINGS

1. Premolar- #2 horizontal

Demonstrate no less than the distal portions of the canine crowns, all of the first premolar, second premolar, and first molar crowns, and the mesial of the second molar crowns. Interproximal spaces open with emphasis on the maxillary canine/first premolar and first premolar/second premolar. Flat vertical projection geometry through open contacts is required for caries diagnosis and accurate assessment of crestal bone height. Open contacts in mandibular periapical images with flat vertical projection geometry may be used in place of unopened contacts in bitewing films. Flat vertical imaging geometry is not typically possible with maxillary periapical images.

2. Molar- #2 horizontal

Demonstrate all of the first molar, second molar, and third molar crowns or the crowns of the most distal tooth present. Interproximal spaces open with emphasis between maxillary first molar and second molar. Note: because of the difference in tooth morphology (maxillary molars are rhomboid and mandibular molars are trapezoid) and arch form, it may be difficult to open maxillary and mandibular contacts simultaneously; if this is the case, favor opening the maxillary molar contacts.

VERTICAL BITEWINGS

1. Premolar- #1 vertical

If all posterior teeth are present, it may be necessary to take a six film survey with vertical bitewings. Under these circumstances, it is necessary to use a #1 size vertical film in the canine/premolar position. This projection should demonstrate the distal portions of the canine crowns, all of the first premolar crowns, and the mesial portions of the second premolar crowns. Interproximal spaces open with emphasis on the maxillary canine/first premolars and first premolars/second premolars. Then, use a #2 size vertical film placed so as to demonstrate the distal portions of the second premolar crowns, all of the first molar crowns, and mesial portions of the second molar crowns. Interproximal spaces open with emphasis on the maxillary first and second molars. A third film (#2 size vertical) is placed as to demonstrate the distal portions of the second molar crowns and all of the third molar crowns. Interproximal spaces open with emphasis on the maxillary second and third molars. **On vertical bitewings include 5 mm of crestal bone distal to the most distal tooth.** If necessary expose additional films to obtain the information needed.

If only two films are used for vertical bitewings, the following criteria should be used.

1. Premolar- #2 vertical

Demonstrate no less than the distal portions of the canine crowns, all of the first premolar, second premolar, and first molar crowns and the mesial of the second molar crowns. Interproximal spaces open with emphasis on the maxillary canine/first premolar and first premolar/second premolar areas.

2. Molar- #2 vertical

Demonstrate all of the first molar, second molar, and third molar crowns or the crowns of the most distal tooth present. Interproximal spaces open with emphasis between maxillary first molar and second molar. Note: because of the difference in tooth morphology (maxillary molars are rhomboid and mandibular molars are trapezoid) and arch form, it may be difficult to open maxillary and mandibular contacts simultaneously; if this is the case, favor opening the maxillary molar contacts. **On vertical bitewings include 5 mm of crestal bone distal to the most distal tooth.** If necessary expose additional films to obtain the information needed.

Updated July, 1997

APPENDIX K

Projection Evaluation Form

TO RECEIVE CREDIT, FILMS MUST BE RETURNED WITH COMPLETED ANALYSIS FORM WITHIN ONE WEEK

Patent Name (last, first)	Chart Number	RADIOGRAPHIC ANALYSIS FORM School of Dentistry University of North Carolina
Student Name (last, first)	Student Number	

Radiographic Exam Date:	Clinical Remarks	Instructor

STUDENT COMPLETES THIS SECTION

Radiographic Area	Error and Reason	Retake made? ✓	Technique Points Off and Reason	Analysis Points Off
1-Maxillary Right Molar				
2- Maxillary Right Premolar				
3-Maxillary Right Lateral/Canine				
4-Maxillary Centrals				
5-Maxillary Left Lateral/Canine				
6-Maxillary Left Premolar				
7-Maxillary Left Molar				
8-Mandibular Left Molar				
9-Mandibular Left Premolar				
10-Mandibular Left Lateral/Canine				
11-Mandibular Incisors				
12-Mandibular Right Lateral/Canine				
13-Mandibular Right Premolar				
14-Mandibular Right Molar				
15-Right Molar Bitewing				
16-Right Premolar Bitewing				
17- Left Premolar Bitewing				
18- Left Molar Bitewing				
19-Distal Projection Teeth #				
20-Other				

Indicate the error demonstrated in each image and comment using the notation listed below:

B	**exposed backwards**	**H**	**horizontal angulation**	**N**	**noisy image**	**S**	**scanning error**
C/	**cone cut**	**ID**	**Image distortion**	**OK**	**clinically acceptable**	**V**	**vertical angulation**
D	**displayed incorrectly**	**M**	**movement**	**P**	**packet placement**	**XX**	**double image**

/ cone cut requires one or more modifiers (H, V, T, R) to indicate vertical and/or horizontal angle error or translation or rotation of cone off receptor center.

THE GRADING SECTION BELOW WILL BE COMPLETED BY INSTRUCTOR.

Patient Management _____ Radiation hygiene _____ Infection control _____

Total error points _____ Percent score _____ Grade _____ Faculty Signature _____

Competency Exam (no instructor assistance ✓) _____

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APPENDIX L

Post-participation Survey

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
SCHOOL OF DENTISTRY
GRADUATE STUDENT MASTERS THESIS DEVELOPMENT PROGRAM

Project Survey

Study Title: Technical performance and dosimetry using two intraoral radiologic device/collimator combinations

Subjects participating in the project are to record their study number, device they are assigned, DXTTR used, and indicate their start and finish times in the appropriate spaces provided. Make sure to answer the five questions at the completion of participation.

Study Number: _____

Date	Operatory	DXTTR	Device Used	Start Time	Finish Time

Post Participation Survey Questions:

1. State any complications/malfunctions of the device/collimator combinations that you experienced when exposing the projections?
2. Which enhancement features (audible and visual signals, magnetic ring), if any, were helpful to the operator?
3. Which device did you perceive provided the best diagnostic images?
4. In general, which device did you find to be easier to use as the provider?
5. Please tell us your overall device preference and why.

APPENDIX M

Randomized Participant Table

Subject	Unique ID#	Room	DXTTR	Device	Date
1)	01212	2	1	2	3-22-12
1)	01121	1	2	1	
2)	02111	1	2	1	3-26-12
2)	02222	2	1	2	
3)	03122	1	2	2	3-26-12
3)	03211	2	1	1	
4)	04211	2	1	1	3-26-12
4)	04122	1	2	2	
5)	05112	1	1	2	3-30-12
5)	05111	1	1	1	
6)	06221	2	2	1	3-30-12
6)	06222	2	2	2	
7)	07221	2	2	1	4-2-12
7)	07222	2	2	2	
8)	08111	1	1	1	4-2-12
8)	08112	1	1	2	
9)	09221	2	2	1	4-2-12
9)	09222	2	2	2	
10)	10112	1	1	2	4-3-12
10)	10111	1	1	1	
11)	11222	2	2	2	4-9-12
11)	11221	2	2	1	
12)	12111	1	1	1	4-9-12
12)	12112	1	1	2	
13)	13112	1	1	2	4-19-12
13)	13111	1	1	1	
14)	14112	1	1	2	4-19-12
14)	14111	1	1	1	
15)	15111	1	1	1	4-20-12
15)	15112	1	1	2	
16)	16222	2	2	2	4-23-12
16)	16221	2	2	1	
17)	17111	1	1	1	4-23-12
17)	17112	1	1	2	

Key:

(#)Order on participant list

(#)Room: 1=A / 2=B

(#)DXTTR: 1=757 / 2=758

(#)Device: 1=Rinn Rectangular (Standard) / 2=Tru-Align (Test)

APPENDIX N

Comparison of Thyroid Level in Child and Adult

The values calculated for thyroid dose are based on readings from two dosimeters positioned at level 10 of the Adult ATOM phantom. This is where the greatest bulk of the lobes and isthmus of the gland are located. For the Child phantom, thyroid dose calculation is based on two dosimeters in level 9 averaged with a single dosimeter in level 8. The rationale for this difference in dose measurement is based on the proximity of the thyroid gland to the lower border of the mandible, which is closer in children than adults (Figure 1). This proximity means that direct exposure of the thyroid is more likely in children than adults when the base of the FOV is situated just below the chin. In addition the child's thyroid is closer to the oral/perioral tissues that are responsible for scatter radiation; therefore, the intensity of scatter at the thyroid is greater in the child than the adult. Because the thyroid has a tissue weight of .04, this organ provides a significant contribution to the calculation of effective dose. With patients, direct thyroid exposure may be reduced by rotating the chin upward and positioning the lower border of the mandible parallel with the rotational plane of the beam (parallel to the floor); however, this strategy is not possible with the ridged phantoms utilized in this research.

* A.D.A.M. medical images http://www.adamimages.com

Figure 1. Comparison of thyroid level in child and adult

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