Pediatric Phantom Dosimetry Evaluation of the Tru-Image® Rectangular Collimator

Amanda Martinez* • Juan F. Yepes • James E. Jones • Phillip Wong •
Brandon Johnson • Sarah Canady • Qing Tang
Indiana University School of Dentistry, Indianapolis, Indiana – Riley Hospital for Children
and Adams School of Dentistry, University of North Carolina at Chapel Hill, Chapel Hill, NC

BACKGROUND

Dental radiographic images are an important aspect of a clinician's examination for diagnosis and treatment of various oral diseases.[1] When prescribing radiographs during an examination, a clinician should weigh the risks versus the benefits of the dental radiographic images required.[1,2] Previous studies have shown that children are more sensitive to radiation compared to adults.[3] One of the most effective methods to reduce radiation exposure is by utilizing rectangular collimation.[4] Various studies have shown a significant reduction of patient exposure to radiation when using a rectangular collimator.[1, 7] The main perceived barriers of dentists to the utilization of rectangular collimators are the lack of adequate training, difficulty in training staff, increased risk of cone cuts that can lead to increased patient exposure with retakes, cost of changing existing equipment, and implementing the use of the collimator.[8, 17] In order to address this concern of cone cuts with rectangular collimators, various devices have been produced such as the Tru-Image® rectangular collimator, which has a position locking device. The Tru-Image® rectangular collimator has a light on the device that indicates proper positioning of the collimator. There is a lack of research publications evaluating the patient exposure with the use of this Tru-Image® rectangular collimator in children. One method to safely test the patient exposure is through the use of a child imaging phantom.

OBJECTIVE

The aim of this study was to compare the effective dose (E), or the tissue weighted sum of the equivalent dose of tissues or specific organs, on a pediatric phantom using the Tru-Image® rectangular collimator and a universal round collimator for two bitewing radiographs (right and left bitewing).

METHODS

- A pediatric phantom with tissue equivalency of a 10-year-old child was utilized (Figure 1).
- 24 dosimeters in each set were placed within the 9 slabs.
- The phantom was placed on an articulating tripod and kept at a consistent position.
- The Planmeca® wall-mounted radiograph unit was used for all exposures using the manufacturer's child settings for bitewings of 63 kV, 8mA, 0.1 seconds.
- For each set of dosimeters, 50 clinical exposures of two bitewings (right and left) were exposed, and this was repeated three times for the universal round collimator (Figure 2) and three times for the Tru-Image® rectangular collimator (Figures 3 and 4).
- The OSLD dosimeters were read using the Microstar commercial reader at the University of North Carolina.
- The equivalent dose for each location and the overall effective dose (E) was calculated.
- Equivalent dose values at each location and overall effective doses (E) were analyzed separately using two-sample t-tests to compare between the collimators. A 5% significance level was used for all tests.

Figure 1. Pediatric Tissue Equivalent Phantom

Figure 2. Universal Round Collimator with the Pediatric Phantom

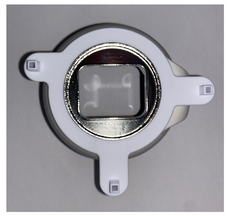


Figure 3. Tru-Image® Rectangular Collimator

Figure 4. Tru-Image® Rectangular Collimator with the Pediatric Phantom

Figure 5. Equivalent Dose (µSv) by Location

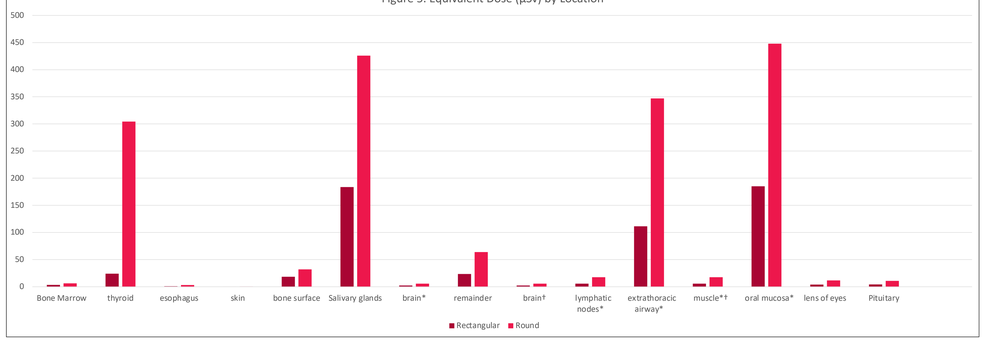
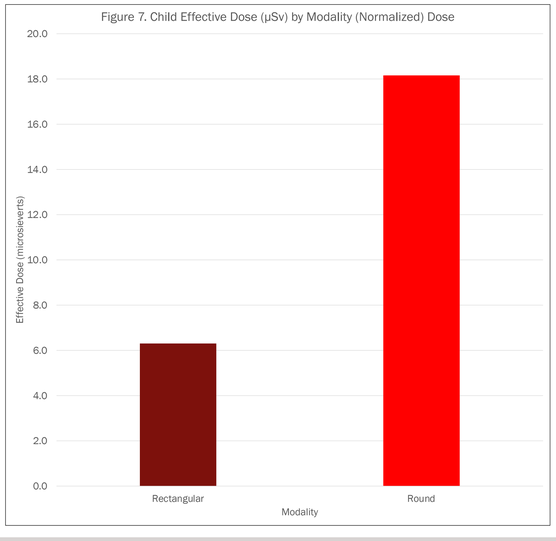


Figure 6. Summary of Equivalent Dose by Location, Mean Difference for Each Modality, and Total Effective Dose in Microsieverts

Location	Type	Mean ± (SD)	Mean ± (SE)	Min	Max	p value (sig)
Bone Marrow	Round	6.2 (0.2)	6.2 (0.1)	5.9	6.4	<.0001 (*)
	Rectangular	3.6 (0.1)	3.6 (0.1)	3.5	3.7	
thyroid	Round	304.3 (10.4)	304.3 (6.0)	292.7	312.9	0.0004 (*)
	Rectangular	24.0 (0.7)	24.0 (0.4)	23.3	24.7	
esophagus	Round	3.3 (0.2)	3.3 (0.1)	3.1	3.4	<.0001 (*)
	Rectangular	0.9 (0.1)	0.9 (0.0)	0.8	1.0	
skin	Round	0.5 (0.0)	0.5 (0.0)	0.5	0.5	<.0001 (*)
	Rectangular	0.2 (0.0)	0.2 (0.0)	0.2	0.2	
bone surface	Round	31.9 (1.2)	31.9 (0.7)	30.6	33.0	<.0001 (*)
	Rectangular	18.3 (0.5)	18.3 (0.3)	17.7	18.8	
Salivary glands	Round	425.9 (11.1)	425.9 (6.4)	413.7	435.5	<.0001 (*)
	Rectangular	183.6 (6.7)	183.6 (3.9)	176.3	189.6	
brain*	Round	5.8 (0.2)	5.8 (0.1)	5.6	6.0	<.0001 (*)
	Rectangular	2.3 (0.1)	2.3 (0.1)	2.2	2.5	
remainder	Round	63.9 (1.7)	63.9 (1.0)	61.9	65.1	<.0001 (*)
	Rectangular	23.7 (1.1)	23.7 (0.6)	22.5	24.6	
brain†	Round	5.8 (0.2)	5.8 (0.1)	5.6	6.0	<.0001 (*)
	Rectangular	2.3 (0.1)	2.3 (0.1)	2.2	2.5	
lymphatic nodes*	Round	17.7 (0.5)	17.7 (0.3)	17.1	18.1	<.0001 (*)
	Rectangular	5.6 (0.2)	5.6 (0.1)	5.3	5.8	
extrathoracic airway*	Round	347.2 (9.5)	347.2 (5.5)	336.4	354.7	<.0001 (*)
	Rectangular	111.3 (4.8)	111.3 (2.7)	106.2	115.6	
muscle*†	Round	17.7 (0.5)	17.7 (0.3)	17.1	18.1	<.0001 (*)
	Rectangular	5.6 (0.2)	5.6 (0.1)	5.3	5.8	
oral mucosa*	Round	447.8 (11.6)	447.8 (6.7)	434.5	456.1	<.0001 (*)
	Rectangular	185.1 (8.5)	185.1 (4.9)	175.8	192.5	
lens of eyes	Round	11.7 (0.8)	11.7 (0.4)	10.9	12.4	0.0025 (*)
	Rectangular	4.0 (0.2)	4.0 (0.1)	3.9	4.2	
Pituitary	Round	10.9 (0.7)	10.9 (0.4)	10.2	11.7	0.0001 (*)
	Rectangular	4.2 (0.3)	4.2 (0.2)	4.0	4.5	
Effective Dose	Round	25.3 (0.7)	25.3 (0.4)	24.5	25.9	<.0001 (*)
	Rectangular	6.3 (0.2)	6.3 (0.1)	6.1	6.5	

Figure 7. Child Effective Dose (µSv) by Modality (Normalized) Dose



RESULTS

- The whole-body E for the Tru-Image® rectangular collimator was 6.3 µSv, and the whole-body E for the universal round collimator was 25.3 µSv. This difference in E was statistically significant (p<.05).
- For the Tru-Image® rectangular collimator, the highest equivalent dose was seen with the oral mucosa (185.1 µSv). For the universal round collimator, the highest equivalent dose was seen with the oral mucosa (447.8 µSv) (Figures 5 and 6) .
- For the thyroid, the equivalent dose for the Tru-Image® rectangular collimator was 24 µSv and for the universal round collimator was 304.3 µSv.
- For all locations, the mean differences in the equivalent doses between both collimators was statistically significant (p<.05).
- The normalized effective dose was 6.3 µSv for the Tru-Image® rectangular collimator and 18.2 µSv for the universal round collimator. Based on these doses, the overall percentage of dose reduction of the rectangular collimator was 65% (Figure 7).

CONCLUSIONS

Based on this study's results, the following conclusions can be made:

- The average effective dose (µSv) of two bitewings using the Tru-Image® rectangular collimator was significantly lower than the universal round collimator when using the manufacturer settings for a child.
- Once normalized for source to end distance, there was an overall 65% reduction of radiation with the Tru-Image® rectangular collimator when compared to the universal round collimator.
- The equivalent dose of the thyroid was reduced by 12 times when two bitewings were taken with the Tru-Image® rectangular collimator compared to the universal round collimator.

REFERENCES

1. Affairs, A.D.A.C.o.S., *The use of dental radiographs: update and recommendations.* J Am Dent Assoc, 2006. 137(9): p. 1304-12.
2. Law, C.S., et al., *The image gently in dentistry campaign: partnering with parents to promote the responsible use of x-rays in pediatric dentistry.* Pediatr Dent, 2014. 36(7): p. 458-9.
3. Okano, T. and J. Sur, *Radiation dose and protection in dentistry.* Japanese Dental Science Review, 2010. 46(2): p. 112-121.
4. Johnson, K.B., et al., *Technical Performance of Universal and Enhanced Intraoral Imaging Rectangular Collimators.* J Dent Hyg, 2015. 89(4): p. 238-46.
5. Goren, A.D., et al., *Evaluation of radiation exposure with Tru-Align intraoral rectangular collimation system using OSL dosimeters.* N Y State Dent J, 2011. 77(2): p. 24-7.
6. Johnson, K.B. and J.B. Ludlow, *Intraoral radiographs: A comparison of dose and risk reduction with collimation and thyroid shielding.* J Am Dent Assoc, 2020. 151(10): p. 726-734.
7. Horner, K., *Review article: radiation protection in dental radiology.* Br J Radiol, 1994. 67(803): p. 1041-9.
8. Shetty, A., et al., *Evidence on radiation dose reduction using rectangular collimation: a systematic review.* Int Dent J, 2019. 69(2): p. 84-97.
9. Zhang, W., et al., *Comparison of the efficacy and technical accuracy of different rectangular collimators for intraoral radiography.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2009. 108(1): p. e22-8.
10. Magill, D., et al., *Kerma area product (KAP) and scatter measurements for intraoral X-ray machines using three different types of round collimation compared with rectangular beam limiter.* Dentomaxillofac Radiol, 2019. 48(2): p. 20180183.
11. Ludlow, J.B., L.E. Davies-Ludlow, and S.C. White, *Patient risk related to common dental radiographic examinations: the impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation.* J Am Dent Assoc, 2008. 139(9): p. 1237-43.
12. White, S.C. and M.J. Pharoah, *White and Pharoah's Oral Radiology E-Book: Principles and Interpretation.* 2018: Elsevier Health Sciences.
13. Campbell, R.E., et al., *A survey on radiation exposure reduction methods including rectangular collimation for intraoral radiography by pediatric dentists in the United States.* J Am Dent Assoc, 2020. 151(4): p. 287-296.
14. Platin, E., A. Janhom, and D. Tyndall, *A quantitative analysis of dental radiography quality assurance practices among North Carolina dentists.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 1998. 86(1): p. 115-20.
15. Bohay, R.N., S.L. Kogon, and R.G. Stephens, *A survey of radiographic techniques and equipment used by a sample of general dental practitioners.* Oral Surg Oral Med Oral Pathol, 1994. 78(6): p. 806-10.
16. Tugnait, A., V. Clerehugh, and P.N. Hirschmann, *Radiographic equipment and techniques used in general dental practice: a survey of general dental practitioners in England and Wales.* J Dent, 2003. 31(3): p. 197-203.
17. Parks, E.T., *Errors generated with the use of rectangular collimation.* Oral Surg Oral Med Oral Pathol, 1991. 71(4): p. 509-13.
18. Horton, P.S., et al., *A comparison of rectangular and cylindrical collimation for intraoral radiographs.* J Dent Educ, 1983. 47(12): p. 771-3.
19. Johnson, K.B., et al., *Reducing the risk of intraoral radiographic imaging with collimation and thyroid shielding.* Gen Dent, 2014. 62(4): p. 34-40.
20. *The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103.* Ann ICRP, 2007. 37(2-4): p. 1-332.

IUPUI
INDIANA UNIVERSITY
School of Dentistry