Reducing Pediatric Intraoral Radiography Radiation Dose Using Reduced-Power Dental X-Ray Units: A Randomized Trial

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ABSTRACT

Purpose: To assess the diagnostic confidence of intraoral radiographic image quality while reducing the pediatric patient's radiation exposure using a longer position indicating device (PID), additional X-ray beam filtration and rectangular collimation while using modern, lower-power intraoral dental X-ray units.
Methods: A randomized prospective study scored bitewing intraoral dental images based on relevant clinical features. Observer studies with pediatric dentists and dental residents were conducted to verify whether diagnostic confidence remained unchanged after dose reduction modifications. The study involved a two-phase investigation to determine: (1) the best thickness of aluminum (Al) 2024-T3 alloy filter and (2) required increased exposure time to maintain intraoral radiographic image quality. A 30 cm PID with a rectangular collimator was used to further manage patient dose. For each phase, images from 125 patients were collected from February 2017 to September 2018 and analyzed.
Results: The results from the observer study using a 30 cm PID, 1.02 mm thick Al alloy filter, and a rectangular collimator resulted in a patient dose reduction between 64 percent (exposure time of 400 msec) to 77 percent (250 msec), without any statistically significant effect to the diagnostic confidence of the observers in evaluating the reduced radiation images.
Conclusion: Long recognized dose reduction methods, when implemented on a modern, low-power intraoral dental X-ray unit, do not impact confidence in bitewing diagnostic images, but substantially reduce patient dose and should be adopted to increase patient safety, especially for children. (J Dent Child 2022;89(2):95-103)

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Dental intraoral radiographs are obtained routinely as part of dental examinations.[1,2] The radiation dose to an individual patient from a dental radiographic examination is small compared to other common radiographic examinations, such as chest radiographs or a computarized tomography scan of the abdomen.[3] While a radiation dose from a dental radiograph is small, dental radiographs are more frequently performed than other radiographic examinations, including at a younger age.[4] This suggests that dental professionals should properly manage the delivered radiation dose for dental images, especially for pediatric patients, while actively maintaining image quality.[5] According to the American Academy of Pediatric Dentistry (**AAPD**) policy on patient safety, assuring patient safety is an essential component in providing quality dental care to the pediatric dental patient.[6] Furthermore, the AAPD's recommendation to practitioners regarding prescribing dental radiographs for the pediatric population places a strong emphasis on reducing radiation exposure.[7]

Dental radiation dose reduction techniques using aluminum (**Al**) and copper (**Cu**) filters, rectangular collimation and a longer position-indicating device (**PID**) were recommended 60 years ago.[8,9] The use of an Al and Cu beam filter removes low-energy X-rays from the beam that primarily contribute to patient dose, not the creation of the radiograph. Standard dental rectangular collimation (3.2 cm by 4.0 cm, area 12.8 cm^2) is 50 percent of the area of standard circular collimation (5.7 cm diameter, area 25.5 cm^2), The rectangular collimator reduces the area of patient's skin exposed to direct X-rays in half. Furthermore, with a longer PID, the distance from the radiation source (i.e., the X-ray tube focal spot) to the patient's skin surface is increased, which leads to a reduction of radiation incident to the mouth. These methods were designed to achieve better patient dose management during dental X-ray examinations based on well-known physics principles that have been carefully studied elsewhere: extended PID,[9,10] additional radiographic filters[2,10-16] and collimation.[3,10,12,15,17-19] Yet, to date, none of these reported suggestions have been widely implemented in dental clinics in the United States.

One possible reason for not using the three documented radiation dose reduction techniques is the concern that the reduced electrical power of state-of-the-art dental X-ray units may not be sufficient to clinically support these three dose reduction techniques. Reduced dental unit power in today's marketplace occurred in response to the adoption of faster radiographic film and digital image receptors, both of which require lower levels of radiation to create good intraoral radiographs.[20] However, the recommendations of additional X-ray beam filtration and a longer PID to reduce radiation to the patient were made in an era when intraoral dental X-ray units were more powerful.[8,9] Dental X-ray units 60 years ago produced more than double the electrical power at 1,050 watts (15 mA * 70 kV)[21] compared to 420 watts (6 mA * 70 kV) of current state-of-the-art intraoral dental radiographic units.[22]

With the limited electrical power of current dental units, the X-ray exposure time must increase to generate sufficient radiation output to maintain image quality. While longer exposure times can reduce image noise levels in the radiograph, the potential downside is a blurred image due to patient motion during the radiation exposure.

The purpose of this study was to determine if the recommended dose reduction strategies, namely a longer PID, additional X-ray beam filter and a rectangular collimator, can be used to reduce patient radiation dose using modern, low-power dental intraoral X-ray units without reducing diagnostic confidence in the dental radiograph due to patient motion during longer required exposure times.

METHODS

DATA COLLECTION

This randomized prospective study was completed on pediatric patients that underwent an intraoral dental radiographic examination as part of their routine dental visit. This study was compliant with the Helsinki Declaration, Health Insurance Portability and Accountability Act and was approved by the Institutional Review Board (IRB) at Cincinnati Children's Hospital, Cincinnati, Ohio, USA (#2017-7355). Bitewing images were acquired from one of the dental radiographic units (Gendex model 765, Gendex Dental, Hatfield, Pa., USA) in the dental clinic of a large academic pediatric hospital. This unit had a single voltage and tube current setting of 65 kV and 7 mA and an operator selectable exposure time from 20 to 2,000 msec. The radiographic unit was retrofitted with a commercially available 30 cm long PID, rectangular collimator (EDC 3.2 by 4.0 cm, model 1999146, General Electric, Waukeshaw, Wis., USA), and Al X-ray beam filter (2024-T3 alloy, McMaster-Carr, Elmhurst, Ill., USA). This replaced the standard circular 5.7 cm diameter, 20 cm long PID. ScanX intraoral phosphor plates (Air Techniques, Melville, N.Y., USA) using a 503 dpi setting were used as the digital image receptor. The same operator produced all radiographs for this study to minimize variation in radiographic technique. Patients were randomized by a blinded clinical scheduler. Scheduled patients were randomly assigned to the single dental procedure room with dose reduction modifications in situ. The IRB waived the need for consent since the medical physicists who designed the study made sure that all combinations of added filter and exposure time included in the study resulted in patient radiation doses less than or equal to the standard dose used within the clinic prior to the beginning of the study.

The purpose of this study was to assess the diagnostic confidence of intraoral radiographic image quality while reducing the pediatric patient's radiation exposure using a longer position indicating device (PID), additional X-ray beam filtration and rectangular collimation while using modern, lower-power intraoral dental X-ray units. This study was divided into two observer studies conducted to: (1) select the thickness of the Al alloy filter that provided good image contrast; and (2) assess noise and or motion unsharpness in the image with different exposure times.

DATA FOR OPTIMAL FILTER THICKNESS

Data were collected between February 2017 and April 2017, for the first part of this study, using one of five experimental configurations. The standard technique used in the clinic prior to the start of the study (i.e., 160 msec exposure time, 65 kV, 7 mA, 20 cm PID, no additional filter and circular collimator) was used as the experimental control. Dental radiographs obtained from the control group were compared with radiographs obtained using commercially available 0.51 mm, 0.64 mm, 0.81 mm and 1.02 mm of added Al alloy filter thickness inserted into the X-ray beam at the proximal end of the PID. Added filters greater than 1.02 mm were not tested to avoid the possibility of motion unsharpness in noncooperative pediatric patients where exposure times would have been more than double the baseline exposure time of 160 msec. The rectangular collimator was placed at the distal end of the 30 cm PID. Twenty-five patients were selected using random sampling for each of the five experimental configurations, resulting in a total of 125 cases analyzed.

To evaluate the impact of filter thickness on image contrast and observer confidence, image noise in the dental images was held constant for each filter thickness. This was achieved by adjusting the radiographic technique for each filter thickness to maintain a radiation output of 1.25 mGy (measured output of control examination, Table 1, first row) one cm beyond the rectangular collimator, the normal location of the patient's mouth. Radiation measurements were performed using a solid-state detector (RTI Electronics AB, Molndal, Sweden).

DATA FOR OPTIMAL EXPOSURE TIME

The selected Al alloy filter thickness from part one of this study was paired with a 30-cm PID and rectangular collimator. Data were collected between July 2018 and September 2018, for the second observer study, to select exposure time based on the effect of image noise and possible motion blur on diagnostic confidence by acquiring patient radiographs using fixed technique factors of 65 kV and 7 mA at five different exposure times: 200 msec, 250 msec, 320 msec, 400 msec and 500 msec. The 500 msec acquisition technique was used as the control group in part two. The radiation output at 500 msec was selected because it was within 10 percent of the radiation output of the control group from part one (Table 1); the 10 percent deviation stemmed from a limitation of discrete exposure times available on the intraoral X-ray unit. Twenty-five patients were selected using random sampling for each of the five exposure times, resulting in a total of 125 cases analyzed.

PATIENT DOSE REDUCTION CALCULATIONS

Two different indicators of patient dose reduction were calculated. The first was the reduction of radiation output at the entrance to the patient. Technically, this was the measured air KERMA without backscatter, $K_{a,i}$, hereafter simply indicated as "radiation output." The second indicator was the reduction of KERMA Area Product (**KAP**), a measurement of patient radiation output that accounts for the total area of exposure of the patient's mouth. KAP reduction was calculated as the ratio of KAP of the investigated acquisition techniques and the standard clinical technique (Table 1).

OBSERVER STUDY FOR IMAGE QUALITY ASSESSMENT

To avoid observer preferential bias to image display settings, all images were processed for viewing with an identical postprocessing setting in MiPACS (Dental Enterprise Viewer 3.1.1.404; Dental Enterprise, Charlotte, N.C., USA). The observer study was performed using a modified version of the open-source software Vqone[23] (Visual Cognition Research Group, University of Helsinki, Helsinki, Finland) presented the images in a random sequence and recorded observer responses in an Excel database (Microsoft, Seattle, Wash., USA). The images for the observer study were displayed on HP LCD monitors (Hewlet Packard, Palo Alto, Calif., USA). The brightness, contrast and color balance of the monitors were calibrated using the open-source tool Calibrize 2.0[24] (Colorjinn, Amsterdam, Netherlands) and defective pixels, uniformity, gradients and sharpness were assessed using EZIO's monitor test[25] (EZIO, Hakusan, Ishikawa Prefecture, Japan).

OBSERVER STUDY DESIGN

The clinical quality of the intraoral images was scored by five blinded participants: a board-certified orthodontist (filter thickness and exposure time); two board-certified pediatric dentists (filter thickness and exposure time); one first-year pediatric dental resident (exposure time only) and one final-year pediatric dental resident (filter thickness only). They used five clinical criteria: (1) How confident are you in identifying interproximal caries? (2) How confident are you in distinguishing occlusal caries (occlusal enamel/dentin boundary)? (3) How confident are you in detecting interdental papillae? (4) How confident are you in visualizing alveolar crest height sharpness versus rounded corners? (5) How confident are you in assessing pulp horns? All observers were blinded to the intraoral radiograph acquisition methodology.

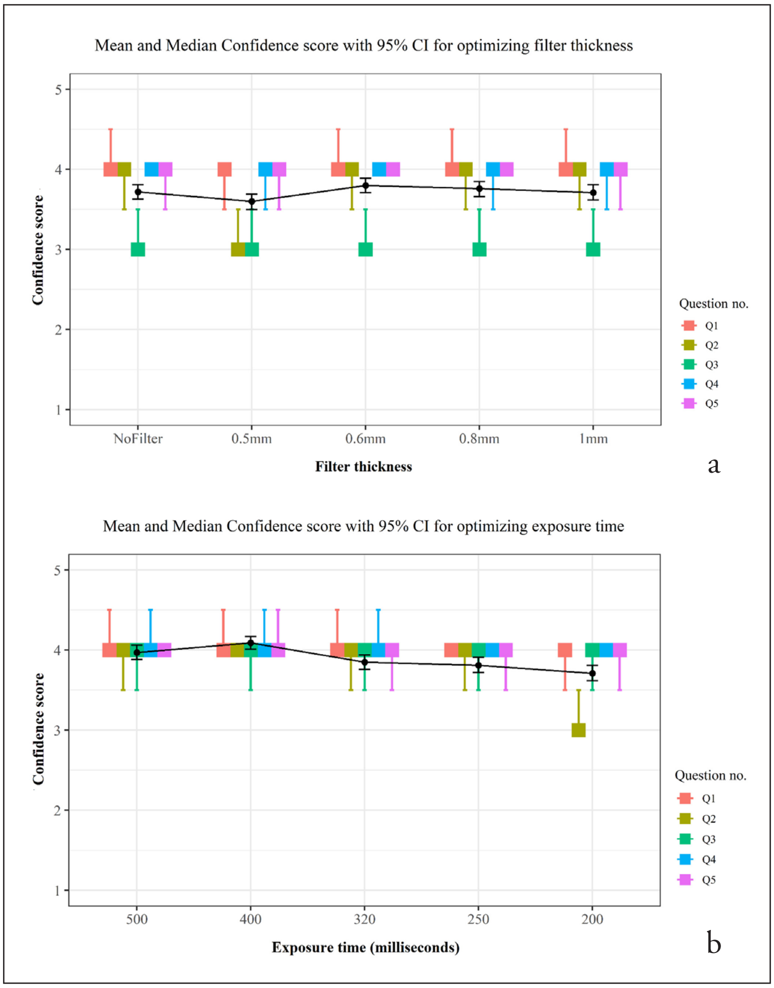

Figure 1. The median confidence score for each question type (colored) and overall mean confidence score (black dots) for (a) part one filter thickness and (b) part two exposure time observer studies. Hidden wicks indicate either the median lower or higher confidence limit was the same. Questions: (1) How confident are you in identifying interproximal caries? (2) How confident are you in distinguishing occlusal caries (occlusal enamel/dentin boundary)? (3) How confident are you in detecting interdental papillae? (4) How confident are you in visualizing alveolar crest height sharpness vs rounded corners? (5) How confident are you in assessing pulp horns? Confidence rating score: (1) not confident; (2) minimally confident; (3) somewhat confident; (4) mostly confident and (5) very confident.

A scoring scale similar to a five-point Likert scale[26] was developed to assess observer confidence concerning five major clinically relevant observations by analyzing image features described using the survey questions. The Likert scale and the responses were decided by the participating dentists themselves after they agreed upon the corresponding interpretations. The scale was defined as: (1) not confident; (2) minimally confident; (3) somewhat confident; (4) mostly confident and (5) very confident. Equal importance was assigned to each question. Subjective scales similar to this have been used in many other studies to evaluate radiographs.[27-33] Bitewing images were reviewed because they are most suited to evaluate interproximal enamel surfaces for caries and alveolar crest height for periodontal disease.[34,35] Occlusal caries may be identified clinically and confirmed radiographically at the occlusal enamel dentin interface.[36] The size and shape of pulp horns are important in planning restorations, especially in children, and should be evaluated radiographically.[37] The amount of contrast may be evaluated by the ability to detect the soft tissue interdental papilla.[34]

STATISTICAL ANALYSIS

R statistical software[38] with the "ordinal" package[39] (Free open source designed by Thakia R and Gentleman R) was used to model the observer response data using cumulative link mixed models (CLMM).[40] A more detailed explanation of the specific CLMM model used for this study is given in the Appendix. Ordinal confidence intervals of the mean and median confidence scores with confidence

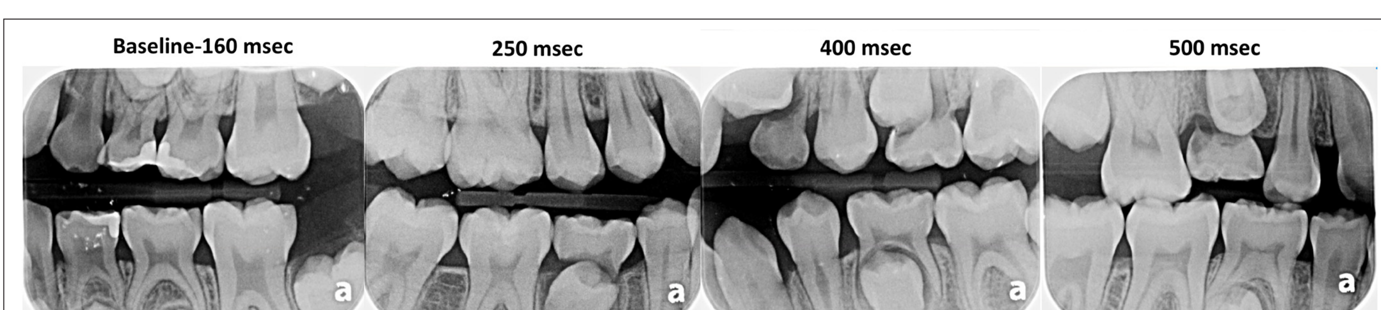

Figure 2. Sample bitewing images from part two observer study are presented. The images acquired at 200 msec to 500 msec were rated using a 30-cm long position indicating device, 1.02-mm Al filter and rectangular collimator in place. Three images at exposure times of 250, 400 and 500 msec are presented along with a baseline image for image quality comparison. A small increase in image noise at exposure times less than 400 msec and a slight unsharpness in the image at an exposure time of 500 msec were observed.

intervals were calculated via the nonparametric Wilcox method using bootstrapping.[41]

SAMPLE SIZE SELECTION

The number of patient images for each stage of the observer study was determined by a Monte Carlo simulation using a simplified ordinal logistic regression model with the logit link function and a single treatment effect. The model parameters for this simulation were determined from a pilot observer study. The simulation was run with multiple samples and assigned to control and treatment groups (i.e., filter thickness and exposure time) using uniform random sampling. The average power was determined based on a type one error rate of 0.05 and an odds ratio of 0.20 for the effect size. The 0.20 odds ratio indicated a 1.8 times greater likelihood to choose a lower confidence score for the treatment groups in comparison to the control group. A total sample size of 125 for each observer study was determined based on a power level of 0.80.

RESULTS

SELECTED AL ALLOY FILTER THICKNESS

The CLMM analysis of the confidence ratings for part one showed no statistically significant effect (P=0.74) due to any of the Al alloy filter experimental thicknesses, indicating that the observer's confidence rating was not affected by the use of filters ranging in thickness from 0.51 to 1.02 mm. Therefore, the 1.02 mm Al alloy filter, which gave the greatest patient dose reduction potential of the filter thicknesses tested, was chosen for part two of the study.

The median observer's confidence rating was four (mostly confident) for all questions and filter combinations, except question three (How confident are you in detecting interdental papillae?), which had a median rating of three consistently for all filters and the control group.

Table 1. Radiographic Techniques and Measured Radiation Output 1 cm Beyond the Position Indicating Device

PID* (cm)	Exposure time (msec)	Added filtration (mm Al)	Radiation output (mGy)	Circular cone KAP** (mGycm²)	Circular cone KAP reduction	Rectangular cone KAP (mGycm²)	Rectangular cone KAP reduction
20	160	0	1.25	32	0%	16	50%
30	500	1.02	1.12	29	9%	14.5	55%
30	400	1.02	0.90	23	28%	11.5	64%
30	320	1.02	0.72	18	44%	9	72%
30	250	1.02	0.57	15	54%	7.5	77%
30	200	1.02	0.46	12	62%	6	81%

* PID=position indicating device; KAP reduction was calculated for each of the exposure time configurations with 1.02 mm of added aluminum alloy filtration. Dose reduction potential for no collimation (i.e., circular cone only) and for rectangular collimation was compared. The control group for which all radiation output reduction was compared (row 1) was for the acquisition configuration acquired using 65 kV, 7 mA, 160 msec with no added filtration, circular cone (i.e., no collimation) and a 20-cm PID.

** KAP=air KERMA Area Product.

SELECTED EXPOSURE TIME

For part two, the best overall mean confidence score was achieved when the exposure time was 400 msec (Figure 1a). The three clinical images in Figure 2 exposed with the 30 cm long PID, 1.02-mm Al filter in place and rectangular collimator (250, 400 and 500 msec exposure time) illustrated a small increase in image noise at exposure times less than 400 msec and a potential unsharpness in images at an exposure time of 500 msec. Figure 1b showed the median confidence rating for each question type along with the overall mean confidence score at each exposure time. The median ratings for all survey questions were four (mostly confident) for all exposure times, except question two (How confident are you in distinguishing occlusal caries [occlusal enamel/dentin boundary]?) acquired at 200 msec. Based on the 95 percent confidence interval, the lowest acceptable exposure time with a median diagnostic confidence rating of four, for all questions, was determined to be 250 msec (Figure 1b). The statistical likelihood of finding a lower or higher confidence score for each of the experimental exposure times compared to the control group was reported in Table 2.

Table 2. Cumulative Link Mixed Models with the Odds Ratio and Wald's P-Value Compared Experimental Exposure Timings to 500 msec (Control Group)

Parameters (msec)	Odds ratio*	P-value
Exposure 400	1.24	0.056
Exposure 320	0.80	0.051
Exposure 250	0.75	0.013
Exposure 200	0.64	< 0.001

* Odds ratio calculations indicated a 24 percent chance of selecting a higher confidence rating for 400 msec over 500 msec, but the difference was not significant (P=0.056). There was also a 20 percent (P=0.051), 25 percent (P=0.013) and 36 percent (P<0.001) chance of choosing a lower confidence rating for 320 msec, 250 msec, and 200 msec, respectively, compared to 500 msec.

PATIENT DOSE REDUCTION

The standard clinical technique with 20 cm PID, no added X-ray beam filtration and no rectangular collimator resulted in a radiation output of 1.25 mGy and KAP of 32 $mGycm^2$ (Table 1). KAP reductions were calculated for each exposure time configuration in part two, with and without the rectangular collimator (columns six and eight, respectively, Table 1). The reductions in the KAP in column six are due to the longer PID and filter, while the increased reductions in column eight are due to the addition of the rectangular collimation. The configuration with the best overall mean confidence scores (i.e., 400 msec, 30 cm PID, 1.02 mm Al alloy filter and rectangular collimation) measured a KAP of 11.5 $mGycm^2$, 64 percent [1 – (11.5/32)] patient dose reduction, as compared to the original clinical setup. The greatest radiation output reduction potential that resulted in a median diagnostic confidence rating of four (mostly confident) for all questions was realized for the configuration of 250 msec, with a 30 cm PID, 1.02 mm Al alloy filter and rectangular collimator. This configuration led to a KAP of 7.5 $mGycm^2$ and a 77 percent [1 – (7.5/32)] patient dose reduction.

DISCUSSION

Multiple methods were used to demonstrate that patient radiation dose reduction using currently available state-of-the-art, low-power dental X-ray units was feasible. Patient radiation dose (i.e., KAP) was reduced by 64 percent (acquired at 400 msec) to 77 percent (250 msec), which is a greater KAP reduction than previously reported (20 to 50 percent).[30,32,35]

Added X-ray beam filtration removed low-energy X-rays from the beam to reduce radiation dose to the patient's skin and other organs. The remaining higher-energy X-rays were more efficient for image formation. Using higher-efficiency X-rays, due to added filtration, led to patient dose reduction while maintaining adequate image quality in the dental radiograph. For standard radiographic machines in a radiology department, patient dose reduction using an X-ray beam filter is typically achieved using a one mm 1100 alloy Al filter with an added layer of 0.1 mm Cu.[42] This provides a composite filter of approximately 11 percent Cu and 89 percent Al, which more effectively reduces the number of low-energy X-rays from the beam than Al alone. However, the use of such filtration would require unacceptably long exposure times in a dental clinic, leading to motion unsharpness in dental images. Since foils of Cu less than 0.05 mm thick are neither cost-effective nor readily available, the Al alloy 2024-T3 was selected. This alloy has approximately 94 percent Al, 4.4 percent Cu and trace amounts of other higher atomic number elements, such as manganese, silicon, zinc, nickel, chromium, lead and bismuth,[43] which more effectively reduced patient dose than the standard alloy of 1100 Al.

The measured KAP reductions in this study are an indication of the potential reduction in radiation risk. Any potential risk associated with dental radiographs depends on radiation doses received by the patient's organs. In this study, the radiation output was reduced by 28 percent to 54 percent due to the added filter and longer PID for 400 to 250 msec exposure times. The rectangular collimation cut the area of skin surface irradiated in half, further reducing the KAP to 64 percent to 77 percent for the same exposure time range. This estimated reduction of risk occurred without any significant loss of diagnostic confidence when using an exposure in the range of 250 to 400 msec.

Implementing the results of this study may be best performed with the consultation of a qualified medical physicist, who can carefully measure the radiation output one cm beyond the distal end of the PID for different choices of radiographic technique, filter thicknesses and PID length. However, a general implementation strategy would begin by installing the longer PID with an Al alloy filter and rectangular collimator, and selecting an exposure time between 250 and 400 msec. Diagnostic confidence was shown to be statistically similar within this exposure time range, provided the X-ray unit operates at 65 or 70 kV and 6 or 7 mA, respectively. The image quality preference for any dentist in any clinic can be adjusted by either reducing exposure time down to 250 msec (slightly noisier images at less patient dose) or increasing exposure time up to 400 msec (slightly less noisy images at increased patient dose).

A dental clinic might choose to implement only the longer PID and added filtration without introducing the use of a rectangular collimator. Once the longer PID and added filtration are installed and appropriate exposure times are determined by reviewing the image noise in the dental radiographs, the operator should be able to readily adapt to a longer PID with added filtration. This should reduce measured radiation output by 54 percent of its original value if 250 msec is selected. Adding the rectangular collimator would provide a reduction of KAP up to 77 percent, but this change requires more careful positioning of the tube head to avoid unacceptable cone cuts.

This study has limitations. Since the observer study was limited to the analysis of intraoral images, the results apply only to this specific examination. Reductions in KAP reported in this study may vary due to the maximum electrical power of the dental unit, existing added filtration in the X-ray beam, length of PID, image receptor brand and type (e.g., photostimulable phosphor, direct radiographic image receptor, film speed, etc.) and the dentist's tolerance of motion unsharpness, image contrast and image noise in the dental radiographs. The 30 cm PID, 1.02 mm thick 2024-T3 Al filter, 0.425 kW dental unit and 4.0 by 3.2 cm collimator may not be the specifications that result in optimum patient dose reduction. These specifications were chosen due to their availability and should be generalizable to most intraoral X-ray units in most dental clinics.

CONCLUSIONS

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

1. The limited power of modern-day dental radiographic units (e.g., 65 or 70 kV and 6 or 7 mA) is sufficient to allow the use of patient radiation reduction features, such as a 30 cm PID, 1.02 mm of additional Al alloy 2024-T3 X-ray beam filtration and rectangular collimation, without statistically significant loss of diagnostic confidence to common diagnostic tasks during intraoral dental imaging.
2. KAP can be reduced to one-half to one-quarter of its original value by using the patient radiation reduction techniques studied.
3. Dentists should strongly consider the use of a longer PID, X-ray beam filtration and rectangular collimation to increase patient safety for all patients, especially children.

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APPENDIX

Cumulative link mixed models (**CLMM**) models are used to perform logistic regression on ordinal response variables with multiple treatment effects, including both categorical and continuous predictors. By analyzing the parameters of the CLMM model, the variation in the confidence score, due to the primary predictor variable studied, (i.e., the effect on diagnostic confidence) such as for (part 1) Al alloy filtration thickness or (part 2) expo-sure time, was inferred. Further, any variation in the confidence scores due to the type of survey question and any interaction effects between the primary predictor variable and question type were also studied by modeling them as fixed effects.

The CLMM model[38] with the logit link function predicts the logarithmic odds of observing a confidence score (Y) in category j or below, versus observing a confidence score in category j+1 or above as shown in equation (1):

$$logit\,(P(Y_i \leq j)) = \theta_j - \beta_1(T_i) - \beta_2(\mathbf{Q}_i) - \beta_3(T_i Q_i) - u_1(O_i) - u_2(O_i) \quad \text{Eq 1}$$

$$logit\,(P(Y_i \leq j)) = log\,\frac{P(Y_i \leq j)}{P(Y_i > j)},$$

$i = 1,..N$ and $j = 1,..J-1$, where N is the number of observations in the study and J (equals 5) is the number of output response categories. The parameters in vector θ are the intercepts of the model, with each category j having its own cut point θ_j . Variation in the confidence score due to the primary effect (T) Al alloy filtration thickness, or exposure time and the type of survey question (Q) along with its interaction to the primary effect (TQ), are modeled as fixed effects (β with slope parameters). The variation due to the observers (O) was modeled as random effects (u, a standard normal distribution with zero mean and variance σ^2). The parameter estimates for the fixed effects are evaluated for statistical significance using Wald's *t*-test. Positive estimates for β indicate that the confidence score category might be higher for the treatment effect over the control, while negative estimates indicate the opposite. The odds ratio of choosing a different confidence score category for the treatment compared to the control group are obtained from the exponent of the parameter estimate (e^{β}. Maximum likelihood tests[37] were used to reduce the complexity of the models shown in equation (Eq. 1) for analysis by eliminating effects that were not statistically significant.