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TECHNICAL REPORT

A manufacturer's role in reducing the dose of cone beam computed tomography examinations: effect of beam filtration

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Objectives: The dosimetry of the Kodak 9500 cone beam CT (CBCT) unit (Carestream Health, Rochester, NY) was measured before and after installation of copper filtration.
Methods: Dosimetry of a pre-production Kodak 9500 CBCT unit was compared with a current production unit with 0.4 mm of added filtration and increased kVp. Thermoluminescent dosimeter 100 chips were placed at 24 locations in a RANDO (radiation analogue dosimetry) head phantom (Nuclear Associates, Hicksville, NY). Small, medium and large adult default exposure settings were used in separate dosimeter runs for large and medium field of view (FOV) examinations with both units. Equivalent dose and effective dose were calculated using International Commission on Radiological Protection (ICRP) 1990 and 2007 tissue weights.
Results: Estimations of risk using 2007 ICRP calculations increased by an average of 77% for large FOV scans and 125% for the medium FOV scans in comparison with 1990 calculations. With added filtration, effective dose for medium FOV examinations for default settings were: small adult 76 μSv, medium adult 98 μSv, and large adult 166 μSv. Effective doses for large FOV examinations were: small adult 93 μSv, medium adult 163 μSv, and large adult 260 μSv. Effective dose was reduced by an average of 43% in examinations made with increased filtration and adjusted kVp.
Conclusion: The manufacturer's installation of additional filtration with the adjustment of kVp in the Kodak 9500 CBCT unit resulted in significant patient dose reductions for examinations at all adult default settings.
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Keywords: cone beam computed tomography; radiation dosimetry; phantoms; risk assessment

Introduction

A review paper published at the end of 2007 in the *New England Journal of Medicine* estimated that between 1.5% and 2% of all cancers in the United States may be attributable to the radiation from CT studies.[1] While these figures may be debatable, there is substantial evidence supporting the risk of exposure to X-rays. Over the last two decades the per capita dose from all sources of ionizing radiation has almost doubled from 3.6 mSv to 6.2 mSv, largely owing to the increased use of CT[2]. Perception of the risk of exposure from examinations of the maxillofacial area[3] has also increased owing to the revision of tissues and tissue weighting factors in the International Commission on Radiological Protection (ICRP) 2007 recommendations for calculating effective dose.[4]

Cone beam CT (CBCT) has been cited as a lower dose technique for imaging of the maxillofacial area in comparison with CT, which may be as efficacious as CT for certain diagnostic tasks.[5,6] However, large variations in dose have been noted for different CBCT units for comparable examinations.[7] Furthermore, sevenfold differences in dose for the same examination by the same unit may be created by varying combinations of exposure factors for some units. Doses from some CBCT examination protocols have been shown to equal or exceed doses from comparable medical CT scans.[7]

Against this backdrop of increasing public concern over the risk of X-ray imaging, there has been a tremendous increase in the number of CBCT units purchased by non-radiology practices and operated by

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individuals with minimal training in radiation biology and protection. Dentistry is still in the first decade of dedicated commercial maxillofacial cone beam devices and we already have 15 manufacturers of 24 different units. These manufacturers play a critical role in determining examination dose through decisions regarding default exposure settings and exposure options. Continued effort to reduce the dose by manufacturers in new and post-release CBCT units will be important in reducing examination doses. This paper illustrates this concept using an example of dose reduction in the Kodak 9500 unit (Carestream Health, Rochester, NY) examination after the manufacturer increased beam filtration and adjusted exposure parameters of the unit.

Materials and methods

In December 2008, dosimetry measurements were made on a pre-production model of the Kodak 9500 three-dimensional cone beam radiography system (Carestream Health, Rochester, NY). The protocol described below was used to evaluate dosimetry. Subsequent to this the manufacturer increased filtration of the unit's X-ray beam and increased kVp of the generator, while maintaining mA for each of the default examination settings. The purpose of these changes was first to reduce dose and secondly to increase the image quality through a reduction of beam hardening artefacts that generally affect CT reconstruction algorithms. Testing the dose reduction was the primary purpose of the current study. Average tissue-absorbed dose, equivalent dose and effective dose are calculated for the anatomy of the head and neck area. Effective doses are reported using the 1990 ICRP recommendations[7] and superseding 2007 recommendations.[4]

The Kodak 9500 is a patient standing or seated format CBCT unit, which uses a flat panel detector with two field of view (FOV) options. The large FOV produces a cylinder that is nominally 18 cm high and 21 cm in diameter. The smaller or medium FOV is 9 cm high by 15 cm in diameter. The 9500 unit has variable mA and kVp options, which can be determined individually by the operator or selected from a display of default settings. Dosimetry evaluation of the pre-production unit included medium and large adult default settings for the large FOV and small and medium adult settings for the medium FOV (Table 1). Subsequent modification of the pre-production Kodak 9500 unit added 0.4 mm copper filtration and increased kVp at all default settings. This is the configuration of currently manufactured units. Default settings for small, medium and large adult exposures were used for both FOVs (Table 1).

Table 1 Examination exposure factors

	Initial configuration		*Added filtration*	
Default setting	*kVp*	*mAs*	*kVp*	*mAs*
Small adult	70	86.4	80	86.4
Medium adult	70	108	85	108
Large adult	74	108	90	108

Dosimetry was acquired using an average adult skull and tissue-equivalent phantom (RANDO — radiation analogue dosimetry system, Nuclear Associates, Hicksville, NY). Thermoluminescent dosimeter (TLD) chips were used to record the distribution of the absorbed radiation dose at selected locations in the head and neck region of the phantom. The 24 phantom sites measured in this study are shown in Figure 1. Neck, cheek and thyroid surface dosimeters were positioned at the vertical centre of the designated slice level and taped in position. The lens of eye dosimeters were centred over the anatomical location for the lens and taped in position. Internal dosimeters were approximately positioned in the vertical centre of the selected slice level and held in position by friction from the TLD's protective plastic envelope and the surface of the drilled space at the sampled anatomical location. During scanning the phantom was orientated with the occlusal plane approximately parallel to the scan rotation plane. Nine or ten scans were used for each dosimeter run to provide a more reliable measure of radiation in the dosimeters. TLD doses were divided by the number of scans to determine the "exposure per scan" for each dosimeter.

Pre-calibrated $3 \times 3 \times 1$ mm TLD 100 lithium fluoride chips were supplied and analysed by Landauer Inc (Landauer, Glenwood, IL). The standard deviation of readings from a sample of the supplied TLD 100 chips was less than $\pm 5\%$. Doses from TLDs at different positions within a tissue or organ were averaged to express the average tissue-absorbed dose in micrograys (μGy). The products of these values and the percentage of a tissue or organ irradiated (Table 2) in radiographic examination were used to calculate the equivalent dose (H_T) in microsieverts (μSv).[4] Overall reproducibility of calculations of effective dose in repeated examinations using this phantom and dosimeter protocol was within 2.5%.[8]

For bone marrow, the equivalent dose to the whole-body bone marrow was calculated using the summation of the individual equivalent doses to the calvarium, the mandible and the cervical spine. Determination of these equivalent doses is based on the distribution of active bone marrow throughout the adult body. The mandible contains 1.3%; the calvaria, 11.8%; and the cervical spine, 3.4%.[9] Following the technique of Underhill et al,[10] three locations within the calvarium were averaged to determine calvarial dose. For bone, a correction factor based on experimentally determined mass energy attenuation coefficients for bone and muscle irradiated with mono-energetic photons was applied.[11] An effective beam energy, estimated to be two-thirds of the peak beam energy for each X-ray unit, was used to determine bone:muscle attenuation ratios. A linear fit ($R^2 = 0.996$) of ratios from 40 kV to 80 kV obtained from published data[11] produced the following equation:

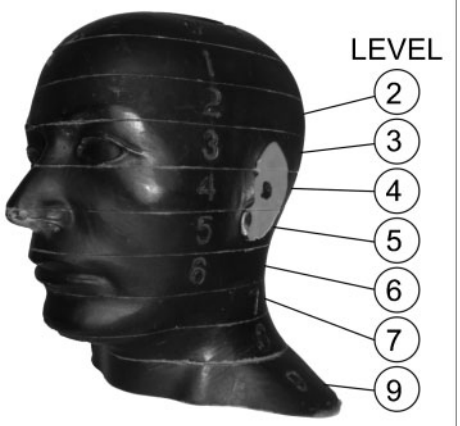
Phantom location (level of TLD location)	TLD ID	Phantom levels
Calvarium anterior (2)	1	
Calvarium left (2)	2	
Calvarium posterior (2)	3	
Mid brain (2)	4	
Pituitary (3)	5	
Right orbit (4)	6	
Left orbit (4)	7	
Right lens of eye (3)	8	
Left lens of eye (3)	9	
Right cheek (5)	10	
Right parotid (6)	11	
Left parotid (6)	12	
Right ramus (6)	13	
Left ramus (6)	14	
Centre C spine (6)	15	
Left back of neck (7)	16	
Right mandible body (7)	17	
Left mandible body (7)	18	
Right submandibular gland (7)	19	
Left submandibular gland (7)	20	
Centre sublingual gland (7)	21	
Midline thyroid (9)	22	
Thyroid surface — left (9)	23	
Oesophagus (9)	24	

Figure 1 Locations of thermoluminescent dosimeter (TLD) chips in radiation analogue dosimetry (RANDO) phantom

$$\text{Bone:muscle attenuation ratio} = -0.0618 \times \text{kV peak} \times 2/3 + 6.9406$$

Values calculated from this equation provided a bone:muscle attenuation ratio of 3.63 at 54 kV (80 kV peak), 3.42 at 57 kV (85 kV peak) and 3.21 at 60 kV (90 kV peak).

The proportion of skin surface area in the head and neck region directly exposed during maxillofacial CBCT imaging is estimated at 5% of the total body

Table 2 Estimated percentage of tissue irradiated and thermoluminescent dosimeter (TLD) used to calculate mean absorbed dose to a tissue or organ

	Fraction irradiated (%)	*TLD ID (see Figure 1)*
Bone marrow	16.5	
Mandible	1.3	13, 14, 17, 18
Calvaria	11.8	1, 2, 3
Cervical spine	3.4	15
Thyroid	100	22, 23
Oesophagus	10	24
Skin	5	8, 9, 10, 16
Bone surface[a]	16.5	
Mandible	1.3	13, 14, 17, 18
Calvaria	11.8	1, 2, 3
Cervical spine	3.4	15
Salivary Glands	100	
Parotid	100	11, 12
Submandibular	100	19, 20
Sub-lingual	100	21
Brain[b]	100	4, 5
Remainder		
Brain[c]	100	4, 5
Lymphatic nodes[b]	5	11–15, 17–22, 24
Muscle[b,c]	5	11–15, 17–22, 24
Extrathoracic airway[b]	100	6, 7, 11–15, 17–22, 24
Oral mucosa[b]	100	11–14, 17–21

[a]Bone surface dose is the bone marrow dose multiplied by the bone:muscle mass energy absorption coefficient ratio, which is equal to: $(-0.0618 \times {}^{2}/_{3}\ \text{kV peak}) + 6.9406$ using data taken from NBS (National Bureau of Standards) Handbook No. 85[11]
[b]2007 recommendations of the ICRP[4]
[c]1990 recommendations of the ICRP[13]

to calculate radiation weighted dose to the skin following the procedure reported by Ludlow et al.[12] Similarly, muscle and lymphatic node exposures are estimated to represent 5% of the total-body complement for these tissues. The proportion of the oesophageal tract that was exposed was set at 10%.

Effective dose (E) is a calculation that permits comparison of the detriment of different exposures to ionizing radiation with an equivalent detriment produced by a full-body dose of radiation. E, expressed in μSv, is calculated using the equation:

$$E = \sum w_T \times H_T$$

where E is the summation of the products of the tissue weighting factor (w_T), which represents the relative contribution of that organ or tissue to the overall risk, and the radiation weighted dose H_T.[4] The whole-body risk is found by the summation of the radiation weighted doses to all tissues or organs exposed. Both previous 1990 ICRP tissue weighting factors and new 2007 weighting factors found in Table 3 were used to calculate E.[4,13]

The 1990 weighting factors were assigned to 12 organs or tissues and a group of remainder organs for the purposes of calculating total E (Table 3). Of the individually weighted tissues or organs only bone marrow, oesophagus, thyroid, bone surface and skin doses are included in dose calculations for this study. Of the ten organs making up the remainder category, only brain and muscle are included. The other individual or remainder organs are not directly exposed in the protocols used in this study. While an assumption

Table 3 Tissue weighting factors for calculation of effective dose: ICRP 1990[13] and 2007[4] recommendations

Tissue	*1990*	*2007*
	w_T	w_T
Bone marrow	0.12	0.12
Breast	0.05	0.12
Colon	0.12	0.12
Lung	0.12	0.12
Stomach	0.12	0.12
Bladder	0.05	0.04
Oesophagus	0.05	0.04
Gonads	0.20	0.08
Liver	0.05	0.04
Thyroid	0.05	0.04
Bone surface	0.01	0.01
Brain	Remainder	0.01
Salivary glands	—	0.01
Skin	0.01	0.01
Remainder tissues	0.05[a]	0.12[b]

[a]Adrenals, *brain*, upper large intestine, small intestine, kidney, *muscle*, pancreas, spleen, thymus and uterus; [b]Adrenals, *extrathoracic region*, gall bladder, heart, kidneys, *lymphatic nodes*, *muscle*, *oral mucosa*, pancreas, prostate, small intestine, spleen, thymus and uterus/cervix. (Text in italics refers to the remainder tissues used for calculation of maxillofacial dose)

Table 4 Equivalent dose (μSv) to tissues and organs in the head and neck from Kodak 9500 large field of view (FOV) (18 × 21 cm) and medium FOV (9 × 15 cm) examinations using default exposure settings for small, medium and large adults and comparing pre-production and current production units

									Remainder				
Field (Adult size)	*Unit status*	*Bone marrow*	*Thyroid*	*Oesophagus*	*Skin*	*Bone surface*	*Salivary glands*	*Brain*[b]	*Brain*[a]	*Lymphatic nodes*[b]	*Extrathoracic airway*[a]	*Muscle*[a,b]	*Oral mucosa*[b]
18 × 21 cm (small)	Added filtration	134	471	36	70	485	1513	1017	1017	63	1262	63	1437
18 × 21 cm (medium)	Pre production	292	2000	216	345	1181	4573	2030	2030	190	3736	190	4239
	Added filtration	218	835	131	123	747	2645	1640	1640	114	2286	114	2549
	% reduction	25%	58%	39%	65%	37%	42%	19%	19%	40%	39%	40%	40%
18 × 21 cm (large)	Pre production	399	2045	307	451	1548	5447	2730	2730	233	4669	233	5219
	Added filtration	342	1356	233	182	1098	4161	2694	2694	185	3655	185	4048
	% reduction	14%	34%	24%	60%	29%	24%	1%	1%	21%	22%	21%	22%
9 × 15 cm (small)	Pre production	150	960	89	132	1039	3672	180	180	155	2738	155	3572
	Added filtration	70	475	52	33	255	1582	100	100	68	1196	68	1530
	% reduction	53%	51%	42%	75%	75%	57%	44%	44%	56%	56%	56%	57%
9 × 15 cm (medium)	Pre production	173	1010	117	176	1202	4682	265	265	189	3386	189	4413
	Added filtration	113	533	54	55	386	1680	264	264	94	1738	94	2143
	% reduction	35%	47%	54%	68%	68%	64%	0%	0%	50%	49%	50%	51%
9 × 15 cm (large)	Added filtration	170	840	90	86	547	3612	350	350	156	2836	156	3570

[a]ICRP 2007; [b]ICRP 1990

of no dose may underestimate actual exposure to these organs, the impact on total E is negligible.

Tissue weighting factors for 2007 increase the number of independently weighted tissues by 2 and expand the number of remainder tissues to 14 (Table 3). Of the new individually weighted tissues, both brain and salivary gland tissues were used in this study's calculations. 2007 remainder tissues directly exposed in maxillofacial CBCT exams include oral mucosa, lymphatic nodes, muscle and extrathoracic region (airway). A body fraction of 100% was used in the calculation of dose to oral mucosa and extrathoracic region tissues for the scanning protocols used in this study. Because the uterus and cervix is present only in females and the prostate only present in males, the number used in the weighted averaging of remainder tissues is 13.

Radiation detriment, defined as the total harm to an exposed population and their descendants, can be calculated using E. Detriment includes the weighted probabilities of fatal and non-fatal cancer, hereditary effects and the relative length of life lost. The coefficient assigned to these combined effects is 7.3×10^{-2} Sv^{-1} following the 1990 ICRP recommendations.[13] Because of great uncertainty on the form of the dose response below 1 Sv, the ICRP currently suggests that no specific judgment on low-dose risk of non-cancer diseases is possible. Therefore, a risk coefficient of 5.5×10^{-2} Sv^{-1} based on cancer risk alone was used for 2007 risk estimates (see ICRP 2007 Annex A).[4]

Results

Equivalent dose is summarized in Table 4, which provides equivalent doses for the weighted tissues and organs that receive direct exposure during maxillofacial imaging. Salivary gland contribution to effective dose is the highest of all weighted tissues. Oral mucosa and extrathoracic tissues received the next highest doses for weighted tissues and display similar patterns across large and medium FOVs. When the pre-production unit doses are compared with a current unit's doses, reduction in dose with added filtration is seen in almost every case. Table 5 compares E for the pre-production and currently configured Kodak 9500 units with added filtration. An average exposure reduction of 43% was found using default adult settings for both large and medium FOVs when the unit was equipped with additional filtration.

Table 6 compares E calculated with 1990 and 2007 tissue weighting factors for the current Kodak 9500 unit configuration. 2007 ICRP calculations of effective dose resulted in an average increase of 77% for large FOV scans and an increase of 125% for the medium FOV scans in comparison with 1990 calculations. Table 7 depicts an alternate means of comparing effective doses for the examinations tested using the current Kodak 9500 configuration. These comparisons include doses as multiples of average dental panoramic examinations, days of per capita background dose (based on an annual full body exposure of 3 mSv) and probability of a stochastic effect (ICRP 1990) or fatal cancer (ICRP 2007).

Table 5 Effect of filtration and kVp changes of pre-production and current Kodak 9500 cone beam CT units on effective dose

Technique	*Effective dose in μSv — ICRP 2007 pre-production configuration*	*Effective dose in μSv — ICRP 2007 added filtration configuration*	*% reduction in dose for current unit configuration*
Large FOV (18 × 21 cm)			
Small adult		93	
Medium adult	282	163	42
Large adult	339	260	23
Medium FOV (9 × 15 cm)			
Small adult	171	76	56
Medium adult	200	98	51
Large adult		166	
Average reduction			43

FOV, field of view; ICRP, International Commission on Radiological Protection

Table 6 Effective dose for large field of view (FOV) and medium FOV examinations with the Kodak 9500 unit[a]: Comparison of International Commission on Radiological Protection (ICRP) 1990 and 2007 calculations

Technique	*Effective dose in μSv — ICRP 1990 tissue weights*	*Effective dose in μSv — ICRP 2007 tissue weights*	*% change in effective dose 1990–2007*
Large FOV (18 × 21 cm)			
Small adult	52	93	78
Medium adult	92	163	77
Large adult	148	260	76
Average			77
Medium FOV (9 × 15 cm)			
Small adult	39	76	96
Medium adult	49	98	101
Large adult	76	166	118
Average			105

[a]Currently configured unit with 0.4 mm added copper filtration

Table 7 Doses of Kodak 9500 CBCT unit[a] adult default examinations using alternate measures of risk

Technique	*Effective dose in μSv — ICRP 1990 tissue weights*	*Effective dose in μSv — ICRP 2007 tissue weights*	*Dose as multiple of average panoramic dose (ICRP-1990)*	*Dose as multiple of average[b] panoramic dose (ICRP 2007)*	*Days of per capita background (ICRP 1990)*	*Days of per capita background (ICRP 2007)*	*Probability of x in a million stochastic effect ICRP 1990 (dose in μSv x 7.3×10^{-2})*	*Probability of x in a million fatal cancer ICRP 2007 (dose in μSv x 5.5×10^{-2})*
Large FOV (18×21 cm)								
Small adult	52	93	8	6	6	11	4	5
Medium adult	92	163	14	10	11	20	7	9
Large adult	148	260	23	16	18	32	11	14
Medium FOV (9×15 cm)								
Small adult	39	76	6	5	5	9	3	4
Medium adult	49	98	8	6	6	12	4	5
Large adult	76	166	12	10	9	20	6	9

CBCT, cone beam CT; ICRP, International Commission on Radiological Protection
[a]Currently configured unit with 0.4-mm added copper filtration
[b]Average of 5 units: Sirona-Orthopos XG, Planmeca-ProMax, Kodak-9000, SCANORA 3D, Instrumentarium-OP 200 VT = 16.1 μ

Discussion

Increases in kVp and beam filtration have the potential to reduce dose by reducing the number of low-energy photons in the X-ray beam. Low-energy photons with high probabilities of being absorbed in the patient regardless of the absorption characteristics of the tissue contribute little diagnostic information while adding to patient dose. Adjustments made in beam filtration and kVp in the current study have resulted in impressive reductions in dose, which were averaged at 43% for both FOVs and all adult default settings. The effect of these changes on image quality was not tested; however, subjectively, all images appeared diagnostic. Examples of images produced during dosimetry testing are seen in Figures 2 and 3.

Changes in tissue weighting factors and the inclusion of salivary glands as a weighted tissue in the 2007 recommendations of the ICRP have resulted in an upward reassessment of effective dose from oral and maxillofacial radiographic examinations in previously published studies.[3,7,14] The results of the current study also support this statement.

Concern has been voiced over increasing numbers of CT examinations in the United States and the increased cancer risks, especially in children, which result from these examinations.[1] Child exposure settings provided by the Kodak 9500 unit could not be tested with the adult phantom used in this study. While default child exposures are lower than adult settings, risk is inevitably greater owing to greater sensitivity of developing organs and tissues to radiation.

A recent report assessing the lifetime attributable risk of common CT examinations cited an average 13-fold difference in dose for the same examination in different facilities, even when using the same equipment.[15] Within small, medium and large FOV groups, similar percentage differences in dose are also possible for the different units and exposure options available for dedicated maxillofacial CBCT imaging.[7] The current study found a 2.8-fold difference between default small and large adult settings for large FOVs and a 2.2-fold dose difference for medium FOV settings in the current configuration of the Kodak 9500 unit. The median dose (medium adult default) for the Kodak 9500 large FOV (0.16 mSV) is 12 times less than the median dose from a head CT examination (2 mSv) cited in the Smith-Bindman et al study.[15] An extension of this comparison is that, on average, an order of magnitude dose reduction can be obtained when substituting a Kodak 9500 CBCT scan for a standard CT scan for dental diagnosis. Furthermore, the current configuration of the Kodak 9500 produces default patient doses that are 43% less than the initially shipped units. Carestream-Kodak has offered to retrofit pre-production units and has completed most retrofits so that units in the field meet the new specifications for beam quality and exposure. It is hoped that other manufacturers will emulate this model.

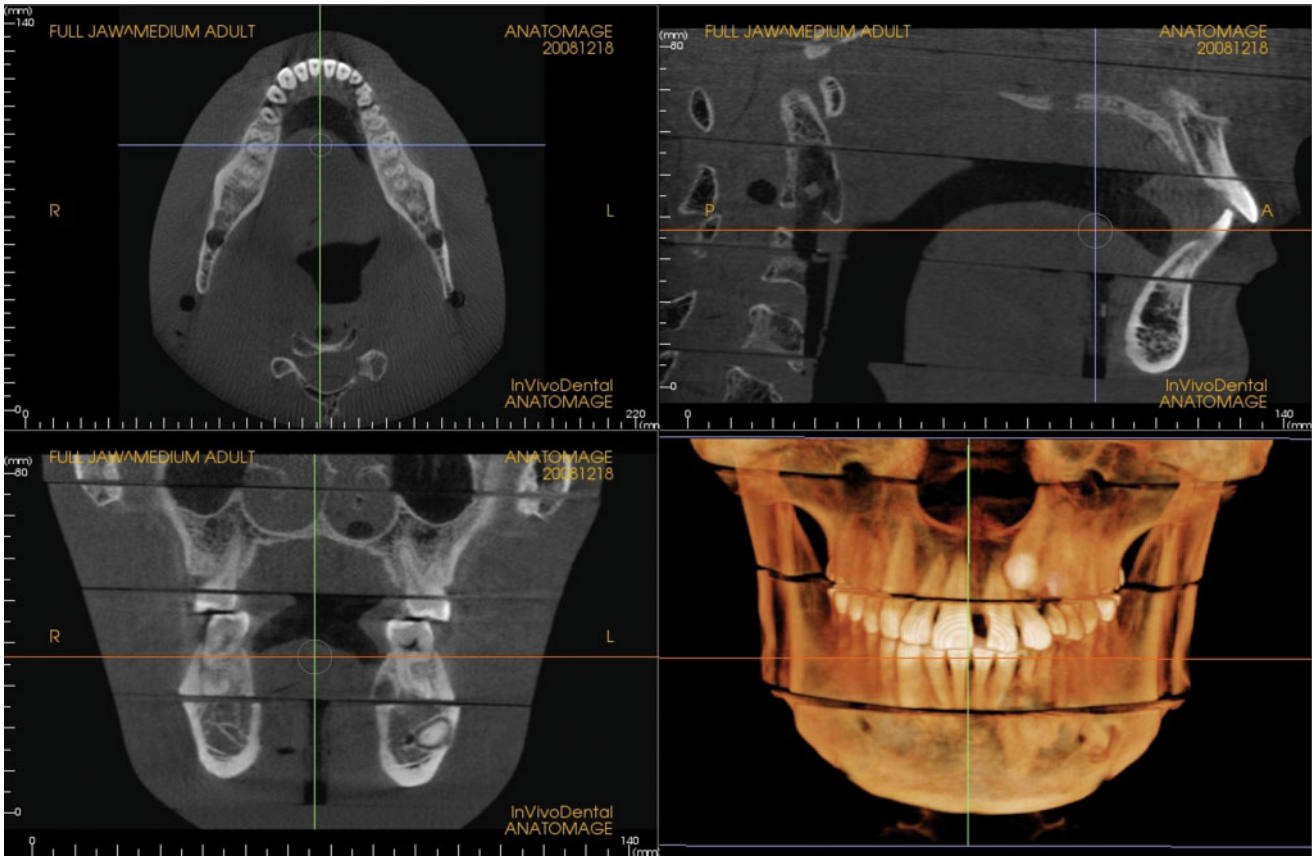


Figure 2 Medium field of view, medium default exposure setting, pre-production unit

Numerous radiographic parameters act in concert to influence diagnostic information, image quality and patient dose. Dose is proportional to size of the FOV when other factors are held constant. This should prompt practitioners to choose the smallest FOV that is needed to achieve the diagnostic aims of a particular examination. The Kodak 9500, with a medium and large FOV option, should lower practice-based doses through this mechanism. Location of the FOV also has a significant impact on dose. While this is most apparent with smaller FOVs, even large FOVs may produce differing patient risks depending on how peripheral organs, such as the thyroid gland, are positioned with respect to direct exposure from the X-ray beam. This should prompt radiographers to use thyroid shields and careful positioning strategies when possible. The shape of the FOV also influences dose to peripheral tissues. A sphere, used by image intensifier-based imaging systems, tends to increase brain and thyroid exposures in large FOVs. A cylinder, produced by flat panel detector-based CBCT units, has the potential to be collimated to image the anatomy between the condyles and chin with a reduced vertical beam height.

The number of basis images that are acquired for an image volume and the amount of exposure per basis image have a direct effect on patient dose. For some units these factors are under the operator's control. When this is the case, choice of factors resulting in the lowest tube current and exposure time (mAs) consistent with the diagnostic task should be chosen.

Use of continuous or pulsed X-ray sources also impact dose. Image receptors do not acquire information during short phases of the imaging cycle when the charge in the receptor is integrated and sent to the frame grabber for storage. Because of this some manufacturers pulse X-ray output, turning the beam off during the integration/data transmission phase of image acquisition. If the X-ray source is left on during this period, when no new data can be acquired, the exposure is wasted and contributes unnecessarily to patient dose.

Ideally exposure factors are selected on the basis of image quality required to achieve the examination goals. Because image quality is proportional to dose, selection of image quality becomes a decision on dose and *vice versa*. Ideally these decisions should be informed by the training and expertise of the dentist who will be using the examination for diagnosis. The reality is that the majority of scans will simply follow the manufacturer's suggested scanning protocol without further consideration of the potential for dose/image quality optimization. Therefore it will be important for future research to establish criteria for the optimal level of image quality taking into consideration both diagnostic yield and dose. It is critical that professional

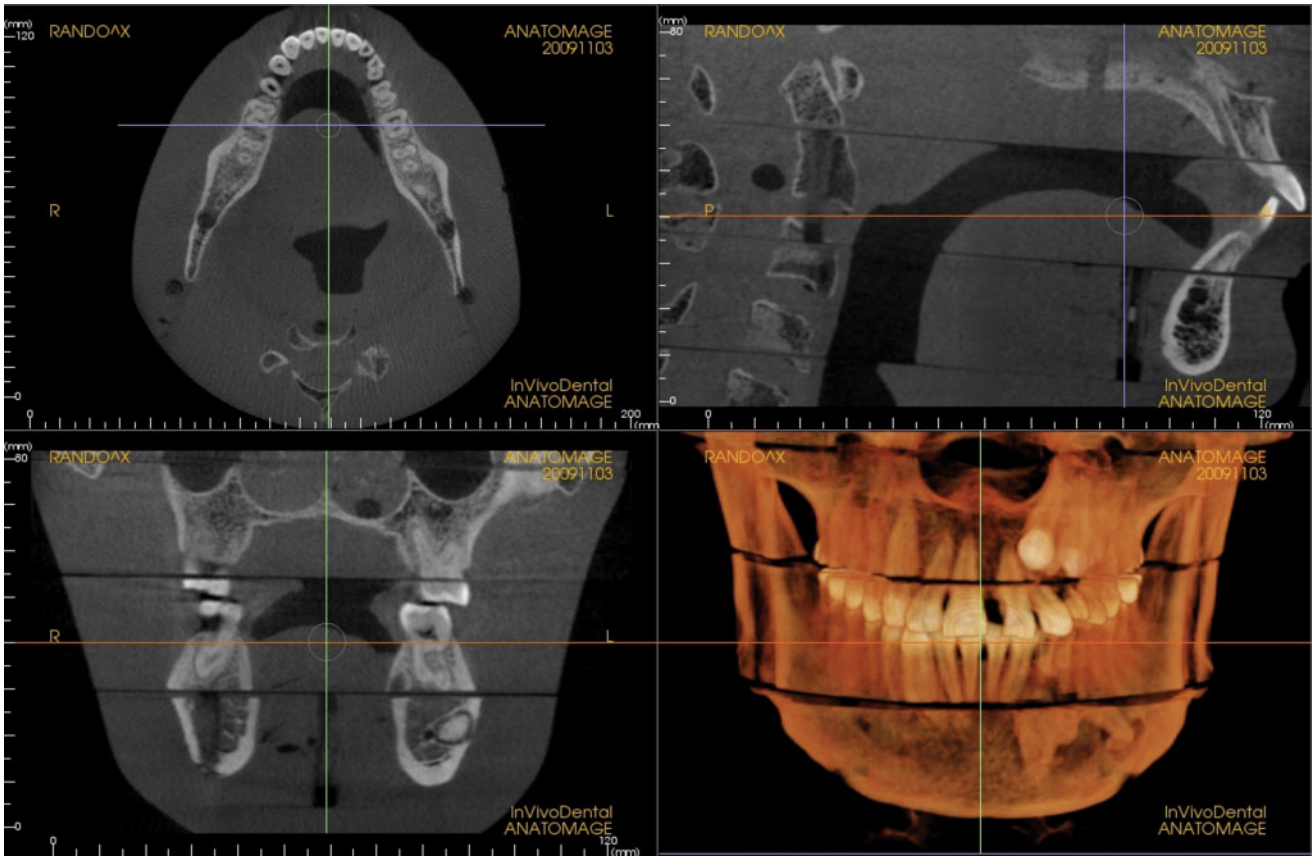


Figure 3 Medium field of view, medium default exposure setting, current unit

radiology associations use these findings to guide manufacturers and end users to establish standard parameters for the operation of each CBCT unit. If, as a profession, we are to continue to have our patients benefit from this evolving technology while reducing patient risk, it will be essential for us to work in concert with manufacturers and to provide encouragement and guidance through research and sound clinical practice.

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