The Benefit vs Risk is in the Hands of the Operator: Seven Steps to Help Reduce the Risk of a CBCT

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Cone beam technology was first introduced in the European market in 1996 by QR s.r.l. (NewTom 9000) and entered the US market in 2001. The 9000 utilized a dental grade tube head with a point 5mm focal spot, charged coupled device (CCD), and an image intensifier. The images are 8 bit with 256 shades of gray with a minimum voxel size of 0.3mm. There are two fields of view, 6 and 9 inch. In 2003 Mah, Danforth, Bumann, and Hatcher's study determined due to the 9000 low dose as compared to medical CT, the 9000 was ideal for dental imaging procedures[1]. They measured an effective dose of the 9000 at 50.3 µSv which equals two Ortho Panographic surveys. The Radiographic Health Board (RHB) in California also determined the 9000 could be used by imaging centers because of its low dose compared to medical CT. The introduction of the NewTom CBCT 9000 changed imaging in dentistry forever.

In 2003 Imaging Sciences introduced the iCat Classic with a 12 bit amorphous silicon flat panel imaging detector. The imaging plate with 4,096 shades of gray provided a much improved image when compared to the 9000 and its image intensifier. Today there are over 35 different manufactures of CBCT machines. The image intensifier first used by NewTom is no longer used in manufacturing. With only two or three fields of view to choose from, the NewTom 9000 and iCat classic were easy to use. The only change in dose was directly related to the size of the field of view.

Today CBCT machines are manufactured with 16 bit amorphous silicon flat panel imaging plates, with 64,000 shades of gray, medical or dental grade tube heads, and focal spots from 0.2 to 0.8 mm, multiple fields of view with different settings within each field of view. These new improvements change image quality and may decrease or increase dose. The operator is now required to understand how to employ different settings and adhere to the ALARA principle (As Low as Reasonably Achievable).

When necessary the benefit of a CBCT scan far outweighs the risk. Today CBCTs are routinely used for the diagnosis of dental disease, evaluation of the temporomandibular joint, maxillofacial pathology, placement of implants, relationship of the inferior alveolar nerve canal to a laterally impacted third molars, orthodontics, orthognathic surgery, and endodontic procedures. The January 2010 issue of the CDA Journal Vol 38 No1 authored by Stuart White and Satirios Tetradis clearly describes the benefit versus risk[2].

To increase the benefit and reduce the risk of a CBCT examination the following seven steps are recommended to the doctor, x-ray technologist, and x-ray technician.

STEP 1 : INSTALLATION

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[1] Radiation absorbed in maxillofacial imaging with a new dental computed tomography device James K. Mah, DDS, DMSc[a,*,]Correspondence information about the author DDS, DMSc James K. MahEmail the author DDS, DMSc James K. MahRobert A. Danforth, DDS[b]Axel Bumann, DDS, PhD[c]David Hatcher, DDS, MSc[d]

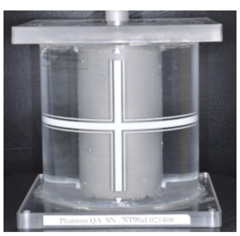
[2] Introduction of Cone beam 1996 in Europe 2001 in us. CDA Journal Vol 38 No1

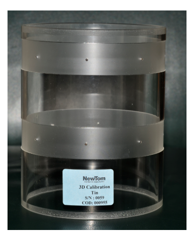
The guidance on the installation and safe use of the CBCT is necessary, because of the higher dose emitted by the CBCT. A physicist should be consulted in the build-out of the CBCT operatory. While visiting different dental offices with limited space the author has seen CBCT machines placed in hallways and closets with inadequate shielding. In a situation like this it is extremely important to add shielding and establish a protocol to protect the operator, staff members and patients in adjacent rooms. The author recommends "Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment, published by the Health Protection Agency UK.

STEP 2 : CALIBRATION

Maintaining the calibration of a CBCT machine after installation is important in establishing a baseline. Check if the manufacturer provides a QA phantom and calibration tin. QA scans should be taken weekly. If the QA scan is out of range a calibration tin is used to restore the proper parameters. The parameters of the QA scan should include density values, image uniformity, artifacts, noise, spatial resolution, contrast, and geometric accuracy. The article published in Dentomaxillofacial Radiology Journal "Quality assurance phantoms for cone beam computed tomography" concludes "QA phantoms rarely allow all image quality parameters stated by the European Commission to be evaluated. Furthermore, alternative phantoms, which allow all image quality parameters to be evaluated in a single exposure, even for a small field of view, should be developed[3].

The Quality Assurance phantom used with the Newtom VGi, 5G, and Evo machines provide 5 different parameters, density values, image uniformity, noise, spatial resolution and geometric accuracy. If the machine fails the QA scan a calibration tin is used to recalibrate.


QA Geometric Phantom


Calibration Tin


Pro-Control Phantom

Establishing a baseline to help understand image quality, and choice of proper settings an additional phantom from Pro-Project can be used. The pro-control phantom provides readings for geometry, homogeneity, image distortion, low contrast resolution, pixel intensity, slice thickness, and spatial resolution. Between the CBCT phantom provided by the manufacturer and the Pro-Control phantom, the end user can be confident of an accurate CBCT calibration and consistent image quality. Knowledge that the CBCT is calibrated correctly is the first step in quality control and reducing the risk of over or under exposure to the patient.

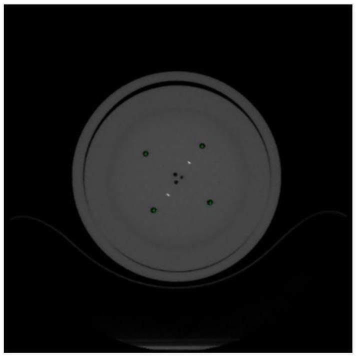
STEP 3 : ESTABLISH BASELINE

Scan the Pro-Project phantom and upload the DICOM to Pro-Control online website; within 24 hours receive the calibration report. (Due to limited space only one of the parameters is shown for illustration). To help fully understand the calibration report the images can be paired to the patient scans taken at

[3] Dentomaxillofacial Radiology (2017) 46, 20160329 ª 2016 The Authors. Published by the British Institute of Radiology

different fields of views and settings. As an example, the boost images from the Pro-Control phantom below can be compared to images taken on a tissue equivalent phantom.

The Boost 18 X 16 scan passed all seven pro -control parameters.



Geometry & Slice Thickness

Homogeneity

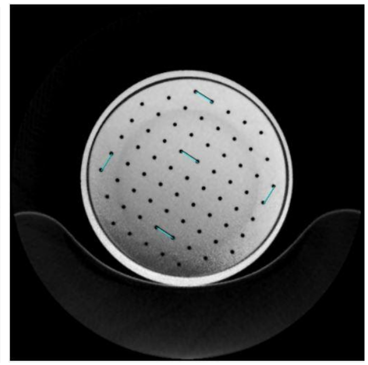
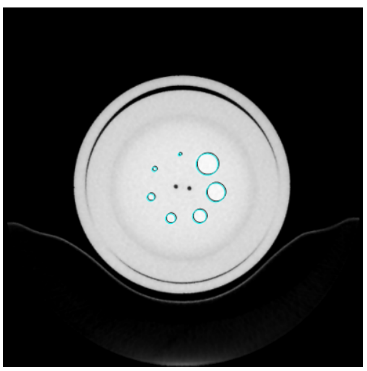
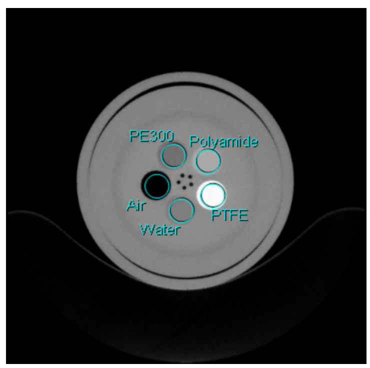


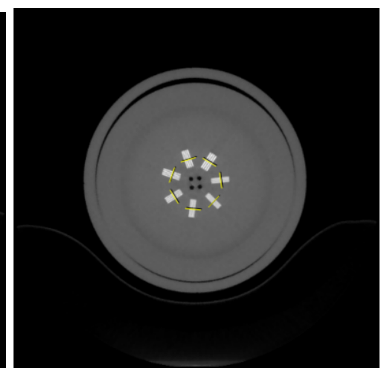
Image Distortion



Low Contrast Resolution



Pixel Intensity



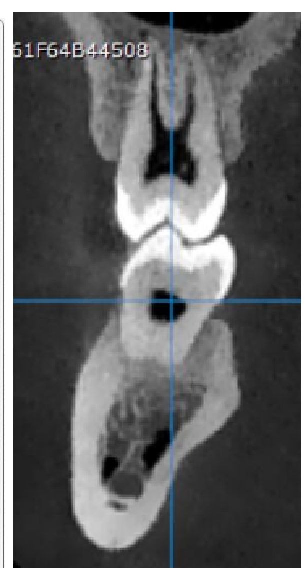
Spatial Resolution

Pixel intensity B

Test passed

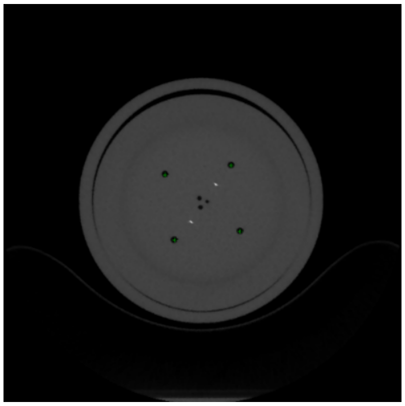
Edit results | Unset benchmark

	RESULT	
HU PTFE:	943.96	from 939.96 to 947.96
HU Polyamide:	319.51	from 315.51 to 323.51
HU H2O:	-10.38	from -14.38 to -6.38
HU PE-300:	-117.21	from -121.21 to -113.21
HU Air:	-992.8	from -996.8 to -988.8
SNR PTFE:	28.26	from 25.44 to 31.09
SNR Polyamide:	17.5	from 15.75 to 19.24
SNR H2O:	0.37	from 0.33 to 0.4
SNR PE-300:	4.55	from 4.1 to 5.01
SNR Air:	36.26	from 32.63 to 39.88

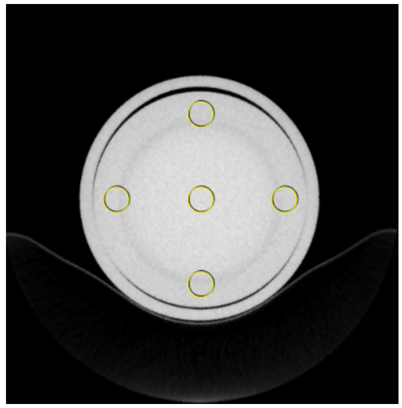


Comparison of tissue equivalent phantom to Pro-Control Phantom (Baseline Boost Scan)

Eco Scan 18X16 scan failed 8 of 10 parameters



Geometry & Slice Thickness



Homogeneity

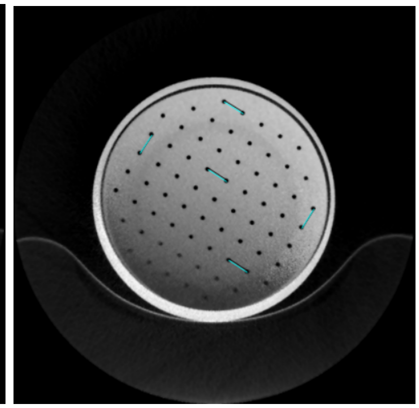
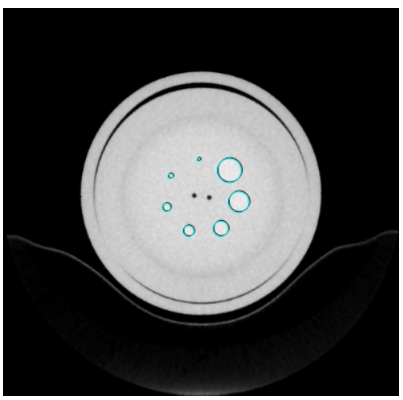
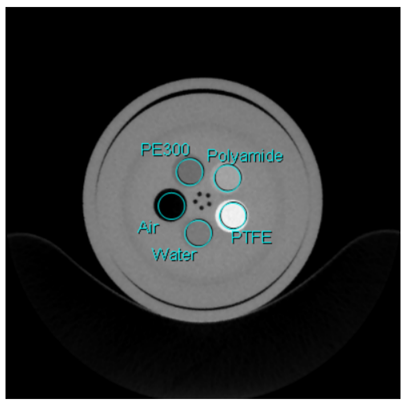


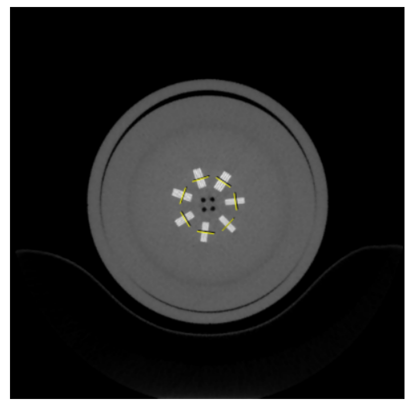
Image Distortion



Low Contrast



Pixel Intensity



Spatial Resolution

Pixel intensity

Test failed

Edit results | Set as benchmark

	RESULT	TOLERANCE
HU PTFE:	974.62	from 939.96 to 947.96
HU Polyamide:	343.99	from 315.51 to 323.51
HU H2O:	9.33	from -14.38 to -6.38
HU PE-300:	-96.53	from -121.21 to -113.21
HU Air:	-977.17	from -996.8 to -988.8
SNR PTFE:	28.16	from 25.44 to 31.09
SNR Polyamide:	18.79	from 15.75 to 19.24
SNR H2O:	0.29	from 0.33 to 0.4
SNR PE-300:	3.92	from 4.1 to 5.01
SNR Air:	31.45	from 32.63 to 39.88

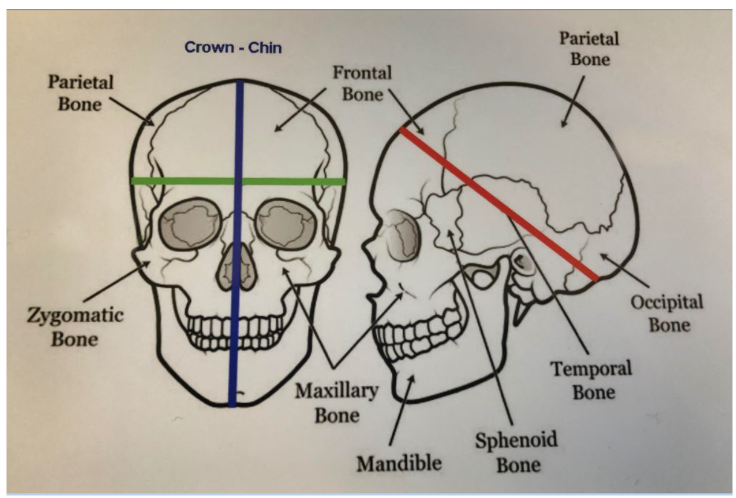
Eight out of the 10 intensity parameters failed

(Baseline ECO Scan)

If a CBCT machine is calibrated properly, by scanning the Pro-Control Phantom, a baseline image quality can be established. The high resolution scans should pass all parameters. The low resolution scans will fail. Low resolution scans will always have poor image quality due to lower mA kVP and reduced time settings. The images above of the Pro-Control and a tissue equivalent phantom clearly illustrate the degradation of image quality when comparing low and high dose scans.

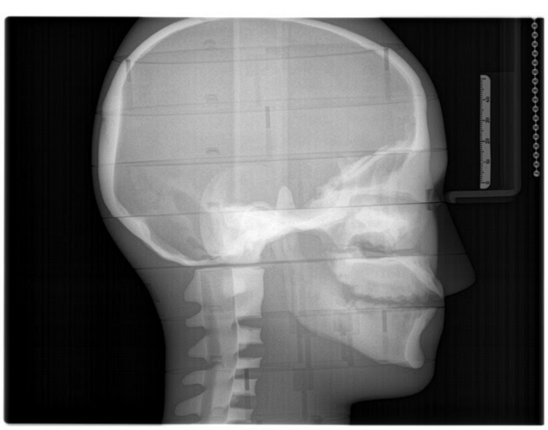
STEP 4 : HEAD SIZE & SETTINGS

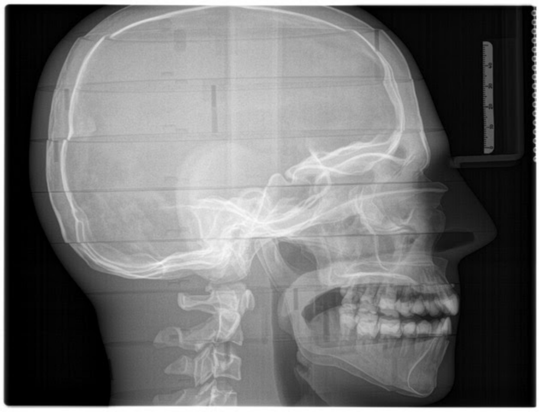
Use a head caliper to determine patient head size for comparison of the adult and child RANDO phantom used by Ludlow to establish dose. Three different measurements are taken: forehead to the occipital bone, transverse temple, and thyroid to the top of the head. Pick the desired field of view and determine the setting. ECO Child, Standard, Boost, ECO Hi Res or Hi Res are examples of settings from the NewTom. All CBCT machines have different settings, dose factors, and image quality. Check with the manufacturer to determine the dose of your machine.

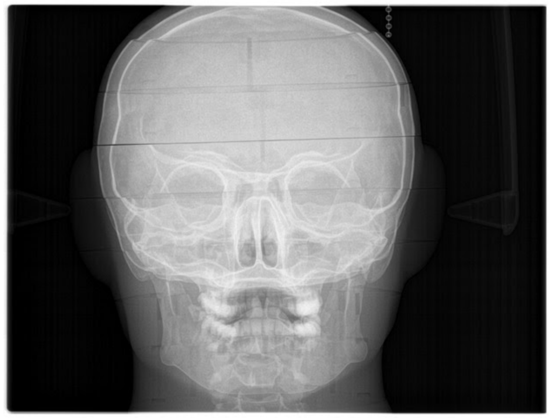


Child & Adult Atom Phantom Head Size

cm	Front - Occiput	Trans-Temporal	Crown-Chin
Child	17.1	14.4	19.3
Adult	20.2	15.8	19.9







Fields of View		Adult microsieverts (µSv) ECO	Standard	Boost	ECO Hi-Res	Standard Hi-Res	Child microsieverts (µSv) ECO	Standard	Boost	ECO Hi-Res	Standard Hi-Res
Focus Views	6x6cm anterior	N/A	N/A	N/A	68	102	N/A	N/A	N/A	145	218
	6x6cm posterior	N/A	N/A	N/A	102	152	N/A	N/A	N/A	145	218
Small Views	8x8cm	17	26	43	105	157	41	61	91	220	334
	12x8cm	23	34	54	141	211	45	67	101	247	368
Large Views	12x15cm	65	99	154	N/A	N/A	96	146	267	N/A	N/A
	15x15cm	72	112	174	N/A	N/A	113	175	319	N/A	N/A

STEP 5 : DOSE CREEP

Understanding *dose creep* is an important factor for the operator of a CBCT machine. Dose creep is a term used by the Emergency Care Research Institute (ECRI). Out of the 10 most hazardous health risks, dose creep is listed at number 7[4]. Dose creep results from the desire to obtain better image quality by using a higher dose. Using a dose that is too low will result in poor image quality. It is important that we adhere to the ALARA principle "as low as reasonably achievable." Do not let dose creep increase the risk of a CBCT.

STEP 6 : EXPORTING DICOM TO THIRD PARTY SOFTWARE

Many doctors who own CBCT machines know how to export the data to a viewer but do not know how to export DICOM. Most viewers do not include DICOM; DICOM must be exported separately. A CBCT viewer has a proprietary file format that is not compatible with third party softwares. Dolphin, Simplant, Nobel, Co Diagnostics, OnDemand 3D, and In2Guide are just a few of the third party software used by clinicians for their treatment plans. DICOM is the only data format that allows the doctor to use one of

[4] Volume 15 - Issue 2, 2015 - Cover Story Dose Creep: Unnoticed Variations in Diagnostic Radiation Exposures

these programs. It has always been common practice to share images when a patient consults with different doctors. 2D images such as full mouth x-rays, panographs, lateral cephalometrics, bitewings and periapicals have always been copied and sent to another doctor treating a patient.

Unfortunately it is common for doctors owning a CBCT to say "*I'll just take my own CBCT.*" The proper protocol is to request DICOM and determine if the data is useful for their diagnosis. Previous CBCT scans should always be reviewed before exposing the patient to an additional scan. There are two reasons DICOM is not shared: the operator has not been trained by the manufacturer or the operator does not need to export DICOM from their CBCT machine to view images.

DICOM is an acronym for *Digital Imaging and Communications in Medicine*. The owner of a CBCT is responsible for making sure his or her staff know how to share DICOM files. Not being able to export DICOM and reimaging a patient creates a high risk instead of a benefit.

STEP 7 : RADIOLOGIST REPORT

Send your DICOM to a qualified Oral Radiologist for a report. The report will reduce the risk and increase the benefit.

In conclusion, install the CBCT properly, learn how to calibrate, establish your baseline, determine the proper field of view and settings based on head size, develop a dose chart, don't fall into dose creep to obtain a high quality image, learn how to export DICOM, and have an Oral Radiologist provide a report; following these seven steps will help to decrease the risk of a CBCT to the patient, staff, and the operator.

1. Introduction of Cone beam 1996 in Europe 2001 in us. CDA Journal Vol 38 No1
2. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device James K. Mah, DDS, DMSc[a,*,] Correspondence information about the author DDS, DMSc James K. Mah Email the author DDS, DMSc James K. MahRobert A. Danforth, DDS[b]Axel Bumann, DDS, PhD[c]David Hatcher, DDS, MSc[d]
3. Dentomaxillofacial Radiology (2017) 46, 20160329 ª 2016 The Authors. Published by the British Institute of Radiology; SYSTEMATIC REVIEW Quality assurance phantoms for cone beam computed tomography: a systematic literature review
4. Quality control in cone-beam computed tomography (CBCT) EFOMP-ESTRO-IAEA protocol Final version 2 nd of June 2017
5. DentomaxillofacRadiol. 2017 Mar; 46(3): 20160329. Published online 2017 Feb 27. doi: 10.1259/dmfr.20160329
6. Volume 15 - Issue 2, 2015 - Cover Story Dose Creep: Unnoticed Variations in Diagnostic Radiation Exposures