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Influence of mA settings and a copper filter in CBCT image resolution.

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Abstract:

The purpose of this study was to evaluate the influence of different milliampere (mA) settings and a CT copper filter in the resolution of Cone Beam Computerized Tomography (CBCT) images. A C-Phantom containing 9 sets of metal lines submerged in water is used to test image resolution from 1 mm to 0.35 mm of resolution. A CBCT scanner was used to obtain multiple volumes with fixed 120 kVp, and a field of view of 6 inches (15.24 cm). The variables were different mA settings (2, 5, 10 or 15) and presence or not of a copper filter. Two different resolution analyses were performed. In the first method, 10 professionals were asked to q-sort the images. The second method had 2 operators analysing the sets of lines and assigning a resolution value according to the phantom manufacturer's recommendations. For the first method, the mean score and standard deviation for the images used were, from best image to worse: 10 mA Y (1.6, 0.84), 15 mA Y (2, 0.94), 15 mA N (3.1, 1.37), 5 mA N (4.1, 0.99), 5 mA Y (5.1, 1.37), 10 mA N (5.3, 0.95), 2 mA N (7.1, 0.74), and 2 mA Y (7.7, 0.48). The second method of evaluation showed agreement with the first method's results. The assigned resolution from best to worse were: 10 mA Y (0.43 mm), 15 mA Y (0.43 mm), 15 mA N (0.45 mm), 5 mA N (0.45 mm), 5 mA Y (0.55 mm), 10 mA N (0.55 mm), 2 mA N (0.58 mm), and 2 mA Y (0.63 mm). The images with the higher milliamperage and a copper filter showed the best resolution. The combination of 5 mA and no filter would be considered acceptable according to resolution standards, and would offer a considerable reduction in radiation exposure to the patient. The data also suggests that for lower mA settings of 2 and 5 mA the image quality is better without the addition of a Copper filter.

Keywords: Cone beam CT, CBCT, image quality, resolution, milliamperes, copper filter, q-sort.

1. Introduction

Craniofacial CBCTs were designed to counter some of the limitations of conventional CT scanning devices, and to make 3D technology practical for dentistry. The radiation source consists of a conventional low-radiation X-ray tube and the resultant beam is projected onto a flat panel or charge coupled device (CCD) detector, producing a more focused beam via image intensifier (II) if required and considerably less scatter radiation compared to the conventional fan-shaped CT devices (Figure 01).[1, 2, 3] The total radiation is approximately 20% of conventional CTs and can be equivalent to a full mouth periapical radiographic exposure. [4] CT systems nowadays use fan as well as cone beams and both x-ray tube and detector assembly is in a gantry to facilitate fast rotation. On the other hand, in CBCT, the tube produces cone shaped x-ray passing through the patient's head, falls on to Image Intensifier, which works as an amplifier, improving the photon count so the CCD will detect signal reasonably given the low dose.

These innovations in components are significant because they allow the CBCT unit to be cheaper and smaller in size. CBCT images are comparable to conventional CT images in quality, capability for segmentation, and possibility of both surface and radiographic view modes, but in its 3D mode, CBCT images also look similar to the traditional radiographs familiar to craniofacial practitioners.

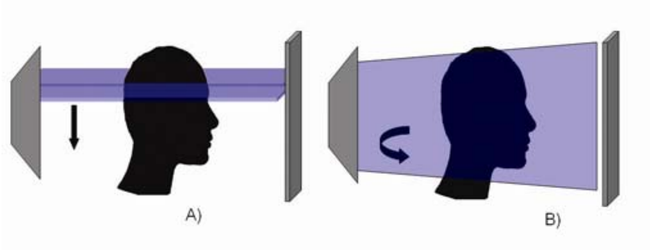


Figure 01 - Illustration showing the difference between the data capture system of a regular CT machine and a Cone Beam CT machine. A) A regular CT machine captures the data in a fan way, and B) The Cone Beam CT captures the data in a volumetric fashion.

With the CBCT technology, all possible craniofacial radiographs can be taken in under a minute. Dental clinicians now have the diagnostic quality of periapicals, panoramic, cephalograms, occlusal radiographs, and TMJ series at their disposal, along with views that cannot be produced by regular radiographic machines such as axial and cross sectional views. A number of clinical applications have already been reported in the literature. [5, 6, 7, 8, 9]

Even though the cone beam technology is able to provide volumetric images with up to 4 times less radiation than a conventional CT [10, 11], the resulting effective radiation is dependent on the settings used (kVp and mA). The use of lower mAs, and/or collimation are some of the ways to reduce the amount of radiation, but at the same time might produce a lower image quality. Patient effective exposure dose from a CBCT machine has been reported to be as low as 45 µSv to as high as 650 µSv. Exposure for an analog full mouth series has been reported as 150 µSv [12], for an analog panoramic radiograph as 54 µSv [13, 14], while a roundtrip from Paris to Tokyo adds 139 µSv of effective dose per passenger. [15, 16]

The ADA Council on Scientific Affairs recommends the use of techniques that would reduce the amount of radiation received during dental radiography. Known as the "As Low As Reasonably Achievable" or ALARA, principle, this includes taking radiographs based on the patient's needs (as determined by an examination), using the fastest film compatible with the diagnostic task, collimating the beam to a size as close to that of the film as feasible and using leaded aprons and thyroid shields. An accepted ratio between exposure and image quality needs to be reached in order to use the ALARA principle.

The purpose of this study was to evaluate the influence of different milliampere (mA) settings and a CT copper filter in the resolution of Cone Beam Computerized Tomography (CBCT) images. The mA reduction and copper filter were chosen since they are directly related to patient exposure and image resolution. If the mA could be considerably reduced and a copper filter added, and the result maintains a good image resolution, the patient radiation exposure could be significantly decreased.

Material and Methods

The CBCT Hitachi CB MercuRay (Hitachi Medical Corporation, Tokyo-Japan) was used to scan a C-Phantom. The C-Phantom is a device conventionally used to evaluate the resolution of CT images,and has an acrylic base with a series of 9 sets of 4 metal lines, submerged in water (Figure 02). The metal lines are parallel and equidistant in each set, and the distance between the lines gets progressively shorter making the lines closer together, but without any contact.

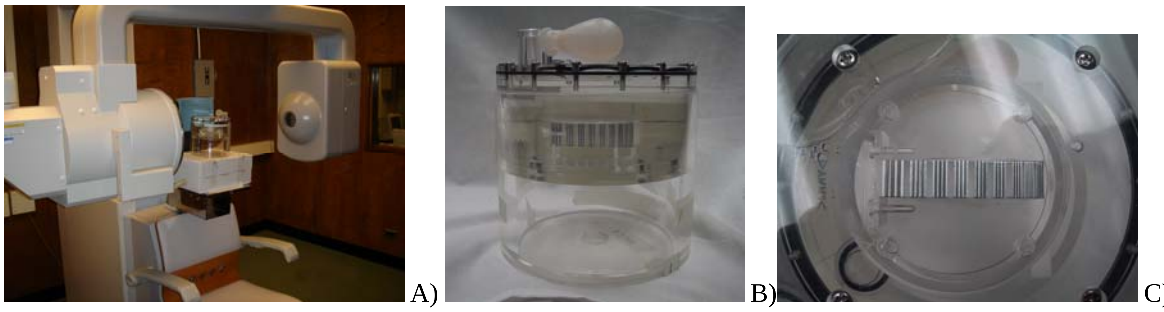


Figure 02 – A) C-Phantom in position to be scanned by the CBCT, B) full view of the C-Phantom, and C) close up view from the top showing the 9 series of metal lines used to assess image resolution.

A resolution test chart was previously developed and commercially used which establishes the image resolution as when the operator is unable to see the separation between the lines on a specific set (Figure 03). The last set of line which the operator can tell there is a separation in between, defines the image resolution.

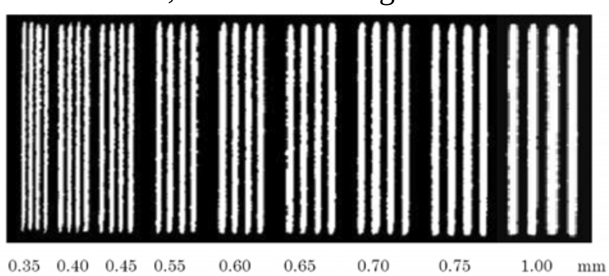
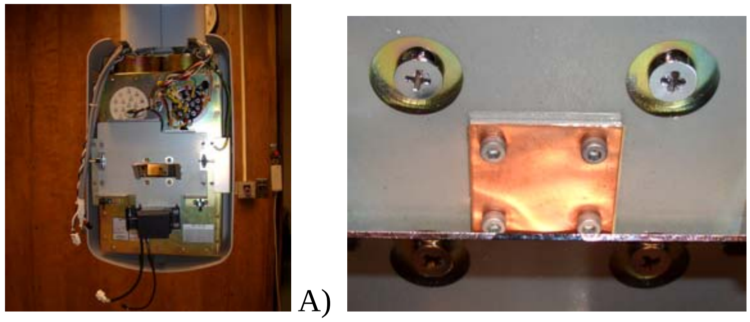


Figure 03 – Resolution test chart. The 9 sets of lines provides resolution options from 0.35 to 1 mm.

A CBCT scanner was used to take 8 different scans of a C-phantom. A fixed 120 kVp, and a field of view of 6 inches (15.24 cm) was used for all images. Different mA's of 2, 5, 10 and 15 were used, as well as a copper filter (Figure 04).

With the different mA settings and presence (Y) or not (N) of copper filter, the final combinations were: 02 mA Y, 05 mA Y, 10 mA Y, 15 mA Y, 02 mA N, 05 mA N, 10 mA N, and 15 mA N. The C-phantom was placed on radiolucent material (a cardboard box with a wood top), in a reproducible way. The modification to the CT scanner was made by CT engineers from Hitachi Medical Corporation and this includes a combination of both software and hardware changes. The recommended image resolution for the field of view used is 0.45 mm.

Two different resolution analyses were performed. In the first method, the 8 images were shown to 10 professionals including engineers, dentists, and dentist sub specialists. The operators were instructed on how to analyze and evaluate the resolution of images when using a C-phantom. With the images randomly arranged the operators were asked to q-sort the images in order of best to worse resolution. A score was given to each image based on the ranking given by each operator. If the image was considered as the best image, a score of 1 was given, if the images was the second best, a score of 2 was given, and so on until the score of 8 for the worst image. Mean and standard deviations were calculated to evaluate the results.



A) B)

Figure 04 – A) A copper filter is added to attenuate radiation providing a more homogeneous final x-ray beam, which would result in a “cleaner” image. B) A close-up of the copper filter in place.

The second method had 2 operators with combined experience in craniofacial imaging of more than 25 years, analyzing the sets of lines and assigning a resolution value, following the phantom manufacturer’s recommendations.

Results:

For the first method the results are shown in Table I.

	02 Ma Y	05 Ma Y	10 Ma Y	15 Ma Y	02 Ma N	05 Ma N	10 Ma N	15 Ma N
	8	4	1	2	7	5	6	3
	8	6	2	1	7	4	5	3
	8	6	3	1	7	4	5	2
	7	3	1	2	8	5	6	4
	8	5	1	2	6	4	7	3
	7	5	3	4	8	2	6	1
	8	7	1	2	6	5	4	3
	7	6	2	1	8	3	5	4
	8	6	1	3	7	4	5	2
	8	3	1	2	7	5	4	6
Mean	**7.7**	**5.1**	**1.6**	**2**	**7.1**	**4.1**	**5.3**	**3.1**
SD	**0.48**	**1.37**	**0.84**	**0.94**	**0.74**	**0.99**	**0.95**	**1.37**

Table I - Scores given, mean and standard deviation for the images:

The second method of evaluation showed agreement with the first method’s results. For the second method the results are shown in Table II.

Rank	Settings	Method 1 - Score	Method 2 – Image Resolution
1	10 Ma Y	1.6	0.43 mm
2	15 Ma Y	2.0	0.43 mm
3	15 Ma N	3.1	0.45 mm
4	05 Ma N	4.1	0.45 mm
5	05 Ma Y	5.1	0.55 mm
6	10 Ma N	5.3	0.55 mm
7	02 Ma N	7.1	0.58 mm
8	02 Ma Y	7.7	0.63 mm

Table II – Scores given and assigned image resolution shows agreement.

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Conclusions:

The images with the higher milliamperage and a copper filter showed the best resolution. The combination of 5 mA and no filter would be considered acceptable according to resolution standards, and would offer a considerable reduction in radiation exposure to the patient. As the CBCT technology evolves, and more products appear in the market, more studies like this will be necessary in order to maintain ALARA standards while image quality continues to improve.

References

[01] Danforth RA, Peck J, Hall P. Cone beam volume tomography: an imaging option for diagnosis of complex mandibular third molar anatomical relationships. J Calif Dent Assoc 2003;31(11):847-52.

[02] Mah J, Hatcher D. Current status and future needs in craniofacial imaging. Orthod Craniofac Res 2003;6 Suppl 1:10-6; discussion 179-82.

[03] Sukovic P. Cone beam computed tomography in craniofacial imaging. Orthod Craniofac Res 2003;6 Suppl 1:31-6; discussion 179-82.

[04] Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96(4):508-13.

[05] Danforth RA, Dus I, Mah J. 3-D volume imaging for dentistry: a new dimension. J Calif Dent Assoc 2003;31(11):817-23.

[06] Mah J, Enciso R, Jorgensen M. Management of impacted cuspids using 3-D volumetric imaging. J Calif Dent Assoc 2003;31(11):835-41.

[07] Aboudara CA, Hatcher D, Nielsen IL, Miller A. A three-dimensional evaluation of the upper airway in adolescents. Orthod Craniofac Res 2003;6 Suppl 1:173-5.

[08] Hatcher DC, Dial C, Mayorga C. Cone beam CT for pre-surgical assessment of implant sites. J Calif Dent Assoc 2003;31(11):825-33.

[09] Hamada Y, Kondoh T, Noguchi K, Iino M, Isono H, Ishii H, et al. Application of limited cone beam computed tomography to clinical assessment of alveolar bone grafting: a preliminary report. Cleft Palate Craniofac J 2005;42(2):128-37.

[10] Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4- and 16-slice computed tomography, cone beam computed tomography systems and conventional radiography. Dentomaxillofac Radiol. 2004 Mar;33(2):83-6.

[11] Schulze D, Heiland M, Schmelzle, R, Rother, UJ. Diagnostic possibilities of cone-beam computed tomography in the facial skeleton. Int. Congress Series 1268 (2004) 1179-1183.

[12] Frederiksen NL. X-Rays: What is the Risk? Texas Dental Journal. 1995;112(2):68-72.

[13] Kiefer H, Lambrecht JT, Roth J. Digital exposition from intra- and extraoral dental radiography. Int. Congress Series 1268 (2004) 1147-1151.

[14] Kiefer H, Lambrecht JT, Roth J. Dose exposure from analog and digital full mouth radiography and panoramic radiography. Schweiz Monatsschr Zahnmed. 2004;114(7):687-93.

[15] Bottollier-Depois JF, Chau Q, Bouisset P, Kerlau G, Plawinski L, Lebaron-Jacobs L. Assessing exposure to cosmic radiation on board aircraft. Adv Space Res. 2003;32(1):59-66.

[16] Bottollier-Depois JF, Trompier F, Clairand I, Spurny F, Bartlett D, Beck P, Lewis B, Lindborg L, O'Sullivan D, Roos H, Tommasino L. Exposure of aircraft crew to cosmic radiation: on-board intercomparison of various dosemeters. Radiat Prot Dosimetry. 2004;110(1-4):411-5.