SHORT COMMUNICATION

Influence of scan mode (partial/full rotations) and FOV size in the formation of artefacts in cone beam CT

¹Eliana Dantas da Costa, ¹Polyane Mazucatto Queiroz, ¹Gustavo Machado Santaella, ²Ana Lúcia Alvares Capeloza, ¹Glaucia Maria Bovi Ambrosano and ¹Deborah Queiroz Freitas

¹Department of Oral Diagnosis, Area of Oral Radiology, Piracicaba Dental School, University of Campinas, Piracicaba, São Paulo, Brazil; ²Department of Stomatology, Area of Oral Radiology, Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil

Objective: To evaluate the influence of rotation degree and field of view (FOV) size on the amount of artefacts produced in cone beam CT (CBCT) images.

Methods: A cylindrical wax utility phantom, with a metallic sample in its interior, was scanned with two FOV sizes (100 x 100 and 40 x 40 mm) and in full (360°) and partial (~180°) rotations. After the acquisitions, images were objectively assessed in the ImageJ software, obtaining the standard deviation in areas around the metal sample. The influence of artefacts produced by the several FOVs and rotation degrees was compared by two-way analysis of variance ($\alpha = 0.05$).

Results The images obtained with a large FOV presented a higher amount of noise compared to a restricted FOV, both for partial ($p = 0.0037$) and full ($p = 0.0023$) rotation degrees. For images obtained with a restricted FOV, full rotation resulted in images with less noise ($p = 0.0259$). For images obtained with large FOV, there was no statistically significant difference ($p = 0.1494$) in noise for both rotation protocols.

Conclusions As there were no significant differences in the amount of artefacts in rotation protocols for large FOVs, the partial rotation can be indicated due to its lower exposure to radiation. For acquiring images with restricted FOVs, the full rotation is recommended.

Dentomaxillofacial Radiology (2019) **48**, 20180340. doi: [10.1259/dmfr.20180340](https://doi.org/10.1259/dmfr.20180340)

Cite this article as: Costa ED, Queiroz PM, Santaella GM, Capeloza ALA, Ambrosano GMB, Freitas DQ. Influence of scan mode (partial/full rotations) and FOV size in the formation of artefacts in cone beam CT. *Dentomaxillofac Radiol* 2019; **48**: 20180340.

Keywords: cone beam computed tomography; rotation; dental alloys; artefacts

Introduction

Cone beam CT (CBCT) is a form of three-dimensional imaging increasingly used in Dentistry for bone tissue diagnosis in the maxillofacial region.¹ However, image quality can be compromised by the presence of different types of artefacts.²

Artefacts are structures that appear in the CBCT images reconstructions and do not represent the real object.^{2,3} Artefacts can be of different types, such as beam hardening effect, ring artefact, cone beam effect, partial volume, subsampling and exomass, for instance.^{2,4}

Exomass refers to any structure that is part of the object but does not match the area of interest to be scanned and, thus, may compromise image quality.⁴

Various types of CBCT devices are available, each with specific settings and the possibility of adjusting various parameters of exposure [milliamperage (mA), kilovoltage (kV), voxel and field of view (FOV) size and device scan modes (~180° and 360°)], which are associated with radiation dose and image quality.⁵

Among these parameters, FOV corresponds to the size of the area to be scanned.⁶ Commercially available devices have different FOV sizes, which can be selected according to the examination indication. As the FOV size determines the scope of the examination, it

Correspondence to: Eliana Dantas da Costa, E-mail: edantasc@yahoo.com.br

Received 17 September 2018; revised 03 November 2018; accepted 11 December 2018

consequently also determines the area that will be irradiated, *i.e.* it is associated with the radiation dose the patient will be exposed to.^{1,6,7}

Some devices provide the option of scanning with full (360°) or partial (~180°) rotation.^{5,8} The device rotation degree determines the number of basis images acquired.^{5,8} Theoretically, the higher the number of images, the greater the amount of information for volume reconstruction and the better the image quality.^{1,5,8} However, the radiation dose will be higher in comparison with a scanning with partial rotation,^{5,8} as the area of interest in partial rotation will be irradiated only in ~180°, *i.e.* half of a full rotation, usually skipping a direct exposition to the face of the patient.^{1,9}

Previous studies have evaluated how different CBCT conditions of image acquisition and reconstruction can affect the formation of artefacts.^{3,10} However, the relationship between the FOV size and amount of exomass with the degree of device rotation regarding the artefact/noise in CBCT images is yet unknown. Therefore, this study aimed at evaluating the influence of rotation degree and FOV size on the number of artefacts produced in CBCT images.

Methods and materials

For image acquisition, a cylindrical utility wax phantom (98 mm diameter x 50 mm height) containing a sample of metal alloy in its interior (5 mm diameter x 5 mm height) was used (Figure 1).³

The phantom was scanned on the 3D Accuitomo 170 unit (J Morita Corp., Kyoto, Japan), while keeping energy parameters fixed at 80 kVp and 6 mA. Acquisition times were 17.5 s for full rotation scans and 9.0 s for partial rotation scans. The positioning of the phantom was standardised for all acquisitions, with the metal sample centred in the FOV, following the scanning protocols shown in Table 1. For each of the protocols, five acquisitions were performed (Figure 2).

After acquisition, images were saved in DICOM format (Digital Imaging and Communications in Medicine) and assessed by an experienced evaluator, using the ImageJ software v. 1.51i (National Institutes of Health, Bethesda, MD). Three axial images with the metal sample were selected by consensus by three

Figure 1 Schematic figure of the utility wax phantom containing metallic alloy sample centred in its interior.

Table 1 Scanning protocols

	Scanning		FOV size	
	Total (360°)	Partial (180°)	100 × 100 mm	40 × 40 mm
Protocol 1	X		X	
Protocol 2	X			X
Protocol 3		X	X	
Protocol 4		X		X

FOV, field of view.

evaluators, being the most central slice, and 1 mm from the top and bottom of the sample, for all the volumes. Then, the macro tool was used in axial reconstructions to define regions of interest (ROI) and quantify noise in the images. A total of eight areas of interest around the metallic alloy sample were measured¹¹ (Figure 3). First, a 5 × 5 cm square ROI was defined over the sample, and then the eight regions around the sample were evaluated with the same sized ROI. The X and Y coordinates for both FOVs of all the regions were saved and reapplied in all the other selected images using the macro tool. The amount of noise (expression of artefacts) was obtained by the standard deviation of the pixel intensity values, representing its heterogeneity (noise). The mean value of the pixel intensities was also obtained. After 30 days, the assessment was repeated for intra examiner agreement.

Figure 2 Axial images obtained in this study. 1-Protocol 1: Full rotation and FOV 100 × 100 mm. 2-Protocol 2: Full rotation and FOV 40 × 40 mm. 3-Protocol 3: Partial rotation and FOV 100 × 100 mm. 4-Protocol 4: Partial rotation and FOV 40 × 40 mm. FOV, field of view.

Figure 3 Schematic representation of the regions corresponding to the eight areas of interest used for objective evaluation. Central hyperdense area corresponds to the image of the metal alloy. Adapted from Queiroz *et al.* (2018).

Data analysis

Intra examiner agreement was conducted through Intra-class Correlation Coefficient (ICC) ($ICC < 0.4$ = Poor; $0.4 \leq ICC < 0.75$ = Satisfactory; $ICC \geq 0.75$ = Excellent).¹²

To evaluate the effect of rotation degree and field of view on image noise, comparisons between the four scanning protocols were performed using the two-way analysis of variance. All analyses considered a significance level of 5% and were done using GraphPad Prism v. 7.0 software (GraphPad Software, La Jolla, CA).

Results

The intra examiner agreement (ICC) was 1.0, indicating perfect reproducibility from the first to the second evaluation.

Images obtained with a larger FOV presented higher amount of noise (standard deviation of pixel intensity values) compared to a restricted FOV, both for acquisitions conducted with partial rotation ($p = 0.0037$) and full rotation ($p = 0.0023$) (Table 2).

For images obtained with restricted FOV, full rotation resulted in images with less noise when compared with images obtained with partial rotation ($p = 0.0259$). For images obtained with a larger FOV, there was no statistically significant difference ($p = 0.1494$) regarding noise for images obtained with either full or half rotations (Table 2).

The mean values of pixel intensities showed the same results as the standard deviations (Table 2). It was also observed that the images obtained with restricted FOV

Table 2 Quantification of noise (standard deviation) and mean pixel intensities in the protocols studied

	Standard deviation		Mean pixel intensities	
	180°	360°	180°	360°
FOV	131.67	88.39	-106.3	-100
40 × 40 mm	(±95.14) ^{Aa}	(±74.04) ^{Ab}	(±43.13) ^{Aa}	(±26.84) ^{Ab}
FOV 100 ×	211.39	166.67	42.5	32.57
100 mm	(±138.18) ^a	(±136.59) ^{Ba}	(±73.55) ^{Ba}	(±89.79) ^{Ba}

FOV, field of view.

Different letters after the values indicate statistically significant difference ($p < 0.05$), with uppercase letters regarding the columns and lowercase letters regarding the rows, for comparisons within the same group ("Standard deviation" and "Mean pixel intensities").

in full rotation had lower mean pixel intensity values variability, confirming the results of the observed noise values by the standard deviation.

Discussion

Amongst parameters for the optimisation of radiation exposure in CBCT, the FOV exerts an important influence on the radiation dose to which patients are exposed.^{4,6,7} Thus, in accordance with the SEDENT-EXCT guidelines (2012),⁷ restricted FOVs should be chosen whenever possible, considering the diagnostic task and aiming at irradiating a smaller region of the patient. It is important also to follow other principles in optimising CBCT exposures, such as ALARA ("As Low as Reasonably Achievable")⁷ and ALADA ("As Low as Diagnostically Acceptable") to understand which acquisition protocols can achieve good image quality.¹³

Restricted FOVs are also associated with a better spatial resolution of the image¹⁴ because they limit the primary beam, lessening spreading radiation.^{4,9} However, one must be attentive about patients' positioning since, although it is related to lower radiation exposure, in restricted FOVs the chances of improper patient positioning and centralisation in the area of interest are higher, which may result in the need for a new image acquisition and, consequently, an increased dose for the patient.⁶

Another factor to be considered when using restricted FOVs is the effect of local tomography.^{4,9} When selecting this FOV, anatomical structures not encompassed by it may generate truncation artefacts¹⁴ caused by exomass.⁴ However, the selection of large FOVs should not be indicated with the sole purpose of reducing this effect, due to the increased exposure of patients to radiation.^{6,7}

It should be noted that exomass mainly affects the values of pixel intensities, not usually being a critical component in the CBCT images performance.⁹ On the other hand, the presence of high-density materials within the FOV can bring serious clinical implications to image quality.¹⁵ In Dentistry, different metal objects may be present in the patients' oral cavity, such as amalgam restorations, metallic crowns, dental implants,

orthodontic brackets and endodontic filling materials.¹⁵ The presence of these materials can lead to the formation of hyperdense streaks radiating from the metallic object, or the presence of hypodense halos, causing changes regarding the contrast-to-noise ratio of the image, including obscure anatomical structures. Such conditions can affect image quality, making its interpretation difficult or impossible.¹⁻³

Regarding FOV size, the larger one showed more noise with rotation protocols when compared with the restricted FOV. Thus, the presence of image noise when using a large FOV can be justified by the higher amount of scattered radiation, namely, X-ray photons deflected from their original path when interacting with the object,^{6,9,16} which had no significant difference in both device rotation protocols. During image acquisition, some CBCT devices perform a rotation of 360° around the patient's head. However, another strategy for optimising the radiation dose is reducing the rotation arc, which is available in some CBCT devices, such as Galileos (Sirona Dental Systems Inc., Bensheim, Germany), Promax 3D (Planmeca, Helsinki, Finland), i-CAT (Imaging Sciences International, Inc., Hatfield, PA) and Accuitomo (J Morita Corp., Kyoto, Japan).^{1,5,8,9} Thus, through filtered projection algorithms, the image is reconstructed in 360°.⁸

It should be mentioned that, during partial rotation, the patient experiences a significant reduction in radiation dose.^{1,5,8,9} In addition, as the partial rotation occurs preferably through the posterior region of the skull, it avoids the direct exposure of radiosensitive organs, such as eyes and the thyroid gland.⁸

Despite the partial rotation being associated with a lower number of basis images, which would render a loss in image quality,^{5,9} previous studies found that the partial rotation did not influence the quality of the images for assessing periapical bone loss,¹⁶ root fracture¹ and planning mini-implants.⁸ Similarly, results of this study showed that partial rotation showed no significant difference in generating artefacts in comparison with full rotation when using a large FOV. Therefore, the use of a partial rotation protocol can be a

viable alternative for large FOVs, in addition to a lower radiation dose.^{1,9}

It is noteworthy that, since in partial rotation the image acquisition time is reduced,^{1,8} there are less chances of the patient moving during the examination, thus avoiding motion artefacts. Furthermore, the reconstruction time and file size are also reduced.⁸

In turn, when using a restricted FOV, our results showed the generation of artefacts was less pronounced in the full rotation. Thus, this protocol must be indicated for assessing limited regions of the maxillomandibular complex, which require higher resolution and lower noise.

Thus, these findings suggest that, clinically, depending on the examination indication, when the use of larger FOVs is required and there are objects that cause artefacts in the scanned area, the partial rotation protocol can be used, since this parameter does not interfere with the amount of artefacts produced and uses a lower radiation dose.^{1,9} When using smaller FOVs, in turn, the full rotation protocol is recommended, as it generates a lower amount of artefacts.

Conclusion

For larger FOVs, as there were no significant differences in artefact generation regarding device rotation, the partial protocol is indicated due to providing a lower exposition of patients to radiation. For restricted FOVs, the full rotation can be recommended due to the lower amount of artefacts, but further studies should be conducted with different methodological models to verify the clinical influence of such variation.

Acknowledgement

The authors thank the Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES) for the PhD scholarship and the Espaço da Escrita (Writing Center) at the State University of Campinas (UNICAMP) for the language services provided.

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