SHORT COMMUNICATION

Evaluation of a metal artefact reduction tool on different positions of a metal object in the FOV

Polyane M Queiroz, Gustavo M Santaella, Thais D J da Paz and Deborah Q Freitas

Department of Oral Diagnosis, Area of Oral Radiology, Piracicaba Dental School, University of Campinas, Piracicaba, Sao Paulo, Brazil

Objectives: To evaluate the action of a metal artefact reduction (MAR) tool when artefact-generator metal object is at different positions in the field of view (FOV).

Methods: A cylindrical utility wax phantom, with a metal alloy sample inside, was made. The phantom was positioned centrally and peripherally in the FOV for image acquisition, with and without the MAR tool activation. The standard deviation values (image noise levels) from areas around the metal sample and the control area were obtained. The numbers were compared by Student's *t*-test ($\alpha = 0.05$).

Results: When the tool was activated, a significant difference of image noise was observed for central and peripheral positioning, for both control area ($p = 0.0012$) and metal area ($p = 0.03$), and a smaller level of noise was observed for images with phantoms in central positioning. A decrease in image noise with the tool activated was found only in phantoms with the metal object positioned centrally in the FOV.

Conclusions: For the MAR tool to be effective, the artefact-generator object needs to be in the central region of the FOV.

Dentomaxillofacial Radiology (2017) **46**, 20160366. doi: [10.1259/dmfr.20160366](https://doi.org/10.1259/dmfr.20160366)

Cite this article as: Queiroz PM, Santaella GM, da Paz TDJ, Freitas DQ. Evaluation of a metal artefact reduction tool on different positions of a metal object in the FOV. *Dentomaxillofac Radiol* 2017; **46**: 20160366.

Keywords: CBCT; artefacts

Introduction

CBCT has been introduced in the 90s by Arai et al¹ and Mozzo et al² and uses a cone-shaped primary X-ray beam, wide enough to cover the region of interest. The images are reconstructed from multiple two-dimensional radiographs taken rotating around the patient. This technique has been shown to be an important auxiliary method for diagnosis in different dentistry specialties, as in oral and maxillofacial surgery, stomatology, endodontics, periodontics, orthodontics and implantology.³

However, in tomographic examinations, some images that do not represent the scanned object may be present, which are called artefacts. These are the results of a discrepancy between the image mathematical

reconstruction and its physical acquisition process.⁴ Such artefacts may cause changes in the quality of the tomographic image, as a result of alterations in image density and contrast patterns, obscuring structures and impairing the analysis, which makes the diagnosis difficult and time consuming⁵ or even impossible through this examination modality. As a way to correct the alterations caused by artefacts, a metal artefact reduction (MAR) tool has been proposed by some CBCT equipment manufacturers, to minimize and, if possible, eliminate the artefact in tomographic images. This tool reduces the variability of grey values and increases the contrast-to-noise ratio, improving image quality.⁶ It is observed that the MAR tool applies a threshold corresponding to grey values of image artefacts, as suggested by Bechara et al;⁷ after that, an image with less artefacts is reconstructed. Then, it is possible to deduce that this tool works in post-acquisition image processing.

Correspondence to: Ms Polyane Mazucatto Queiroz. E-mail: polyanequeiroz@hotmail.com

Received 13 September 2016; revised 13 November 2016; accepted 30 November 2016

Tomographic images have a density variability depending on the region that the object is inside the field of view (FOV).⁸ Based on the region of interest, the FOV can be selected for each patient; however, the greater the number of objects outside the FOV, the greater will be the amount of artefact generated.^{3,9} Furthermore, an object can assume different positions in a FOV, it but is not yet known whether the tool has the same action in different regions of the FOV. Therefore, the aim of this study was to evaluate the action of a MAR tool in different positions of an artefact-generator metal object in the FOV.

Methods and materials

A cylindrical utility wax phantom (98 mm diameter × 50 mm height) was made, with a cylindrical metal alloy sample inside (5 mm diameter × 5 mm height). The main utility wax cylinder was made and perforated in its mid-point in height and diameter for insertion of the metal alloy sample. Posteriorly, utility wax was poured into the perforated hole for closing and finishing the phantom with the metal alloy sample in its centre (Figure 1).

The phantom was scanned in a Picasso Trio CBCT equipment (Vatech, Hwaseong, Republic of Korea). The exposure parameters were established in the pilot study and were fixed for all acquisitions: 80 kVp and 3.7 mA. The acquisitions were performed using a 50 × 50-mm FOV, 0.2 mm voxel size and 24 s acquisition time.

Four acquisition protocols were used, changing the position of the phantom in relation to the laser alignment lights of the equipment (central position—following the alignment lights and peripheral position—the phantom was positioned 30 mm anteriorly to the alignment lights) and activating or not activating the MAR tool. This position variation intended to simulate the variation of metal alloys in the maxillary bones in the anteroposterior direction. The four acquisition protocols are shown in Table 1.

Figure 1 Utility wax phantom created for this study. The metal alloy sample is represented to the right, with the white dots showing its location centralized inside the phantom.

Three CBCT volumes were obtained for each protocol to ensure reproducibility of the studied condition.

After acquisition of the volumes, they were opened in the OnDemand3D™ software (CyberMed, Seoul, Republic of Korea) (Figure 2). The midpoint of the samples was determined in the coronal view, and the corresponding axial slice of this midpoint was obtained. 6 circumferences containing 27 pixels were determined around the metal alloy image, and for each of these circumferences, the standard deviation of the histogram was obtained. The standard deviation is a method proposed by Wenzel and Sewerin¹⁰ as a way to measure the variability of grey shades (image noise).

A control area was evaluated 50 slices (10 mm) below the axial slice of the metal area. An image of the sample was drawn in the control area to simulate positioning of the sample to standardize the evaluated areas, and six circumferences were determined around it to obtain the standard deviation values of the control area.

The standard deviation values were compared by Student's *t*-test ($\alpha = 0.05$) for activating or not activating the MAR tool in central and peripheral positioning.

Results

The standard deviation values obtained for the images acquired with different protocols are shown in Table 2.

In the presence of the MAR tool, a statistically significant difference of image noise was observed for central and peripheral positioning, for both control area ($p = 0.0012$) and metal area ($p = 0.03$). In general, a smaller level of noise was observed for images with phantoms in central positioning.

When the MAR tool was not activated, the images with the phantom in the peripheral position showed greater levels of noise; however, the activation of the MAR tool increased even more the noise in these images. A decrease in image noise with the MAR tool activated was found only in phantoms with the metal positioned centrally in the FOV.

Discussion

Metallic artefacts in CBCT images influence image quality, making diagnosis difficult or even invalidating it.¹¹

Table 1 Protocols for tomographic images acquisition in relation to phantom positioning and use of the metal artefact reduction (MAR) tool

Protocols	Phantom positioning		MAR tool	
	Central ^a	Peripheral ^b	Absent	Present
Protocol 1	X		X	
Protocol 2	X			X
Protocol 3		X	X	
Protocol 4		X		X

^aCentral: centralized with the laser alignment lights of the equipment.
^bPeripheral: 30 mm anteriorly of the central position marked by the alignment lights.

Figure 2 Examples of axial images obtained with different positions in the field of view (central and peripheral) and in presence and absence of the metal artefact reduction tool, for test areas (A–D) and control areas (E–H). (A/E) Central and without tool. (B/F) Central and with tool. (C/G) Peripheral and without tool. (D/H) Peripheral and with tool.

Artefacts are not equally spread across the FOV,¹² and the object position in the FOV alters the image quality.¹³ The position of an object in the FOV affects scatter-induced image noise levels, indicating that this is an important aspect of image quality optimization.¹⁴

According to Taylor,¹⁵ the amount of image noise is increased if the object is moved from a central to a peripheral position, resulting in better quality images (less noise) when the objects to be scanned are centrally positioned in the FOV than those positioned peripherally. In the present study, better quality images were also observed when the phantom was positioned centrally in the FOV than when positioned peripherally in the FOV. The greater amount of noise in images with peripherally positioned phantoms is explained by the cone-shaped beam effect described by Scarfe and Farman.¹⁶ According to these authors, CBCT images have less information for peripheral structures due to divergence of the cone beam, resulting in higher noise to the images of objects peripherally positioned. Ozaki *et al*¹⁷ also observed that central positioning of the object in the FOV is essential for acquiring better quality images.

Because of the greater amount of noise in the peripheral region, it would be expected that the MAR tool have an increased effect in this region; however, as observed in the present study, the tool increased even more the noise levels in these images. Still, in the centrally positioned phantom, the MAR tool reduced the artefact, showing that it is effective only when the artefact-generator object is in the centre of the FOV.

Positioning the metal object centrally in the FOV should be considered in order to have an effective reduction in image artefacts. Bechara *et al*⁷ and Bezerra *et al*¹⁸ studied the effectiveness of the MAR tool in the detection of root fractures in endodontically treated teeth, and Kamburoglu *et al*¹⁹ evaluated peri-implant defects using the MAR tool. The authors found no improvement in diagnosis when using the tool. However, in these studies, the phantoms were positioned centrally in the FOV, but not the artefact-generator objects which were positioned on the periphery of the FOV. This could explain why using the MAR tool had no diagnostic improvement in the studied conditions.

The MAR tool is activated before image acquisition, considering the patient's oral cavity characteristics in relation to the presence of materials that can be a source for artefact formation. In the present study, it was observed that to have an effective reduction of artefact and improve image quality, the MAR tool should be considered only when the artefact-generator object is positioned centrally in the FOV. Therefore, the MAR tool should not be used if the objects that can be a source of artefacts are in the peripheral region of the FOV, as this could compromise even more the image quality in this region. Clinically, the professional can use the lights of the equipment to check the alignment of the scan area and, if dental metal alloys are in its centre, to make the decision whether MAR should be active or not.

This is the first study that intended to evaluate the effectiveness of the MAR tool at varying positions of

Table 2 Noise levels of tomographic images, considering the phantom position in the field of view

Phantom position	Control area		Metal area	
	Without MAR tool	With MAR tool	Without MAR tool	With MAR tool
Central	25.8 ± 2.27	24.47 ± 1.29	250.01 ± 150.05	160.90 ± 310.60
Peripheral	25.7 ± 1.48	26.30 ± 1.94	334.98 ± 152.90	447.16 ± 610.22
<i>p</i> -value	0.98	0.0012 ^a	0.18	0.03 ^a

MAR, metal artefact reduction.

^aStatistical differences ($p < 0.05$).

a metal object in the anteroposterior direction to simulate scans with centralized maxillary bones in which restored teeth and/or implants, among other metal objects, are located peripherally (alveolar process) in the FOV. In the present study, the metal alloy sample was vertically centralized, but we suggest further studies to evaluate the MAR tool effectiveness in, for example,

teeth with metal materials in maxilla when acquiring a volume centralized in the mandible.

In conclusion, the professional needs to be attentive that the MAR tool is effective only when the metal object is in the central region of the FOV; therefore, the MAR tool for CBCT acquisitions should be used only in these cases.

References

1. Arai Y, Tammissalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofac Radiol* 1999; **28**: 245–8. doi: <https://doi.org/10.1038/sj/dmfr/4600448>
2. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA, Tinazzi Martini P, et al. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *Eur Radiol* 1998; **8**: 1558–64. doi: <https://doi.org/10.1007/s003300050586>
3. Farman AG, Scarfe WC. The basics of maxillofacial cone beam computed tomography. *Semin Orthod* 2009; **15**: 2–13. doi: <https://doi.org/10.1053/j.sodo.2008.09.001>
4. Schulze R, Heil U, Gross D, Bruellmann DD, Dranischnikow E, Schwanecke U, et al. Artefacts in CBCT: a review. *Dentomaxillofac Radiol* 2011; **40**: 265–73. doi: <https://doi.org/10.1259/dmfr/30642039>
5. Bechara B, Moore WS, McMahan CA, Noujeim M. Metal artefact reduction with cone beam CT: an *in vitro* study. *Dentomaxillofac Radiol* 2012; **41**: 248–53. doi: <https://doi.org/10.1259/dmfr/80899839>
6. Bechara B, McMahan CA, Geha H, Noujeim M. Evaluation of a cone beam CT artefact reduction algorithm. *Dentomaxillofac Radiol* 2012; **41**: 422–8. doi: <https://doi.org/10.1259/dmfr/43691321>
7. Bechara B, Alex McMahan C, Moore W, Noujeim M, Teixeira F, Geha H. Cone beam CT scans with and without artefact reduction in root fracture detection of endodontically treated teeth. *Dentomaxillofac Radiol* 2013; **42**: 20120245. doi: <https://doi.org/10.1259/dmfr.20120245>
8. Nackaerts O, Maes F, Yan H, Couto Souza P, Pauwels R, Jacobs R. Analysis of intensity variability in multislice and cone beam computed tomography. *Clin Oral Implants Res* 2011; **22**: 873–9. doi: <https://doi.org/10.1111/j.1600-0501.2010.02076.x>
9. Katsumata A, Hirukawa A, Okumura S, Naitoh M, Fujishita M, Arijji E, et al. Effects of image artifacts on gray-value density in limited-volume cone-beam computerized tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **104**: 829–36. doi: <https://doi.org/10.1016/j.tripleo.2006.12.005>
10. Wenzel A, Sewerin I. Sources of noise in digital subtraction radiography. *Oral Surg Oral Med Oral Pathol* 1991; **71**: 503–8. doi: [https://doi.org/10.1016/0030-4220\(91\)90441-e](https://doi.org/10.1016/0030-4220(91)90441-e)
11. Barrett JF, Keat N. Artifacts in CT: recognition and avoidance. *RadioGraphics* 2004; **24**: 1679–91. doi: <https://doi.org/10.1148/rgr.246045065>
12. Parsa A, Ibrahim N, Hassan B, Syriopoulos K, van der Stelt P. Assessment of metal artefact reduction around dental titanium implants in cone beam CT. *Dentomaxillofac Radiol* 2014; **43**: 20140019. doi: <https://doi.org/10.1259/dmfr.20140019>
13. Bechara B, McMahan CA, Moore WS, Noujeim M, Geha H. Contrast-to-noise ratio with different large volumes in a cone-beam computerized tomography machine: an *in vitro* study. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2012; **114**: 658–65. doi: <https://doi.org/10.1016/j.ooral.2012.08.436>
14. Pauwels R, Jacobs R, Bogaerts R, Bosmans H, Panmekiate S. Reduction of scatter-induced image noise in cone beam computed tomography: effect of field of view size and position. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2016; **121**: 188–95. doi: <https://doi.org/10.1016/j.ooral.2015.10.017>
15. Taylor C. Evaluation of the effects of positioning and configuration on contrast-to-noise ratio in the quality control of a 3D Accuitomo 170 dental CBCT system. *Dentomaxillofac Radiol* 2016; **45**: 20150430. doi: <https://doi.org/10.1259/dmfr.20150430>
16. Scarfe W, Farman A. What is cone-beam CT and how does it work? *Dent Clin North Am* 2008; **52**: 707–30. doi: <https://doi.org/10.1016/j.cden.2008.05.005>
17. Ozaki Y, Watanabe H, Nomura Y, Honda E, Sumi Y, Kurabayashi T. Location dependency of the spatial resolution of cone beam computed tomography for dental use. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2013; **116**: 648–55. doi: <https://doi.org/10.1016/j.ooral.2013.07.009>
18. Bezerra IS, Neves FS, Vasconcelos TV, Ambrosano GM, Freitas DQ. Influence of the artefact reduction algorithm of Picasso Trio CBCT system on the diagnosis of vertical root fractures in teeth with metal posts. *Dentomaxillofac Radiol* 2015; **44**: 20140428. doi: <https://doi.org/10.1259/dmfr.20140428>
19. Kamburoglu K, Kolsuz E, Murat S, Eren H, Yüksel S, Paksoy CS. Assessment of buccal marginal alveolar peri-implant and periodontal defects using a cone beam CT system with and without the application of metal artefact reduction mode. *Dentomaxillofac Radiol* 2013; **42**: 20130176. doi: <https://doi.org/10.1259/dmfr.20130176>