Original Article

Evaluation of Metal Artifacts in Cone Beam Computed Tomography by Metal Supported Porcelain Crowns Using Different FOV and Localizations: An In Vitro Study

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Abstract

Introduction: Metal-supported porcelain crowns (MSPC) and bridge restorations may be present in the mouths of patients undergoing CBCT imaging. Artifacts that are caused by these MSPCs may adversely affect image quality. The aim of this study is to determine the effect of different FOV (field of view) and localization in FOV on metal artifacts caused by MSPC. **Methods:** Twenty MSPCs scanned with CBCT at central and peripheral localization at 18x16 and 8x8 cm FOV. The 2.5 mm periphery area of the MSPC cross-sectional image was evaluated. The metal artefact-area within this area was measured. Then, the artifact-area to total-area ratio was converted to form of a percentage. In addition to evaluation of crown periphery area, the lengths of the metal streaks artifacts were measured. The maximum linear dimension of the metal artifact was recorded from the crown margin for each MSPC in cross-sectional image in the bucco-lingual direction. All data collected were evaluated by Kruskal-Wallis analysis and Mann Whitney U test (P<0,05). **Results:** No statistically significant differences were found in the artifacts-area measured (P=0.121). However, there was a statistically significant difference in linear dimension measurements of artifacts (P=0.000). In 18x16 cm FOV localization peripheral linear dimension measurements were higher than other FOV and localizations. **Conclusion:** Linear size artifacts of MSPC were found to be higher in peripheral positioning in wide FOV. However, according to this study, areas evaluated for metal artifacts caused by MSPCs are not affected by FOV and localization.

Keywords: CBCT, Dental image quality, Metal crown, Metal artifact, FOV, In-vitro study

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Introduction

Cone beam computed tomography (CBCT) provides detailed and accurate information for diagnosis and treatment planning of dentomaxillofacial region diseases. CBCT provides high-resolution image of bone and radiation dose is lower than Computed Tomography (CT) (1, 2). CBCT is used successfully in dentistry such as endodontics, orthodontics and surgical procedures (3). Despite the benefits, CBCT could potentially have some complications including metal streak artifacts. Artifacts caused by metals in the scan area affect CT and CBCT images quality (4). Metal artifacts are among the most important factors leading to impaired diagnostic quality of CBCT images (5). These artifacts formed in CBCT reduce the contrast of the image, compromise the image quality by obscuring vital the structures that are desired to be evaluated in the image. Furthermore, interpretation of these images is more time consuming for the operator (6).

In recent years, a wide range of CBCT devices with different exposure parameters have been presented. Radiation dose is affected by exposure time and tube current and x-ray quality is altered by tube voltage, filtration and FOV (field of view). These factors affect quality of image through noise, contrast resolution and artifacts (7). Tomographic images have variable densities according to localization of the object in FOV (8). Artifacts in images will increase when higher number of objects are located outside of FOV (9). Size of FOV affects CBCT quality and artifact formation based on projection data discontinuity effect (10, 11). Metal-supported porcelain crowns (MSPC) and bridges may be present in the dentition of patients undergoing CBCT scans. Metal artifacts caused by these prostheses may adversely affect the image quality. The aim of this study is to evaluate metal artifacts in CBCT images caused by MSPCs in 4 different scanning protocols using two different FOVs (18x16 and 8x8 cm) and two different localizations measuring them spatially and dimensionally.

Materials and Methods

Twenty MSPCs including 9 molars, 6 premolars and 5 incisors were used in this in vitro study. These MSPCs obtained from spare ones which were originally fabricated for clinical use. Block of wax was used to stabilize the crowns during the scan (figure 1A). A 18x16 cm cardboard box was used (figure 1B) to mount each MSPCs in the gantry for CBCT scanning (figure 1C). 18x16 cm and 8x8 cm FOVs were selected for scanning. For localization, two scanning points were identified as central and peripheral for each FOV. The peripheral point was assigned as a midpoint in top level of both FOV. Scout images were taken before actual scan in both FOVs to adjust the position of the object in FOV in lateral and coronal directions. For peripheral position, MSPC was placed at the peripheral point in the cardboard box according to the preferred FOV. Later, in the first lateral scout image taken, MSPC was adjusted to be at midpoint of top and anterosuperior of FOV. Within this setting, image was taken by moving the gantry with imaging computer. In the coronal image, which was the second scout imaging, MSPC was adjusted to be at the midpoint at mediolateral of top point. The central point was determined as midpoint in middle level of both FOVs. These points were checked in lateral and coronal scout images. Despite peripheral position, central position adjustments were performed by choosing the midpoint of top-bottom and antero-superior in lateral scout image and choosing the midpoint of top-bottom and mediolateral in coronal scout images. During the scan, bucco-lingual positions of the crowns were adjusted to simulate a dental arch shape. Each crown was scanned 4 times and a total of 80 CBCT images were obtained for evaluation. Images were obtained by NewTom 5G (Quantitative Radiology, Verona, Italy) CBCT device using a standard protocol of 110 kVp and a maximum of 20). Exposure time was the same in all the scans (18hs). Contrast adjustment were similar to clinical x-rays for patient images. Voxel values were the same in all images (0.25mm). CBCT images were evaluated using NNT software (Quantitative Radiology, Verona, Italy).

For each MSPC, cross-sections were taken in the middle of the crown (thickness: 0.05 mm) to see the bucco-lingual direction. The area around 2.5 mm of the MSPC cross-sectional image was first evaluated. Next, area with metal artifacts within this measured area was measured. Later, artifact-area to total-area ratio was converted to form of a percentage (figure 2). Furthermore, lengths of metal streak artifacts were measured. The cross-sectional image in the bucco-lingual direction was recorded for each MSPC by measuring the maximum linear dimension originated from the metal crown edge (figure 3). In order to determine the end point of metal streaks, these evaluations were conducted in a dark room and hyperdensed border was considered the end point. To obtain a cross-sectional image parallel to long axis of tooth, each MSPC was embedded in a wax block parallel to the surface. The Kolmogorov-Smirnov and Shapiro Wilk tests were used to test the normality of the data. The results indicated that our data do not show normal distribution. For statistical evaluation, data collected were compared with Kruskal-Wallis analysis and Mann Whitney U test ($P<0.05$). To define intraobserver error rate, measurements were repeated on randomly selected 30% of all images intraclass correlation coefficients (ICC).

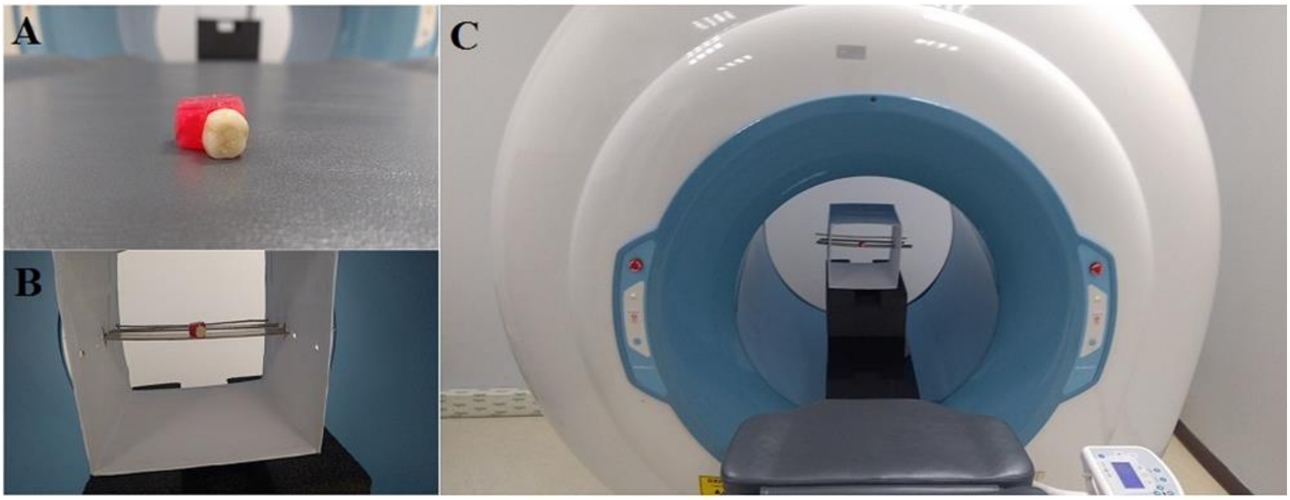

Figure 1: Metal supported porcelain crown with wax (A), Cardboard was used for scanning with metal supported porcelain crown (B), Cardboard and crown in the gantry (C)

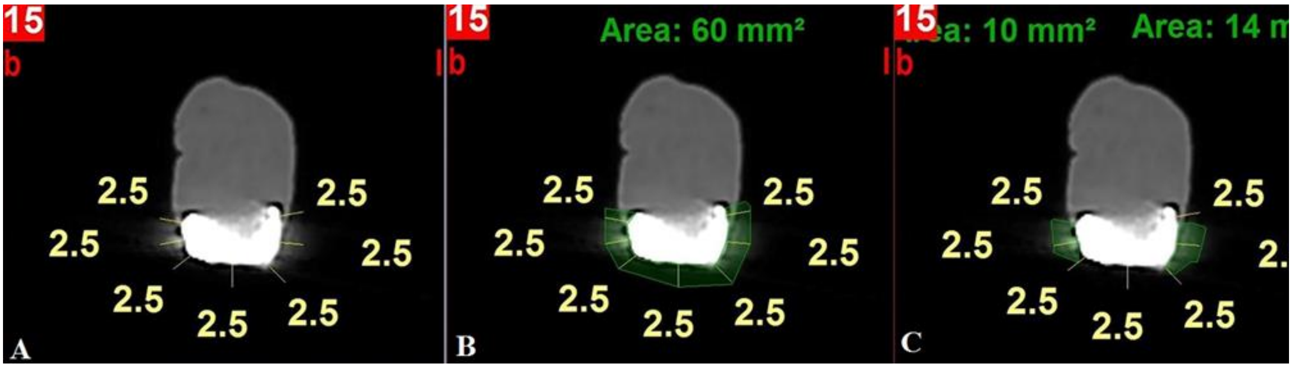

Figure 2: Determining of 2.5 mm area from the edge of crown (A), total area measurement around the crown (B), metal artifact-area measured (C), artifact-area to total-area ratio (B) was measured (C) converted to a percentage value (C:BX100=percentage value)

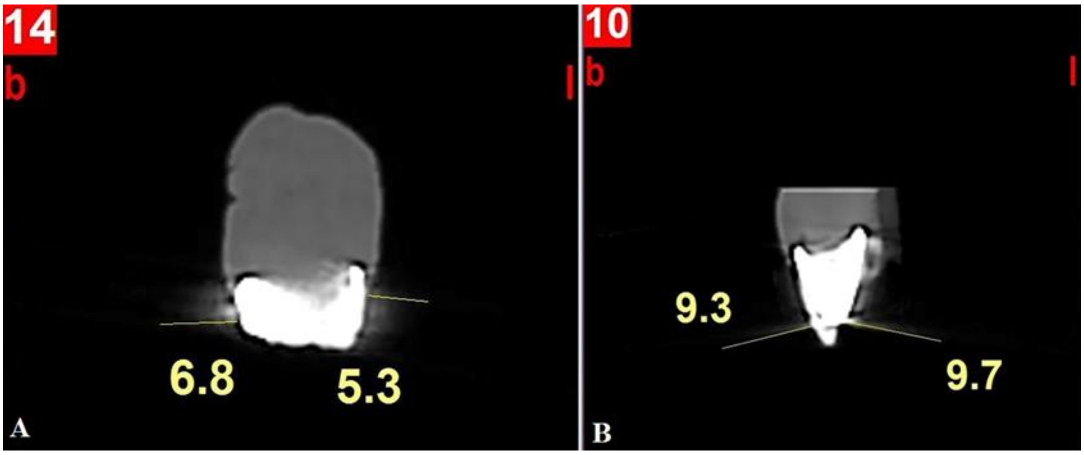

Figure 3: Metal artifact linear dimension measurement in different form crowns (A,B), linear dimension was measured from the crown edge to the metal artifact final point and maximum dimension was recorded for each crown.

Results

ICC scores were 0.87-0.92 for all measurements. Area measured from artifacts and linear size measurements means are presented in Table I. In groups where metal artifacts occurred, there was no statistically significant difference between groups with different FOV and localizations (P=0.121) (Table II). However, there was a statistically significant difference in linear size measurements of metal artifacts occurring at different FOV and localizations in MSPC CBCT scans (P=0.000) (table II). Artifacts of linear size measurements in FOV of 18×16 cm localization peripheral was statistically significant difference than other groups (Table III). A statistically significant difference was found between the FOV of 18x16 cm-localization central with FOV of 8x8 cm localization-central scan artifact dimensional measurements (P=0.046) (Table III).

Table I: Mean value of percentage of measured area and linear dimension measurements.

Groups	Percentage of area measured	linear measurements
	Mean (%)	Mean (mm)
Fov 18x16 Central	29.7	4.5
Fov 18x16 Peripheral	22.5	12.7
Fov 8x8 Central	33.5	5.6
Fov 8x8 Peripheral	33.1	4.8

Table II: Kruskal Wallis test for linear dimension measurements and percentage of area measured of metal artifacts

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		Linear dimension measurements			Percentage of area measured		
Groups	N	Median	Min-Max	P	Median	Min-Max (%)	P
Fov 18x16 Central	20	24.45	2.5-7.5	0.000	41.25	10.2-55	0.121
Fov 18x16 Peripheral	20	70.45	8.4-17		30.08	9.5-44.1	
Fov 8x8 Central	20	37.10	2.5-8.5		45.98	10.2-61.6	
Fov 8x8 Peripheral	20	30	2.5-6.5		44.70	10.2-63.2	

TableIII: Mann Whitney U test for linear dimension measurements

Groups	N	Median	P
Fov 18x16 central	20	10.50	0.000
Fov 18x16 peripheral			

	20	30.50	
Fov 18x16 central	20	16.80	
Fov 8x8 central			0.046
	20	24.20	
Fov 18x16 central	20	18.15	
Fov 8x8 peripheral			0.211
	20	22.85	
Fov 18x16 peripheal	20	30.45	
Fov 8x8 central			0.000
	20	10.55	
Fov 18x16 peripheral	20	30.50	
Fov 8x8 peripheral			0.000
	20	10.50	
Fov 8x8 central	20	23.55	
Fov 8x8 peripheral			0.127
	20	17.65	

Discussion

Artifacts in CBCT images compromise the proper diagnosis. Metallic materials in the oral cavity are the most common cause of major artifacts in x-rays (4,12). Various sizes of metal objects can be found in whole body especially the head and neck. Metal restorations, crowns, brackets and implants adversely affect CT's quality through beam hardening, scatter, quantum noise and photon starvation (13). The low-energy rays in the polychromatic spectrum are absorbed when they encounter a high atomic number of dense matter. The average energy of the spectrum increases and beam hardening occurs due to this dense matter that acts as a filter. As a result, dark lines form around this dense substance (14). When the photons are fully absorbed by metallic objects as they pass through the X-rays (photon starvation), bright lines spread around the metal objects, bright areas and grey value losses between metal objects may emerge (13). In our study, the maximum length of these bright lines around the crowns and the area within a periphery of 2.5 mm area around the crowns were measured according to the localizations with different FOV and FOV percentages. Image noise is increased by the displacement of the object from the central to the periphery of the FOV. In this case, the positioning of the object as a flank will improve image quality (15). Ozakı et al. (16) showed that better quality images are obtained when the object is centrally positioned within the FOV . Scarfe and Farman (17) stated that the noise in the periphery increases due to the cone beam effect. In our study, the area around 2.5 mm of each crown was first evaluated, then the area of the metal artifact was measured and the ratio of this area to the total area was calculated as a percentage. The highest ratio was observed in the small FOV 8x8 (FOV 8x8 center = 33.54%, FOV 8x8 periphery = 33.16%, FOV 18x16 center = 29.74%, FOV 18x16 periphery = 22.55%). However, in the evaluation of 2.5 mm periphery around crowns, no statistically significant difference in spatial measurement was found between groups with variation of central and peripheral localizations and different FOVs. According to these results, in the presence of MSPC in the oral cavity of the patients undergoing CBCT scanning, it was seen that FOV and the choice of localization within the FOV was not significant within

2.5 mm periphery of the crowns. During the CBCT scan, the top and bottom parts of the FOV are exposed to rays only when they are x-rayed to receive less X-rays than other regions (18). In an in-vitro study, Nikbin et al. (19) found that the central position was more accurate and sensitive than the peripheral position in the evaluation of metal posts in the CBCT images before the metal artifact reduction (MAR) algorithm was applied. In our study, the maximum length of artifact was measured from the margin of the MSPC in each CBCT image. Dimensional length was found to be the highest on average FOV 18x16 periphery (FOV 18x16 periphery = 12.71mm, FOV8x8 center = 5.61 mm, FOV8x8 periphery = 4.88 mm, FOV 18x16 center = 4.52). In the evaluation of dimensional length statistically significant difference was found between the FOV 18x16-periphery with other groups. According to these results, in large FOV and peripheral position metal artifacts formed around the crown were found more than other FOV and positions.

Conclusion

According to the results of this study, adverse effects of MSPC metal artifacts on the image was not significant in different FOV and localizations in 2.5 mm periphery of the crown. However, the widest FOV and peripheral positioning, already not common in clinical practice, should be avoided in linear dimension evaluation.

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Conflict of interest

The authors report no conflict of interest.

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