Effect of intracanal posts on dimensions of cone beam computed tomography images of endodontically treated teeth

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ABSTRACT

Objectives: This study evaluated the effect caused by intracanal posts (ICP) on the dimensions of cone beam computed tomography (CBCT) images of endodontically treated teeth. **Methods:** Forty-five human maxillary anterior teeth were divided into 5 groups: Glass-Fiber Post®, Carbon Fiber Root Canal®, Pre-fabricated Post – Metal Screws®, Silver Alloy Post® and Gold Alloy Post®. The root canals were prepared and filled; after that, the gutta-percha filling was removed, and the ICP space was prepared. The post cementation material was resin cement. CBCT scans were acquired, and the specimens were sectioned in axial, sagittal and coronal planes. The measures of ICP were obtained using different 3D planes and thicknesses to determine the discrepancy between the original ICP measurements and the CBCT scan measurements. **Results:** One-way analysis of variance, Tukey and Kruskall-Wallis tests were used for statistical analyses. The significance level was set at $\alpha = 5\%$. CBCT scan ICP measurements were from 7.7% to 100% different from corresponding actual dimensions. **Conclusion:** Gold alloy and silver alloy posts had greater variations ($p>0.05$) than glass fiber, carbon fiber and metal posts ($p<0.05$). Gold alloy and silver alloy post dimensions were greater on CBCT scans than on original specimens.

Keywords: Cone beam computed tomography. Artifact. Intracanal post. Post.

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Introduction

Root canal obturation is a major step in the last phase of endodontic treatment, which is completed with coronal restoration. However, endodontically treated teeth often have a substantial loss of dental structure and need an intracanal post.[11]

Several types of intracanal posts (ICP) have been recommended for dental reconstructions according to the analysis of important restoratives aspects: the possibility of endodontic post failure, which may result in loss of retention; the risk of root canal reinfection due to bacterial microleakage; the effect of intracanal post length on apical periodontitis; the retentive effect of adhesive systems for the different types of posts; the possibility of stress concentration; and the difference in modulus of elasticity between post and dentin.[6,25]

Pathological and clinical findings, often supported by radiographs, provide the basis for endodontic therapy protocols and treatments. Images, however, are necessary in all phases of endodontic treatment.[11]

Since the discovery of X-rays by Roentgen in 1895, radiology has witnessed the constant development of new technologies. The angle variations proposed by Clark and the development of panoramic radiography produced novel applications in endodontics. Cone beam computed tomography (CBCT) has recently introduced three-dimensional (3D) imaging into dentistry[2,24] and brought benefits to specialties that had not yet enjoyed the advantages of medical CT due to its lack of specificity. Computerized tomography (CT) is an important, nondestructive and noninvasive diagnostic imaging tool.[2,5,24,29]

CBCT produces 3D images of a structure because it adds a new plane: depth. Its clinical application ensures high accuracy and is useful in nearly all areas of dentistry.[2,5,8,9,10,24,29] However, dimensions misdiagnoses may result from imaging artifacts. Metal or solid structures (higher density materials) may produce nonhomogeneous artifacts and affect image contrast. Concerns about diagnostic errors have motivated authors to study alternatives to correct for beam-hardening artifacts during image acquisition, image reconstruction, or under other conditions.[11-25]

Jian and Hongnian[16] found that beam hardening is caused by the polychromatic spectrum of the X-ray beam and that artifacts decrease image quality. Katsumata et al[18,19] reported that artifacts caused by halation or saturation from an imaging sensor decrease CT values on the buccal side of the jaws. In dental CBCT imaging, artifacts may change CT values of the soft tissues adjacent to the lingual and buccal sides of the jaws. The CT values of hard tissue structures may also be similarly affected.

CBCT images showing teeth with solid plastic or metal ICP may project ghost images over the areas surrounding it and mask the actual root canal structures, which increases the risk of clinical misdiagnosis. Few studies investigated misdiagnosis in association with CBCT images and ICP. This study evaluated the effect of original ICP on dimensional of CBCT images of endodontically treated teeth.

Material and Methods

Tooth preparation

This study is the continuation of a preliminary evaluation of the effect of CBCT slice on the visualization of endodontic sealers. The study sample comprised 45 maxillary anterior teeth extracted for different clinical reasons at the Dental Urgency Service of the Federal University of Goiás, School of Dentistry, Goiânia, Brazil. This study was approved by the Ethics Committee of the Federal University of Goiás, Brazil. Preoperative radiographs of each tooth were obtained to confirm the absence of calcified root canals and internal or external resorption, and the presence of a fully formed apex.

The teeth were removed from storage in 0.2% thymol solution and were immersed in 5% sodium hypochlorite (Fitofarma, Lt. 20442, Goiânia, GO, Brazil) for 30 min to remove external organic tissues. The crowns were removed to set the remaining tooth length to a standardized length of 13 mm from the root apex. After initial radiographs, standard access cavities were prepared and the cervical third of each root canal was enlarged with ISO # 50 to # 90 Gates-Glidden drills (Dentsply/Maillefer, Ballaigues, Switzerland). Teeth were prepared up to an ISO # 50 K-File (Dentsply/Maillefer) 1 mm short of the apical foramen. During instrumentation, the root canals were irrigated with 3 ml of 1% NaOCl (Fitofarma) at each change of file. Root canals were dried and filled with 17% EDTA (pH 7.2) (Biodinâmica, Ibiporã, PR, Brazil) for 3 min to remove the smear layer.

The teeth were randomly allocated into 5 groups according to the intracanal post material: Group 1 (n = 9) - Pre-fabricated Glass-Fiber Post® (White post DC®, FGM, Joinville, SC, Brazil); Group 2 (n = 9) - Pre-fabricated Carbon Fiber Root Canal® (Reforpost Carbon Fiber RX, Angelus, Londrina, PR, Brazil); Group 3 (n = 9) - Pre-fabricated Post – Metal Screws® (Obturation Screws®, FKG, Dentaire, La Chaux-de-Founds, Swiss); Group 4 (n = 9) – Silver Alloy Post® (Silver Alloy la Croix®, Rio de Janeiro, RJ, Brazil); Group 5 (n = 9) – Gold Alloy Post® (Gold Alloy Stabilor G®, Au-58.0, Pd-5.5, Ag-23.3, Cu-12.0, Zn trace, Ir trace; DeguDent Benelux BV, Hoorn, Netherlands). It was considered as control the original specimen of each group.

After root canal preparation was completed, all teeth were filled with AH PlusTM (Dentsply/Maillefer) and gutta-percha points, and prepared according to the manufacturer's instructions and using a conventional lateral condensation technique. The diameters of the prefabricated posts used in Groups 1 to 3 were compatible with the diameter of prepared root canals. For Groups 4 and 5, silver and gold metal posts were fabricated after obtaining impressions of the root canals.

The gutta-percha filling was removed and an intracanal post space was prepared using Gates-Glidden drills #2 to #3 (Dentsply/Maillefer) and Largo drill #1 (Dentsply/Maillefer) to achieve a post length of 8 mm and to leave at least 4 mm of filling material in the apical third (Fig 1). The post cementation material used was resin cement (RelyX Unicem, 3M ESPE, Seefeld, Germany) strictly according to manufacturer´s instructions.

Images Analysis

CBCT scans were acquired to obtain 3D images. The teeth were placed on a plastic platform positioned in the center of a bucket filled with water to simulate soft tissue, according to a model described in previous studies.[18,26,28] CBCT images were acquired with a first generation i-CAT Cone Beam 3D imaging system (Imaging Sciences International, Hatfield, PA, USA). The volumes were reconstructed 0.2 mm isometric voxels. The tube voltage was 120 kVp and the tube current, 3.8 mA. Exposure time was 40 seconds. Images were examined with the scanner's proprietary software (Xoran version 3.1.62; Xoran Technologies, Ann Arbor, MI, USA) in a PC workstation running Microsoft Windows XP professional SP-2 (Microsoft Corp, Redmond, WA, USA) with an Intel® Core™ 2 Duo-6300 1.86 Ghz processor (Intel Corporation, USA), NVIDIA GeForce 6200 turbo cache videocard (NVIDIA Corporation, USA) and an EIZO - Flexscan S2000 monitor at 1600x1200 pixels resolution (Eizo Nanao Corporation Hakusan, Japan).

Root sectioning

After obtaining the CBCT scans, each specimen was carefully sectioned in axial, sagittal or coronal planes using an Endo Z bur (Dentsply/Maillefer) at high speed rotation under water-spray cooling. The cross-sectional slices for the axial plane were obtained at 8 mm from the root apex; and for sagittal and coronal planes, the roots were sectioned longitudinally along the center of the root canal (Fig 1).

Measurement of specimens and CBCT slices

The CBCT scans of intracanal posts (ICP) were measured in the axial, sagittal or coronal planes. All measurements were made at 8 mm from the root apex (Fig 1). ICP measurements on axial slices were made in the buccolingual direction; on sagittal slices, in the mesiodistal direction; and on coronal slices, in the buccolingual direction. All teeth were measured by two endodontic specialists using a 0.01-mm resolution digital caliper (Fowler/Sylvac Ultra-cal Mark IV Eletronic Caliper, Crissier, Switzerland).

To determine the discrepancy between original ICP values and CBCT values, all measurements were made on the same axial, sagittal and coronal sites. All the CBCT measurements were acquired by two dental radiology specialists using the measuring tool of the CBCT proprietary software (Xoran version 3.1.62; Xoran Technologies, Ann Arbor, MI, USA). CBCT dimensions were reformatted using 0.2-, 0.6-, 1.0-, 3.0- and 5.0-mm slice thicknesses.

The two calibrated examiners measured all the specimens and CBCT images and evaluated ICP dimensions in the directions previously described. When a consensus was not reached, a third observer made the final decision.

One-way analysis of variance (ANOVA), Tukey and Kruskall-Wallis tests were used for statistical analyses. The level of significance was set at $\alpha = 5\%$.

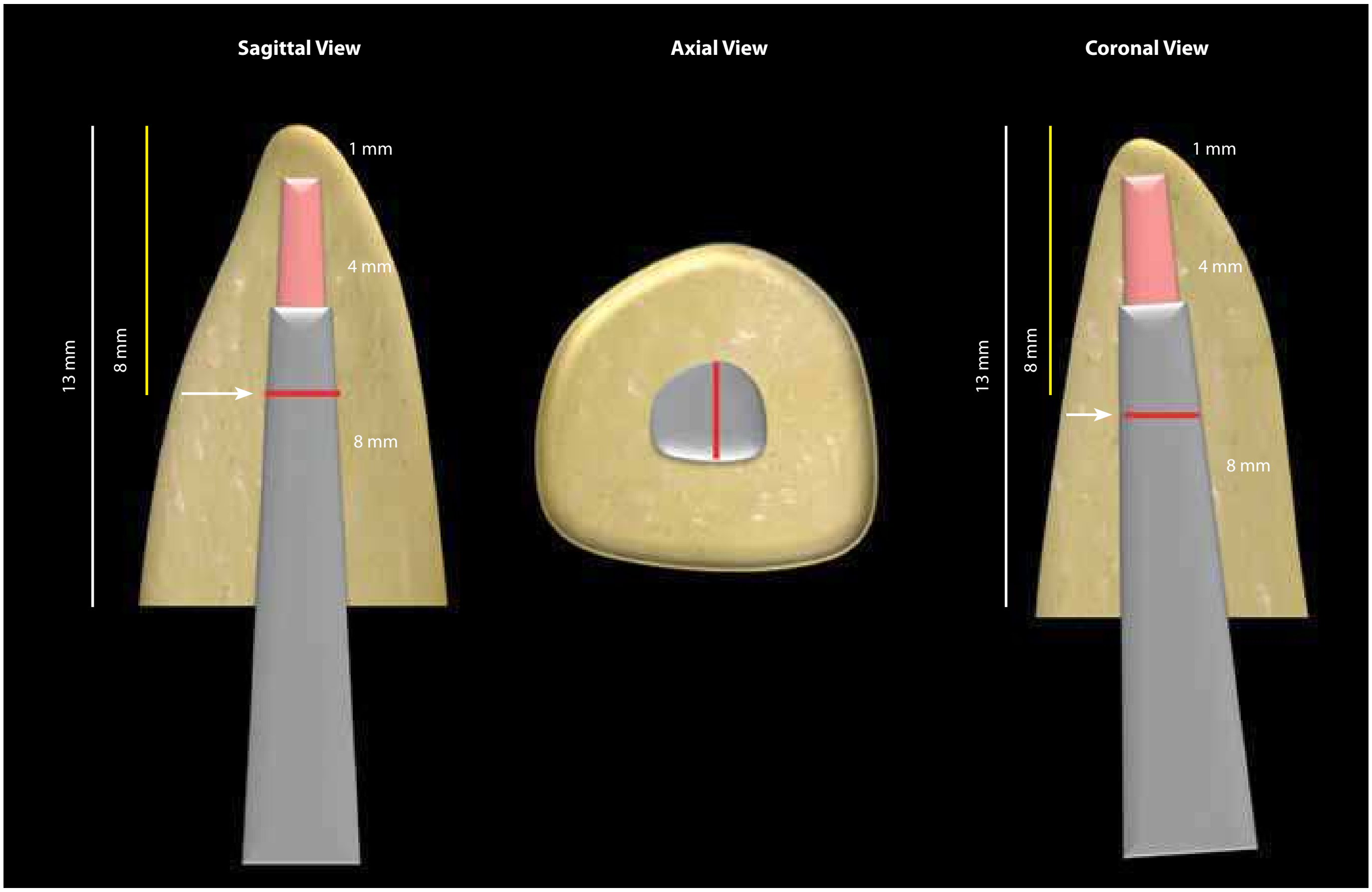

Figure 1. Schematic representation of sectioning root method and posts length, showing the sagittal, axial and coronal views.

Table 1. Percentage (%) of original ICP dimension increase on CBCT scans according to slice thickness and planes for each type of endodontic material (α=5%).

Thickness/Plane	Glass fiber	Carbon fiber	Metallic pre-fabricated	Silver	Gold
0.2 mm/ Axial	16.70	7.70	50.00	100.00	73.30
0.2 mm/ Coronal	16.70	38.50	66.70	85.70	100.00
0.2 mm/ Sagittal	0.00	33.30	53.80	57.10	57.10
0.6 mm/ Axial	16.70	7.70	50.00	100.00	73.30
0.6 mm/ Coronal	16.70	38.50	66.70	85.70	100.00
0.6 mm/ Sagittal	0.00	33.30	53.80	57.10	57.10
1 mm/ Axial	16.70	-7.70	50.00	100.00	73.30
1 mm/ Coronal	16.70	38.50	66.70	85.70	100.00
1 mm/ Sagittal	0.00	33.30	53.80	57.10	57.10
3 mm/ Axial	16.70	-7.70	50.00	100.00	73.30
3 mm/ Coronal	16.70	38.50	50.00	85.70	84.60
3 mm/ Sagittal	0.00	16.70	38.50	57.10	42.90
5 mm/ Axial	16.70	-7.70	50.00	100.00	73.30
5 mm/ Coronal	16.70	38.50	50.00	71.40	84.60
5 mm/ Sagittal	0.00	16.70	23.10	57.10	42.90
P value	**0.001***	**0.001***	**0.001***	**0.001***	**0.001***

*Interaction between type of cut and slice thickness and type of post significantly by Kruskall Wallis test.

Results

The increase of ICP dimensions in CBCT images ranged from 7.7% to 100% (Table 1). Differences were significant between glass fiber post, carbon fiber post and metal posts (Table 2). Figures 2-7 show the CBCT sagittal, axial and coronal views of the ICP. No significant differences were found when different slice thicknesses were used.

Table 2. Percentage (%) of original ICP dimension increase on CBCT scans in each group according to study variables (post, slices thickness and planes) and statistic analysis (α=5%).

Factor	Groups				
Posts*	Glass Fiber	Carbon Fiber	Metallic pre-fabricated	Gold	Silver
	11.13^D	21.20^C	51.54^B	72.85^A	79.98^A
Thickness**	0.2 mm	0.6 mm	1 mm	3 mm	5 mm
	50.44^A	50.44^A	49.41^A	44.20^A	42.22^A
Planes***	Axial		Coronal	Sagittal	
	47.69^A		58.38^A	35.95^B	

Different letters in horizontal demonstrate statistically significant difference with $p < 0.05$.
*p=0.0001 by ANOVA and Tukey test.
**p=0.607 by ANOVA.
***p=0.0001 by ANOVA and Tukey test.

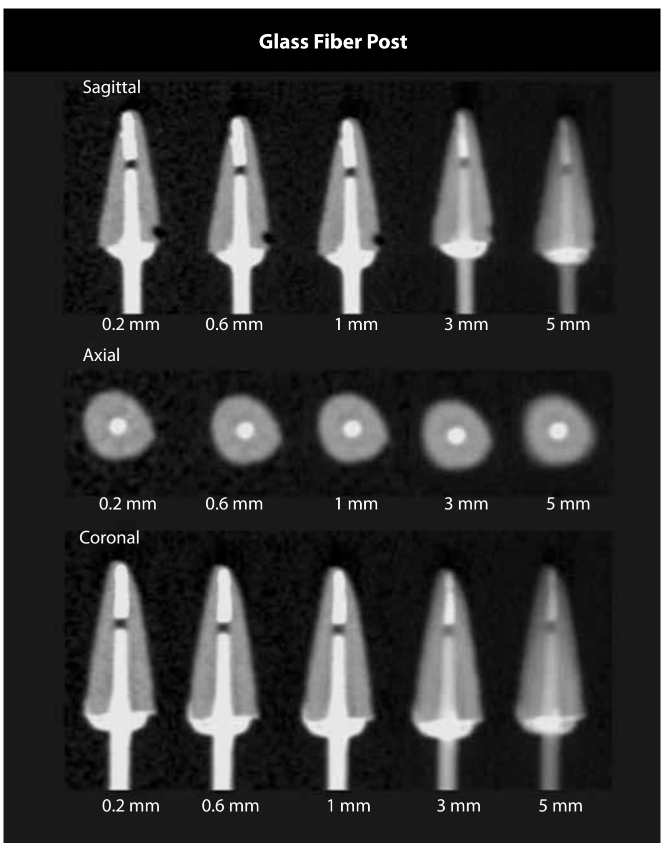

Figure 2. CBCT images of root canal filling with Glass Fiber Post in different slice thickness (0.2 mm, 0.6 mm, 1 mm, 3 mm and 5 mm) and planes (sagittal, axial and coronal).

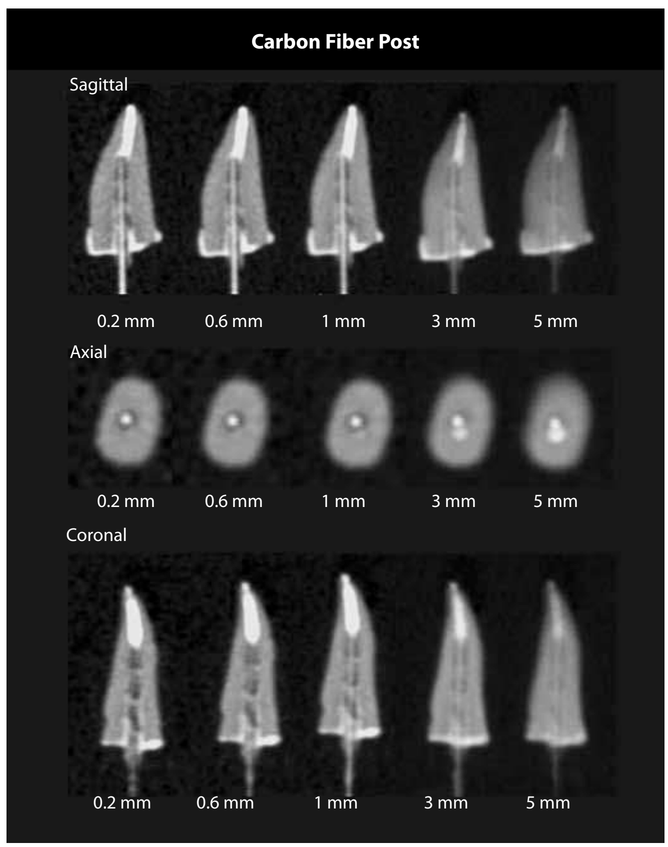

Figure 3. CBCT images of root canal filling with Carbon Fiber Post in different slice thickness (0.2 mm, 0.6 mm, 1 mm, 3 mm and 5 mm) and planes (sagittal, axial and coronal).

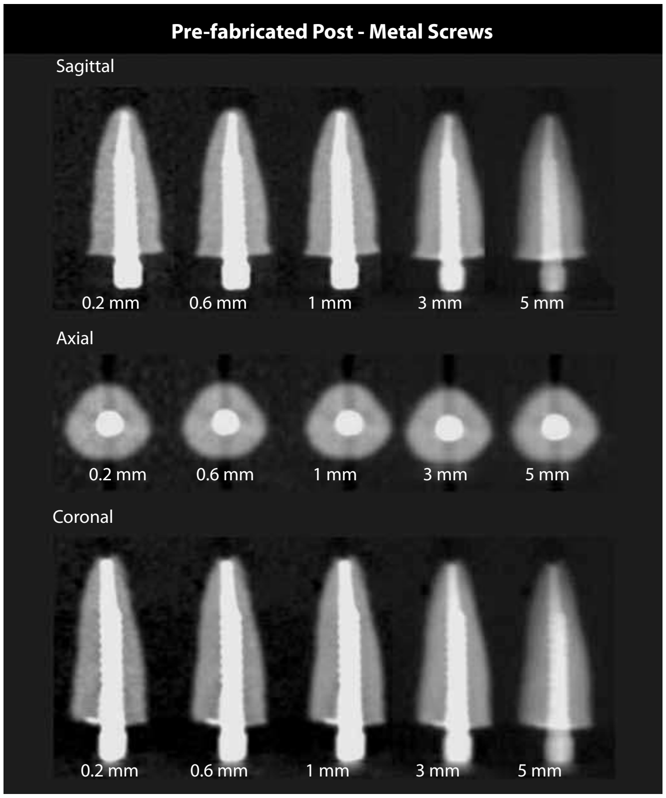

Figure 4. CBCT images of root canal filling with Pre-fabricated Post – Metal Screws in different slice thickness (0.2 mm, 0.6 mm, 1 mm, 3 mm and 5 mm) and planes (sagittal, axial and coronal).

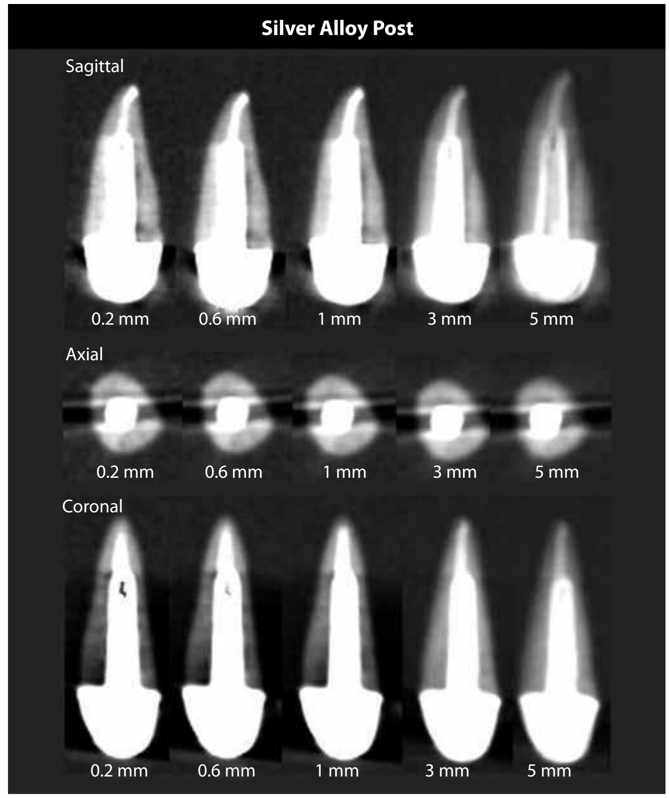

Figure 5. CBCT images of root canal filling with Silver Alloy Post in different slice thickness (0.2 mm, 0.6 mm, 1 mm, 3 mm and 5 mm) and planes (sagittal, axial and coronal).

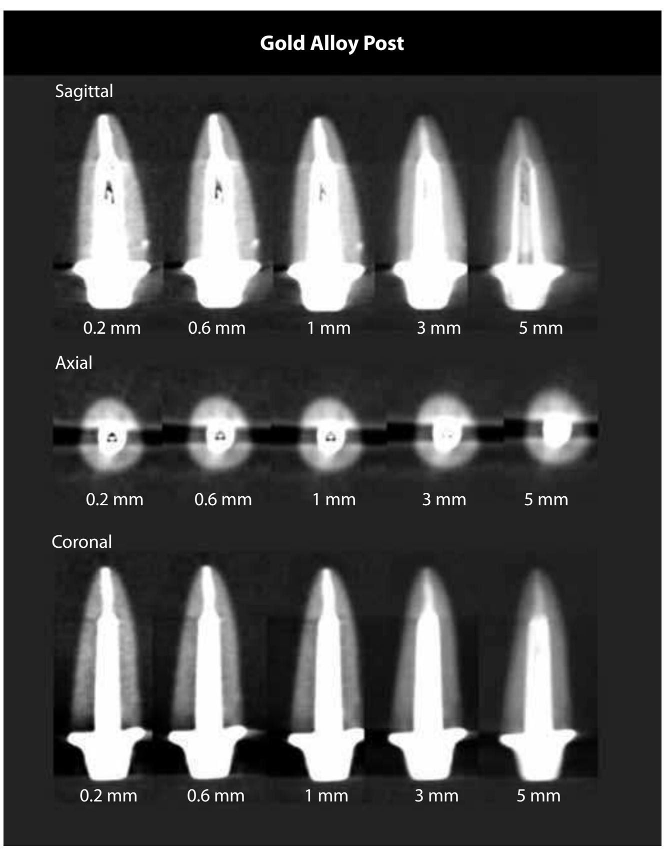

Figure 6. CBCT images of root canal filling with Gold Alloy Post in different slice thickness (0.2 mm, 0.6 mm, 1 mm, 3 mm and 5 mm) and planes (sagittal, axial and coronal).

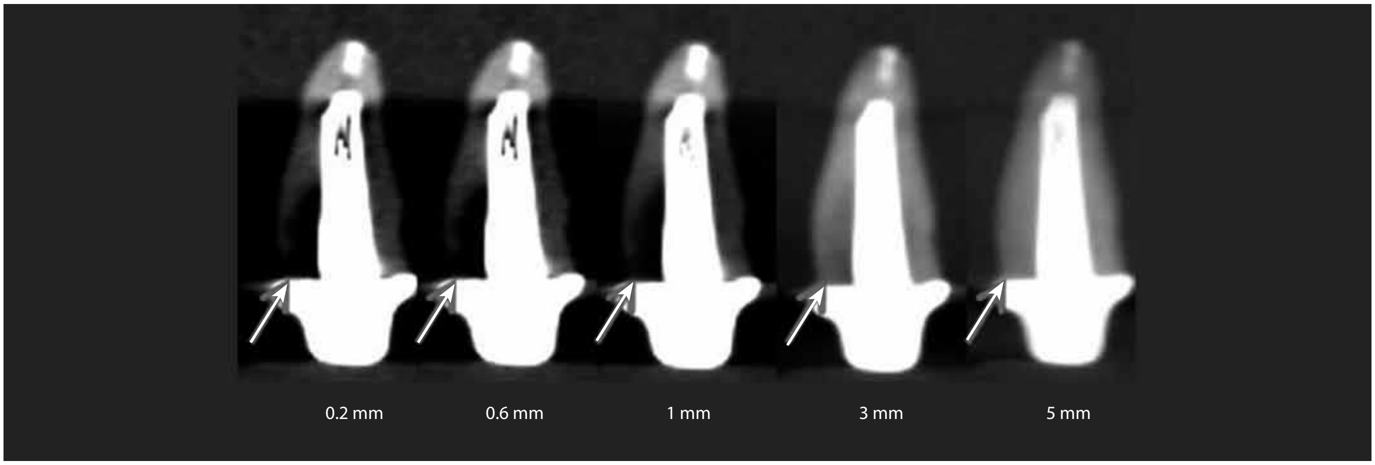

Figure 7. CBCT images of root canal filling with Gold Alloy Post, in different slice thickness (0.2 mm, 0.6 mm, 1 mm, 3 mm, and 5 mm) in coronal view showing metallic artifact in some slices.

Discussion

The 3D visualization of a tooth and oral structures using CBCT imaging represents an impressive advance in dentistry. In the past, 3D structures were superimposed on periapical radiographs; today, they may be perfectly assessed using CBCT scans.[2,5,8,9,10,24,29] Periapical radiographs are the standard method to evaluate root canal filling and ICP. However, several authors have described their limitations.[8,9,10] At the same time, high density materials may produce image artifacts, which may limit interpretation, reduce image quality, and induce diagnostic errors conditions.[3,4,7,12,13,14,16-21,26,27,28]

Few studies have evaluated imaging artifacts associated with ICP. Our findings showed that dimensional values measured on CBCT scans of gold and silver alloy posts are greater than the original specimen measurements (Tables 1 and 2). Beam hardening effects may be seen depending of the type of ICP. These results have important clinical implications, particularly when artifacts cover parts of the root and simulate or mask root pathologies. Therefore, the interpretation of CBCT scans of teeth reconstructed with ICP must be cautiously made, which justifies the use of periapical radiographs as a reference for endodontic diagnoses. Clinical examinations should always be used as a support to imaging diagnoses.

CBCT measurement tools provide satisfactory information about linear distances within an anatomic volume.[1,8,9,10,15,23,30] However, metal ICP may generate artifacts on reconstructed images, which may affect CBCT measurements. Our results did not show any significant differences between gold alloy and silver alloy posts; however, differences between metal, glass fiber and carbon fiber posts were significant (Table 2). The occurrence of imaging artifacts on CBCT scans of metal ICP should always be suspected because artifacts may limit image interpretation and characterize potential risks of misdiagnosis. No significant dimensional differences were found in this study when different slice thicknesses were used (Table 2).

CBCT reconstructions may have greater image dimensional values, as well as lack of image homogeneity and definition. Other studies have already discussed similar findings.[1,4,7,15,17-20,30]

CBCT scans of endodontically treated teeth and ICP should be carefully examined because of the higher density of metal posts and their capacity to generate image artifacts. Density artifacts affect diagnostic procedures,[28] and beam hardening correction methods have already been evaluated. Artifacts appear as cupping, streaks, dark bands, or flare artifacts, and are associated with special absorption of low-energy photons.[4,7,16-21,26,27,28] A recent study[3] suggested that the use of a harder energy beam during scanning may result in less artifact formation. The effects of beam hardening-induced cupping artifacts may also be reduced by using beam filtration.[22]

Further studies should evaluate the clinical implications of metallic artifacts and the strategies to minimize them. Our results revealed that the dimensions of gold-alloy and silver-alloy ICPs were greater on CBCT scan measurements than on the actual specimen.

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