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Impact of Artifact Reduction Tools in Micro–computed Tomography Images for Endodontic

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Abstract

Background:

Microcomputed tomography (mCT) is an imaging technique increasingly used in endodontic research due to its non-destructive technique that allows imaging at the micron scale. In the presence of dense material, artifacts may appear in images obtained using mCT. Therefore, the aim of this study was to evaluate the content and purpose of the effects of artifact reduction tools available for mCT image reconstruction to determine whether their use affects endodontic education.

Materials & Methods:

Ten teeth were examined on the mCT device and images were reconstructed using a set of 13 artifact reduction devices combining radiation reduction device (RAR) and beam-curing artifact reduction (BAR). Images are evaluated based on needs (caregiver preferences) and goals (flow location and volume). Guardian's choice of RAR and BAR protocols is controlled by c2. Analysis of variance was used to compare root canal volume and surface area according to different methods. Intra-observer and interobserver reproducibility was calculated with the weighted kappa test.

Results:

There was no particular regimen preference for BAR (P = .91) or RAR (P = .80). There was no significant difference in volume (P = .999) or surface area (P = .999). 972) of root canals for all protocols.

Conclusions:

Reduction equipment for mCT images can be used to measure root canal volume and root canal area, according to the visual preference of the examiner, without affecting objective image analysis.

Key Words

Artifact reduction tool, image reconstruction, x-ray microtomography

Background

An X-ray sources with microfocal points allow the development of an imaging modality, microcomputed tomography (mCT), with increasing application in dental research, which has a cone-shaped beam (1) and provides high-resolution images. Micro-computed tomography allows for quantitative and qualitative three-dimensional measurements at micrometer and even submicrometer scale (2-4). However, since high X-rays are used during the acquisition of images, it is only suitable for research (4). An advantage of mCT over other methods in the evaluation of tooth structures such as histological sections is that it is an invasive and non-destructive method (3, 5, 6). These features make mCT a valuable tool in dental research (4).

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In the presence of active substances in dentistry, images obtained from cone beam CT are defined as images that are not part of the scanned object. Artifacts are the result of inconsistencies between the mathematical model and the physical image (7) and may hinder the diagnosis (8).
There are many types of artifacts, including scattering, noise, fading, beam hardening, aliasing, resonance, and motion artifacts. Ray-hardening artifacts are image reconstruction errors caused by low-energy beam photons. Another construct is tinnitus (7), which is the appearance of mixed rings in the image, possibly due to damage or lack of calibration.
The presence of artifacts may affect the mCT image analysis and thus the results of related studies. Therefore, methods have been developed to reduce artifacts. Artifacts can be reduced (or eliminated) during mCT image reconstruction using artifact reduction tools, but it is not yet known whether the use of these tools affects the available data in these ways (8-12).
The purpose of this study was to evaluate the impact of available reduction equipment on mCT image reconstruction to determine whether their use affects endodontic education. Materials and Methods mCT Images Reconstruction
The model has 10 single root teeth. Teeth were identified on a SkyScan 1174 instrument (Bruker, Kontich, Belgium) with 0.5 mm aluminum filter, 360° rotation, rotation pitch of 0.4 and 3 frames, 612 512 array/matrix and 33.21 mm voxel size. The test voltage was set to 50 kV and the tube current to 800 mA.
Images were reconstructed using the Ring Artifact Reduction (RAR) and Ray-Hardening Artifact Reduction (BAR) protocols based on the available space in the scanner. For RAR, reduction tools are available in the range of 0 to 20. In this study, RAR levels were chosen as 0, 5, 10, 15 and 20. The reduction tool for BAR is available on a scale from 0 to 100 with BAR levels 0, 25 and 50 selected. Initially, BAR levels 75 and 100 were also requested; however, these levels produce binary images, making them unusable. Also, there is a good correlation between 15 and 20 RAR and 50 BAR. The process leading to the content or objective analysis of the image cannot be separated from the model as shown for 13 operations (Table 1). Figure 1. Control operations can be performed by setting the BAR and RAR levels to 0.
All base images of 10 teeth were reconstructed using 13 techniques, revealing the content and purpose of 130 teeth as a result.

Subjective Evaluation

In the coronal image in Rule 1 (control), determine and average the root height of each tooth from the apex to the cementum junction. Define the slice number and select the axial image from that slice. Therefore, the same axial slice for each rule can be identified by the axis number.
Divide the 130 selected images into 3 groups.
Group 1 consists of axial images used in the evaluation of the RAR device. Images used in protocol 1 (control), protocol 2, protocol 3, protocol 4, and protocol 5 were evaluated for each baseline. The reviewers selected the image they felt had the least resonant structure formation/presence.
Group 2 contains axial images for measuring the BAR device. Images were used for protocols 1 (control), 6 and 11 and evaluated for each baseline.
Reviewers selected the image they felt had the least amount of buildup/beam stiffening artifacts. Group 3 consists of axial images of 13 different rules for each tooth root. Reviewers selected images they believed were least likely to include the formation/presence of ring structures and

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beam-hardening structures. These axial images were evaluated by 3 oral surgeons experienced in the interpretation of microtomographic images. Initially, observers took photographs from Group 1 and Group 2.After that, the supervisors received a third group.Examiners reassessed the 3 groups using the same measures after a 45-day period to assess the reproducibility of the scores.

Objective Evaluation

All reconstructed images from each different protocol were analyzed in the CTAN software (Bruker). Initially, automatic segmentation was used for root canal dentin because it was not possible to segment the root canal directly and therefore the root canal was defined as a cavity. After this, custom construction is required before root canal volume and area measurements can be completed. Seven steps are used to set up the process. These steps include loading the image, saving the resolution, removing the pores at the image border, identifying the region of interest, redrawing the image, applying the threshold, and some work.

The resulting image should represent root canal morphology. A three-dimensional analysis can then be performed in the CTAN software to obtain the volume and area of the root canal.

Statistical Analysis

Intra-individual and inter-examiner reproducibility was calculated with the weighted kappa test. The chi-square test analyzed caregiver preferences for the RAR and BAR protocols. Choose the best option from the description. Root canal volume and surface area determined by different methods were compared with analysis of variance. Use a 5% significance level.

Results

Subjective Evaluation

Kappa values for intra-reviewer and inter-reviewer agreement ranged from 0.90 to 0.93 and 0.12 to 0.17 for the RAR tool, respectively; For the BAR tool, the intra-reviewer and inter-reviewer agreement ranges from 0. 73 to 0.75 and 0.11 to 0.14, respectively; The intra-reviewer and inter-reviewer agreement ranged from 0.78 to 0 for the scenarios. 83 and 0.09 to 0.11 respectively. According to Landis and Koch (13), RAR, BAR and protocol are considered important for near-perfect and poor process, respectively.

Table 2 shows the unpreferred BARs for a particular arrangement (P = .91) or RAR (P = .80). Considering the mixed methods, methods 12, 2, 4 and 7 are preferred (Table 3).

Objective Evaluation

Regarding the objective analysis, Table 4 shows that the evaluation process did not differ significantly in root canal volume (P = .999) or root canal area (P = .972).

Artifact reduction tools	RAR level 0	RAR level 5	RAR level 10	RAR level 15	RAR level 20
BAR level 0	P1 (0; 0)	P2 (0; 5)	P3 (0; 10)	P4 (0; 15)	P5 (0; 20)
BAR level 25	P6 (25; 0)	P7 (25; 5)	P8 (25; 10)	P9 (25; 15)	P10 (25; 20)

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Artifact reduction tools	RAR level 0	RAR level 5	RAR level 10	RAR level 15	RAR level 20
BAR level 50	P11 (50; 0)	P12 (50; 5)	P13 (50; 10)	—	—

Table 1. Protocols used for RAP BAR

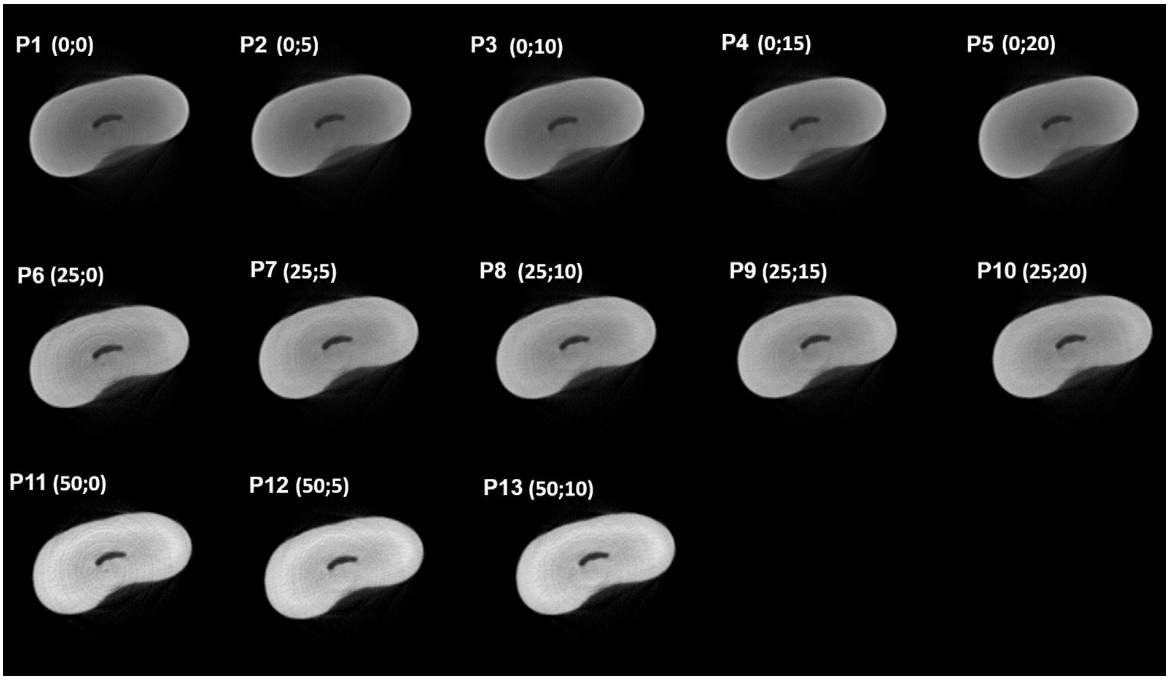

Figure 1. Axial views of same sample with 13 different protocols of artefact reduction tool applied (BAR, RAR).

Discussion

The use of mCT has recently increased in dentistry and has spanned many research areas. Pulp mCT analysis allows for the study of root canal anatomy (4, 14–16), evaluation of different endodontic techniques (4, 6, 17–23), differential evaluation of water (24), and evaluation of different roots. Channel Fill products (4, 25).

As with cone-beam CT, mCT images are prone to artifacts. Although a false image in the cup was considered as a minor disease in one study, it can affect the formation and use of artifacts (8). The presence of noise in the image lowers the contrast and lowers the quality. Different methods can be used to correct noisy images, such as the use of filters, all continuous transformations and block matching, and filtering in 3D (BM3D) (27); the second is based on the mathematical complexity proposed by Dabov et al. (28). Kierklo et al. (23) acquired images using a 0.25 mm copper filter to reduce beam stiffness. In our search, filter(0.5 mm lead) is also used for this purpose.

BAR

RAR	**0**	**25**	**50**	**Total**
0	2 (6.7%)	3 (10%)	1 (3.3%)	6 (20%)

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RAR	0	25	50	Total
5	2 (6.7%)	2 (6.7%)	4 (13.3%)	8 (26.7%)
10	1 (3.3%)	1 (3.3%)	3 (10%)	5 (16.7%)
15	1 (3.3%)	3 (10%)	—	4 (13.3%)
20	5 (16.7%)	1 (3.3%)	1 (3.3%)	7 (23.3%)
Total	11 (36.7%)	10 (33.3%)	9 (30%)	30 (100%)

Table 2. Protocols preference for RAR and BAR individually

As noted by Kierklo et al., although the use of filters can reduce the occurrence of artificial artifacts, they are not sufficient to completely eliminate them all, due to the pleiotropic nature of the X-ray beam. Therefore, this issue needs to be addressed with different techniques/methods (like beam hardening artifact reduction tools). BM3D performs better on textured regions and edges, while all normal transforms perform better on non-textured regions. Therefore, improvements in image noise correction should focus on these 2 strategies (27).

Protocol (BAR and RAR)	Best protocol
P1 (0; 0)	1
P2 (0; 5)	6
P3 (0; 10)	1
P4 (0; 15)	4
P5 (0; 20)	1
P6 (25; 0)	1
P7 (25; 5)	4

Protocol (BAR and RAR)	Best protocol
P8 (25; 10)	1
P9 (25; 15)	1
P10 (25; 20)	1
P11 (50; 0)	0
P12 (50; 5)	8
P13 (50; 10)	1
Total	30

Table 3. Subjective selection of best protocol of RAR and BAR in association

Given a negative image from the original, the mCT reconstruction software allows selection of tools to reduce or eliminate artifacts. Gomez et al. (29) proposed a new method of image segmentation for bone assessment, which involves combining images in one step to reduce the presence of artifacts. Zhu et al. (30) proposes a hybrid data preprocessing approach to reduce randomly varying structures between detectors and staining data, effectively suppressing ring structures without reducing spatial resolution.

Protocols	Volume (mm^3)	Surface area (mm^2)
P1	2572 (1604)	22,9857 (7461)
P2	2577 (1607)	22,9341 (7644)
P3	2491 (1623)	22,1142 (7359)

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Protocols	**Volume (mm^3)**	**Surface area (mm^2)**
P4	2470 (1601)	22,4635 (7217)
P5	2475 (1623)	23,4331 (6850)
P6	2792 (1624)	25,2883 (7414)
P7	2783 (1630)	25,0742 (7434)
P8	2558 (1635)	25,0432 (7379)
P9	2742 (1641)	25,2050 (7422)
P10	2691 (1666)	25,3631 (7187)
P11	2898 (1639)	26,0665 (7522)
P12	2886 (1644)	25,8485 (7508)
P13	2863 (1651)	25,8171 (7511)
P value	0.999	.972

Table 4. Volume (mm^3) and surface area (mm^2) of root canal for different artifact protocols tested

The reduction of RAR and BAR were randomly selected based on the preference of the observer, without knowledge of the impact of these tools on image quality and image focus for endodontic research. Studies using mCT images to evaluate root canals often do not report reconstructions used for artifact reduction (6, 15–19, 31–33). Evaluation of root canal volume and root canal area is important for testing new endodontic instruments, new solutions, endodontic materials and endodontic materials. The mCT images in the study should not show artifacts or should be as little as possible because these could alter the results of the analysis.

In visual analysis, we found that a particular technique did not produce better images, as demonstrated by the non-specific preference for RAR, BAR, and their combination to evaluate mCT images. It is also important to note that content evaluation is influenced by the human perspective and preferences of each observer. Although we did not observe a clear preference for a rule, when the procedures were combined, it was seen that RAR level 5 was preferred the most, regardless of the BAR treatment level. In addition, the reduction equipment used for image reconstruction does not affect the objective analysis of root canal volume and roots. This may be due to the threshold used in image segmentation, which affects the change in gray value caused by using this tool.

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