Diagnosis and decision making in endodontics with the use of cone beam computed tomography
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Chapter 3

Volumetric Changes in Apical Radiolucencies of Endodontically Treated Teeth Assessed by Cone-beam Computed Tomography 1 Year after Orthograde Retreatment.

Metska ME, Parsa A, Adriana Aartman IH, Wesselink PR, Ozok AR.
Abstract

Introduction: Cone beam computed tomography (CBCT) allows us to assess in three-dimensions the location and size of periapical radiolucencies. We aimed to assess by CBCT scans the volumetric changes of periapical radiolucencies in endodontically treated teeth one year after orthograde retreatment.

Methods: Forty-five root-filled teeth with persistent apical periodontitis requiring endodontic orthograde retreatment, from 37 individuals, were included in the study. The research protocol was approved by the VU University Medical Center Amsterdam (VUmc) ethics committee (2007/265) and the participants signed a letter of consent. We made two CBCT scans for every patient; the first one before retreatment and the second one a year later. Two observers measured independently the volume of radiolucencies on CBCT images using AMIRA software. The intraclass correlation coefficient (ICC) was used to evaluate inter-observer agreement and the Wilcoxon signed-rank test was used to assess pre and post treatment volume size.

Results: The ICCs were 0.994 and 0.998 for the scans before retreatment and one year after, respectively. The recall rate was 78% for the teeth and 73% for the patients. The volumetric change in periapical radiolucencies one year after retreatment was statistically significant (z = -3.112, p<0.005). The volume of periapical radiolucencies reduced in 20 teeth (57%), remained unchanged in 8 (23%) and increased in 7 (20%).

Conclusions: One year after endodontic orthograde retreatment the volume of periapical radiolucencies reduced significantly in 57% of the teeth.
Introduction

The gradual decrease in the bone mineral density due to apical periodontitis appears on the radiograph as a radiolucent area around a root apex (1-3). The detection of these periapical radiolucencies and the changes over time in their size (volume) play a significant role in the decision making process of a treatment plan (4-6). An increase in size of a periapical radiolucency after an endodontic treatment indicates that further treatment is necessary, while a decrease in size of a periapical radiolucency or the absence of it, is regarded as a sign of healing (7).

The size of periapical radiolucencies before and one or more years after endodontic treatment is routinely compared using two-dimensional periapical radiographs. However, the sensitivity of two-dimensional periapical radiographs (PA) is quite insufficient, especially in making such a comparison, due to the superimposition of adjacent tissues, the thickness of the overlying cortical bone, the complex anatomy of multi-rooted teeth, or more importantly the lack of capacity of this two-dimensional method to assess the ‘depth’ (buccal-lingual size) of a lesion (8-12, 17).

The three-dimensional reconstruction of an anatomical area at a relatively low radiation dose, has become possible by the use of cone beam computed tomography (CBCT) (13-16). That is why the CBCT imaging has been welcomed in the field of dentistry and particularly in endodontics in the recent years. On CBCT images it is possible to distinguish which root or roots are involved in the lesion, as well as the exact location and the volume of it (8, 17-20). Volumetric changes in periapical lesions in dogs six months after endodontic treatment have been reported (17), and the presence or absence of apical periodontitis in dogs as detected by CBCT scans has been confirmed with histology (18). A recent study used CBCT scans and digital periapical radiographs to determine the radiologic changes in the periapical tissues one year after primary endodontic treatment (21). The evaluation of the preoperative and postoperative radiolucencies was based on a visual
interpretation of the CBCT images that did not involve any measurements. Thus it is possible that their results, especially in case of small changes in the size of the radiolucencies, may be an overestimation or an underestimation. In a recent study (22) the changes in lesion size following root canal treatments were measured both on PA and CBCT. The authors reported 54.9% agreement between the findings of PA and CBCT. It was concluded that the changes in lesion size determined with CBCT data and PA are different and thus the radiographic outcome determined with PA could be untrue. As the reliability of volumetric measurements on CBCT data has been confirmed in in-vitro studies (23-26), the use of the volumetric change could be another way of assessing the outcome of endodontic treatments.

To our knowledge there is no previous clinical study in humans that compared the volume of the lesions before and one year after orthograde retreatment. The aim of the present study was to assess on CBCT scans the volumetric changes in periapical radiolucenties in endodontically treated teeth one year after orthograde retreatment.
Materials and Methods

In total 45 teeth, diagnosed with apical periodontitis, of 37 otherwise healthy individuals (27 females, 10 males) were included in the study. The age range of the participants was 20 to 70 years (mean=45, SD=13). All teeth had been endodontically treated in the past and the participants were referred for orthograde retreatment to the Postgraduate Endodontology Clinic at the Academic Centre for Dentistry Amsterdam (ACTA) from 2009 to 2011. The participants were informed about the aim of the study and signed a letter of consent. The research protocol was approved by the VU University Medical Center Amsterdam (VUmc) ethics committee (2007/265). Every participant had two CBCT scans taken; the first one before the endodontic retreatment and the second one a year later.

Postgraduate endodontology students performed the orthograde retreatments using a standard treatment protocol. Briefly, the protocol was comprised of the use of a rubber dam and an operating microscope (SOM 62, Karl Kaps GmbH, Asslar, Germany), passive ultrasonic irrigation with 2% sodium hypochlorite and 17% EDTA. The canals were filled with gutta-percha and AH 26 using either lateral or warm vertical compaction. The canal orifices were sealed with Vitrebond. The teeth were restored after treatment either with composite (Clearfil TM, Kuraray Dental, Benelux) or glassionomer (Ketac Fil, 3M Nederland) depending on the wish of the referring dentist.

The CBCT scans were made at the department of Oral and Maxillofacial Radiology of ACTA. The occlusal plane of the patient was oriented parallel to the axial scanning plane according to the manufacturer’s recommended protocol. All of the preoperative scans were made using the NewTom 3G (9 inches field of view, 110 kVp, 3.90-5.6 mA, 36 s scan time, 12 bits depth, QR SLR, Verona, Italy). One year after treatment, 35 teeth of 27 individuals were scanned. Nine teeth out of six individuals were scanned using the NewTom 3G (preoperative settings) and 26 teeth out of 21 individuals were scanned with the NewTom 5G (14 bits depth, QR SLR, Verona, Italy), because the NewTom
3G was not available anymore at the Department of Oral and Maxillofacial Radiology of ACTA after the first quarter of 2011. The scan settings for the NewTom 5G were 80x80 mm field of view, normal resolution, standard dose, regular scan time (18 s). NewTom 5G was operated at 110 kVp and 3.76-6.43 mA. The reason of mA variability in the scans is the employment of Safe Beam TM technology in NewTom units which automatically modify the radiation dose based on the size of object under assessment. The mentioned two CBCT scanners differ from each other in detector design. In NewTom 3G the combination of image intensifier tube and charged couple device (IIT/CCD) is used, while it has been replaced by flat panel detector in NewTom 5G. We kept the scanning parameters similar and exported all of the data with a 0.3 mm voxel size to ensure an identical spatial resolution for all of the images.

All scans were converted to digital imaging and communications in medicine format (DICOM3) and were exported with isotropic voxels of 0.3 mm. The DICOM3 data of every scan were saved in separate, randomly numbered, files (http://www.random.org/lists/) and then imported and evaluated with the AMIRA software (5.3.4, Visage Imaging GmbH). The images were displayed on a 22-inch flat-screen panel (L2245wg LCD; Hewlett Packard, Palo Alto, CA). Two independent and calibrated examiners (one endodontist, one radiologist) assessed all scans separately. The identity of the treatment status was concealed from the observers by assigning a random number to each volume and assigning a random viewing order for the volumes. The examiners scrolled through the entire reconstructed volume of every scan to assess the presence of periapical radiolucencies associated with root apices, which were at least twice the width of the periodontal ligament (9, 10). In multi-rooted teeth the radiolucencies were present either solely around the roots or around all roots of a tooth. The volume of each of the periapical radiolucencies was measured by both examiners following the same segmentation procedure in the AMIRA software (Figure 1) and saved in an Excel file.
The segmentation procedure and the volumetric measurements were done with the following steps:

• Locate in each of the three planes (axial, coronal, and sagittal) the slice in which the radiolucency is most clearly seen.

• Perform two-dimensional segmentation in all three planes, to select the radiolucent area in these three slices (blow tool; Gaussian1, Tolerance 35).

• Create a three-dimensional reconstruction of the radiolucency by expanding the selected areas in all slices in the three planes (wrap tool).

• Inspect the borders of the selected volume in all slices and correct when necessary.

• Use the “material statistics” option of the software to automatically calculate the selected volumes in mm3.
Statistical Analysis

The statistical analysis was performed on SPSS software (v.20, IBM, Armonk, New York, U.S.). The agreement between the two observers was calculated with the intraclass correlation coefficient (ICC). The ICC for the preoperative scans was 0.994 (95% confidence interval, 0.988 - 0.997) and for the one-year-after-treatment scans 0.998 (95% confidence interval, 0.996 - 0.999). Because of the high ICCs, the mean values of the measurements performed by the two observers were used for further analysis. A Wilcoxon signed rank test was used to examine whether there was a difference between the volume of the periapical radiolucency before retreatment and one year later. The analysis was done per tooth and not per root, since in multirooted teeth often the radiolucencies involved more than one root at the same time.

Figure 1. The volumetric change of a periapical lesion of tooth number 30 from patient 14 during the 1-year of recall. The DICOM3 data of the preoperative scan transferred in the AMIRA software and the selected volume of the periapical lesion in axial plane (A), sagittal plane (B), coronal plane (C) and in the 3D reconstruction (D). The Dicom3 data of the 1-year recall scan and the selected volume of the periapical lesion in axial plane (E), sagittal plane (F), coronal plane (G) and in the 3D reconstruction (H).
The percentage of volume change was calculated per tooth. In addition, the absolute value of the interobserver difference was calculated in percentage and the maximum value was used as a detection limit to define whether the volume of the lesion was enlarged, reduced or remained unchanged. A lesion was considered to be enlarged or reduced if the percentage of volume change was higher than the detection limit. Lesions whose percentage of change was lower than the detection limit were considered to have remained unchanged.

To validate the comparison between the volumes of periapical lesions seen on NewTom 3G and NewTom 5G a pilot study was performed. A dry human mandible was scanned with both the NewTom 3G and the NewTom 5G using the same scanning parameters as mentioned above. The volumes of seven sockets were measured and the intraclass correlation coefficient (ICC) was calculated. The ICC reports the validity of the measurements with the two scanners and it was 0.998 (95% confidence interval, 0.990 – 1.000). The high ICC value shows that there is agreement between the measurements done on the two scanners. Thus all teeth scanned one year after endodontic retreatment were examined as one group.
Results

Out of the 37 patients included in the study, 27 returned one year after retreatment for evaluation. The recall rate was 78% for the teeth and 73% for the patients. Reasons for dropout were pregnancy (n=10), wishing to discontinue the study (n=2), relocation (n=2) and no show at the appointments (n=5).

The volumetric change for every periapical lesion is presented in Table 1. The change in the volume of periapical radiolucencies one year after retreatment was statistically significant (z=-3.112, p<0.005). The interobserver difference in percentage varied between 0 and 33% with an average value of 10.9%. The value of 33% was considered as the detection limit. Using this limit, the volume of periapical radiolucencies reduced in 20 teeth (57%), remained unchanged in 10 teeth (29%) and enlarged in 5 teeth (14%). Complete absence of the periapical radiolucency one year after orthograde retreatment was observed in two teeth (6%). Participants with teeth showing an enlargement in the volume of periapical radiolucencies were referred for further treatment (endodontic surgery or extraction).

Discussion

In our study we report the volumetric changes as the percentage of reduction or enlargement in the volume of the periapical radiolucency one year after retreatment. This is quite an objective way of reporting the results as it is based on a quantitative assessment. On the other hand, using the percentage of change for the comparison of pre- and postoperative lesion size is much stricter than just a visual interpretation of the images. That could explain the low percentage (6%) of radiolucencies that disappeared completely one year after retreatment in this study.

The volume of 14% of the periapical lesions enlarged in one year. The reasons for the enlargement of the lesion volume can be persistent intra-
canal or extra-canal infection, reinfection, foreign body reaction, the presence of a radicular cyst or a vertical root fracture (27). Although no vertical root fractures were detected in any of these teeth on the CBCT scans, there is a chance that they remained unnoticed because of the voxel size (0.3mm) (28).

As it is not well established whether and under which parameters the CBCT images could be used for the differentiation of periapical cysts, no such attempt was made in the present study (29-31). Histological examination remains the standard clinical procedure for the differentiation between radicular cysts and apical periodontitis (31).

CBCT scans and periapical radiographs were used before to detect apical periodontitis in dogs, and the radiological findings were confirmed with the gold standard (histological findings) (18). CBCT scans were more sensitive (0.91) in detecting periapical lesions, compared to periapical radiographs (0.77). Histological evaluation, however, revealed a few small periapical lesions that were not visible on CBCT scans. The diagnostic accuracy for CBCT was 0.92 and for periapical radiographs 0.78. In the present study, the periapical tissue of the human teeth could not be examined histologically for ethical reasons.

When CBCT scans were used to measure the volumetric changes in periapical radiolucencies 6-months after endodontic treatment in dogs (17), in 65% of the cases either the present radiolucencies enlarged or new ones emerged. In 35% of the roots the volume of the radiolucencies reduced, out of which in 26% the radiolucencies resolved (17). In our study, in 14% of the teeth the radiolucencies enlarged, while no new radiolucencies emerged. In 57% of the teeth the radiolucencies reduced, out of which 6% disappeared completely and in 29% they remained unchanged. The differences in the findings could be explained by differences in the morphology of canine and human teeth, the measurement unit (root versus teeth), the time elapsed after treatment (6 months versus 1 year), the phase of the treatment
(primary endodontic treatments versus orthograde retreatments), and by the size of the radiolucencies before treatment.

In a recent study, CBCT images and periapical radiographs were used to determine the radiologic changes in periapical tissues in human teeth, one year after primary endodontic treatment (21). The comparison of the radiolucencies was based on visual interpretation of the CBCT scans; the most characteristic CBCT images of the radiolucencies were displayed as keynote presentations and they were classified accordingly into six categories (new periapical lesion, enlarged, unchanged, reduced, resolved and unchanged healthy periapical status). Four percent of the radiolucencies enlarged and 7% new radiolucencies emerged. In 22% of the teeth the radiolucencies reduced, and in 28.5% resolved. In 4% of the teeth the radiolucencies remained unchanged. Thirty-four percent of the examined and treated teeth were free of radiolucencies both before and after treatment. The difference in the results with our study could be explained by either the method used for the comparison of the radiolucencies (volumetric measurement versus visual interpretation), the type of treatment (orthograde retreatment versus primary endodontic treatment), or the size of the radiolucencies. Unless a direct quantitative comparison is made, there is room for underestimation or overestimation of the radiolucencies before- and after-treatment.

In a recent study (22) changes in the size of periapical radiolucencies after primary endodontic treatment were compared by PA and CBCT to assess the outcome of the treatment. The authors reported that after assessing CBCT images the size of the radiolucency was reduced or resolved after a period of 10 to 37 months in 77.5% of the examined roots. Possible explanations for the lower percentage of reduced or resolved periapical radiolucencies in our study could be the difference in the detection limit used, the size of the radiolucencies preoperatively and the type of the treatment (both initial treatment and retreatment versus only retreatment).
Measuring the change in the volume of periapical radiolucencies relies on the criteria used to define such radiolucencies and the technical protocol used to reconstruct their volume. The criteria used for defining them have been reported previously (9, 10, 21, 32). There is so far no fully automated method to measure the volume of radiolucencies. Available methods still require a human observer to verify the reconstruction quality. In our study two independent observers who are experienced in assessing CBCT images, carried out the measurements and had an excellent interobserver agreement. The workflow for the comparison of the volumes of periapical radiolucencies was time-consuming and not clinician-friendly. As CBCT systems (both hardware and software) become more mature it is expected that volumetric comparisons become integrated (33, 34). In conclusion, the volumetric measurements revealed a reduction of the size of periapical radiolucencies in more than half of the teeth one year after orthograde retreatment.

Table 1. The raw data for the measurements of each observer and the percentage of the volumetric changes of periapical radiolucencies.
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<td>367.35</td>
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<td>48.82</td>
<td>360.53</td>
<td>45.08</td>
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References


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