

Outcome of Root Canal Treatment in Dogs Determined by Periapical Radiography and Cone-Beam Computed Tomography Scans

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Abstract

The purpose of this study was to compare the favorable outcome of root canal treatment determined by periapical radiographs (PRs) and cone beam computed tomography (CBCT) scans. Ninety-six roots of dogs' teeth were used to form four groups ($n=24$). In group 1, root canal treatments were performed in healthy teeth. Root canals in groups 2 through 4 were infected until apical periodontitis (AP) was radiographically confirmed. Roots with AP were treated by one-visit therapy in group 2, by two-visit therapy in group 3, and left untreated in group 4. The radiolucent area in the PRs and the volume of CBCT-scanned periapical lesions were measured before and 6 months after the treatment. In groups 1, 2, and 3, a favorable outcome (lesions absent or reduced) was shown in 57 (79%) roots using PRs but only in 25 (35%) roots using CBCT scans ($p=0.0001$). Unfavorable outcomes occurred more frequently after one-visit therapy than two-visit therapy when determined by CBCT scans ($p=0.023$). (*J Endod* 2009; 35:723–726)

Key Words

Cone-beam computed tomography (CBCT), favorable (unfavorable) outcome, periapical radiography (PR), root canal treatment

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Both clinical and radiographic findings are used to determine treatment outcome. Because posttreatment apical periodontitis (AP) is often asymptomatic, the outcome has been determined by periapical radiographs (PRs) alone in many clinical studies (1). However, AP with bone loss may not result in an apical radiolucency on PRs, depending on the density and thickness of the overlying cortical bone and the distance between the lesion and the cortical bone (2–5). When a bone lesion is within the cancellous bone and the overlying cortical bone is substantial, the bone lesion may not be visible. Clinically, it has been reported that a large lesion of up to 8 mm in diameter can be present without radiolucency (6, 7).

The aim of root canal treatment is to reduce root infection to a minimal level and eliminate AP (8–10). In two studies in which the relationship between histologic and radiologic signs of inflammation was determined in human cadavers, the negative predictive value of radiologic inflammatory signs was 53% and 67%, respectively (11, 12). In a study on dogs, the negative predictive value of radiologic signs was 55% (13). This means that when an intact periradicular region was diagnosed radiographically, only 55% of the cases were uninflamed histologically. Because posttreatment AP could be radiographically invisible, the unfavorable treatment outcome could be underestimated in previous clinical reports (14, 15). Consequently, some risk factors determined in those reports could be false.

Computed tomography scans have been widely used in medicine since the 1970s (16) and appeared in endodontic research in 1990 (17). It has been shown that computed tomography scans can diagnose AP lesions accurately (15, 18–24).

In this study, root canal treatments were performed in dogs' teeth. The purpose was to compare the treatment outcome determined by PR and cone-beam computed tomography (CBCT) scans.

Material and Methods

All animal procedures performed in this study conformed to protocols reviewed and approved by the Animal Care Committee of the University of São Paulo (Protocol #2007.1.192.53.6).

The third and fourth mandibular premolars of 12 dogs (12 months of age, body weight from 10 to 15 kg) were selected for treatment with a total of 96 root canals. The animals were anesthetized intravenously with sodium thiopental (30 mg/kg body weight; Thionembul; Abbott Laboratories, São Paulo, Brazil). All endodontic procedures were performed aseptically with sterile instruments under a rubber dam, which was surface disinfected with 2% chlorhexidine. Different treatments were performed in four groups, each group consisting of three dogs, for a total of 24 roots per group.

In group 1, root canal treatment was performed in healthy teeth. After coronal pulp exposure, the pulp tissue was extirpated, and the apical cementum layer was perforated with the sequential use of size #15 to #30 K-files, thus creating standardized apical openings. All roots were instrumented to ISO K-file size 60. Root canal filling was performed with gutta-percha cones and AH Plus Jet Mix (Dentsply De Trey, Konstanz, Germany) using a lateral condensation technique.

In groups 2, 3, and 4, crown access was created on the occlusal surface with spherical carbide burs. After pulp removal, the root canals were left exposed to the oral cavity for 7 days to allow microbial contamination. Access openings were then sealed with a quick-setting zinc oxide-eugenol cement (IRM; Dentsply Indústria e Comércio Ltda, Petrópolis, Rio de Janeiro, Brazil). After 45 days, the development of AP was radiographically confirmed.

Group 2 roots with AP were treated as in group 1. In group 3, root canal instrumentation was performed as in groups 1 and 2. The root canal dressing with a calcium hydroxide paste (Calen; SS White Artigos Dentários Ltda, Rio de Janeiro, Brazil) was applied by using an ML syringe (SS White Artigos Dentários Ltda). A sterile cotton pledget was placed in the pulp chamber, and the access cavity was filled with IRM. Fifteen days later, intracanal dressing was removed, and root canal filling was performed as in groups 1 and 2. Group 4 roots with AP were left untreated.

In groups 1, 2, and 3, each canal was irrigated with a 1% solution of sodium hypochlorite between each instrument during the preparation procedure. After the completion of instrumentation, the root canals were dried with sterile paper points, filled with EDTA solution pH 7.4 (Odañcan-Herpo Produtos Dentários Ltda, Rio de Janeiro, Brazil) for 3 minutes, and then irrigated with saline and dried. After the completion of root canal obturation, the crown openings of the three groups were permanently restored with silver amalgam (Velvalloy; SS White Artigos Dentários Ltda), which was condensed on a glass ionomer cement base (Vitremex; 3M/ESPE, Saint Paul, MN).

Both PRs and CBCT scans were obtained at three time points: (1) before any intervention (all groups), (2) confirmation of AP (45 days after root canal infection), and (3) 6 months after filling (groups 1, 2, 3, and 4).

PR Scans and Analysis

Radiographs were taken according to the parallel technique using a Heliodont dental X-ray machine (Siemens, Erlanger, Germany) with exposure factors set at 60 kV, 10 mA, and 0.4 seconds. Ultraspeed periapical films (Eastman Kodak, Rochester, NY) were used. The images were digitized through an optical scanning process (Scanjet 7450C; Hewlett-Packard, Palo Alto, CA) with a resolution of 1,200 dpi. The radiolucent areas of the periapical lesion were delineated on the radiographic image excluding tooth structure (root apex) and including only the area of rarefaction. The lesion size was measured in square millimeters using Image J 1.28 u software (National Institutes of Health, Bethesda, MD) as previously described (25, 26). Three calibrated examiners evaluated the PR images independently ($\kappa = 0.9636$).

CBCT Scans and Analysis

The NewTom 3G (QR Srl, Verona, Italy) apparatus operating at 120 kVp, 3.6 mA, 9 inches field-of-view, matrix size 512 × 512, bit depth of

12 bits, and exposure time of 36 seconds was used. Scans were made according to the manufacturer’s recommended protocol. The same scan and reconstruction protocol was used at the three time points in the study. Volumetric studies were exported in DICOM3 format, and the isotropic voxel size was 0.3 mm. The data were imported into Amira software (v.4.2; Visage Imaging Inc, Carlsbad, CA), and the scan position was corrected using realignment tools. Tomographic sections of 0.3 mm in three planes (axial, coronal, and sagittal) were created. A single observer who was blind to the groups’ order measured the size of each lesion twice with 2 weeks separation between the first and the second measurements, and the mean values were used. Details of the segmentation technique are as follows: a region of interest limited only to the apical third of each root and 5 mm below the apex was selected to ensure standardized measurements of the lesion size. The lesion was then followed on the axial, coronal, and sagittal slices, and the area of the lesion was segmented on each slice using interactive brush segmentation tools. On each slice, the AP lesion border was delineated to include the lesion radiolucency while excluding the root apex. The segmentation criterion for lesion inclusion is that the gray level value of the lesion lies between +380 and -100 (27). This value is valid only for the NewTom 3G scanner and only for the 9-inch field because the histogram scales differ among the different CBCT scanners and scan-field selections (28). The lesion size was calculated as the volume summation of the lesion surface areas across all the segmented slices (29). The software automatically calculates the lesion volume for each root in cubic millimeters.

Evaluation of Treatment Outcome

The treatment outcome for each root was presented in one of the following four categories based on the change of lesions during the 6 months after the treatment: (1) emerged or enlarged, (2) unchanged, (3) reduced, and (4) absent. When a lesion grew or shrank at least 1 mm² (PRs) or 1 mm³ (CBCT scans), enlargement or reduction of the lesion was determined. The outcome of categories 3 and 4 were considered favorable.

Statistical Analysis

Data were analyzed statistically by the chi-square test and the Kruskal-Wallis Test. The level of significance was set at $\alpha = 0.05$.

Results

All 96 roots showed healthy periapex preoperatively determined by PRs and CBCT scans. A periapical lesion was diagnosed in all roots in groups 2, 3, and 4 after root canal infection. All groups had pretreatment lesions of similar sizes ($p > 0.05$). Favorable outcomes (lesion reduced or absent) was shown in 57 (79%) roots in groups 1, 2, and 3 when determined by a PR but in merely 25 (35%) roots when determined by a CBCT scan (Table 1) ($p = 0.0001$).

TABLE 1. Outcome of Root Canal Treatment in Three groups (G1, G2, and G3)* Determined by CBCT Scans and (PRs)

Treatment outcome	Periapical lesion	CBCT			PR		
		G1 (n = 24)	G2 (n = 24)	G3 (n = 24)	G1 (n = 24)	G2 (n = 24)	G3 (n = 24)
Favorable	Reduced	—	1	5	—	15	15
	Absent	16	0	3	21	0	6
	Total (%)		25 (35)			57 (79)	
Unfavorable	Emerged/enlarged	8	23	16	3	5	2
	Unchanged	—	0	0	—	4	1
	Total (%)		47 (65)			15 (21)	

*CBCT, cone beam computed tomography; PR, periapical radiography. In G1, root canal treatments were performed in healthy teeth; in G2, roots with AP were treated by one-visit therapy; and in G3, roots with AP were treated by two-visit therapy.

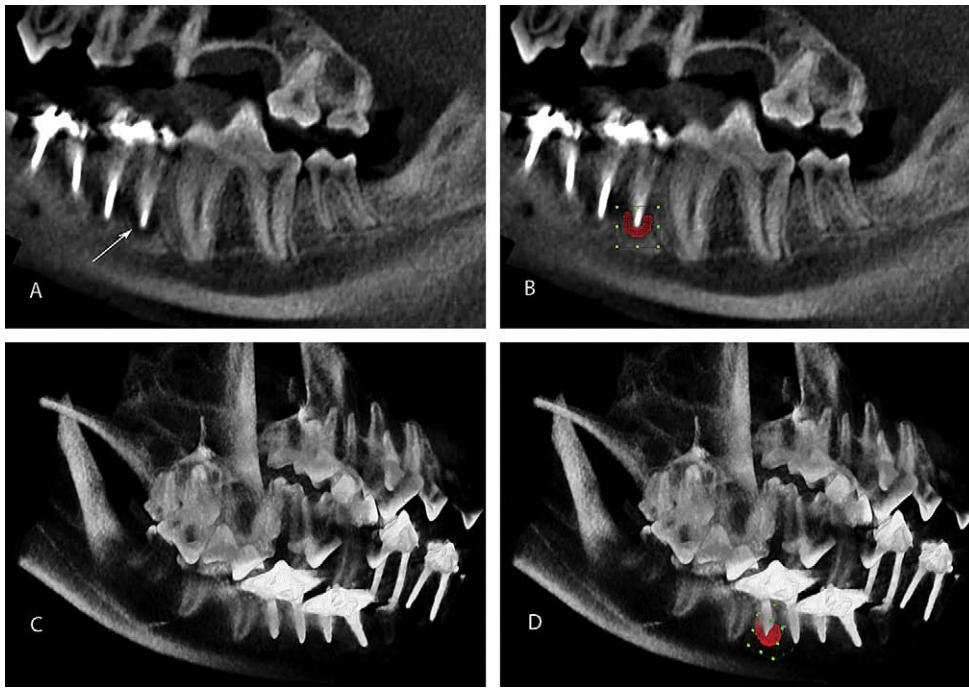


Figure 1. An example of the segmentation procedure on a CBCT scan. The lesion is visible (arrow) on (A) a two-dimensional sagittal slice and is (B) highlighted in red. A three-dimensional volume-rendered image of the jaw is shown in C, and the lesion is highlighted in a three-dimensional view in D. The green box shows the region of interest selection.

Unfavorable outcomes occurred more frequently after one-visit therapy than two-visit therapy when determined by a CBCT scan ($p = 0.023$). However, the difference was not significant when determined by PR ($p = 0.093$). In group 4, when determined by a PR, all lesions were enlarged; when determined by a CBCT scan, 22 lesions were enlarged, whereas 2 lesions were slightly reduced.

Discussion

The volume of extraction sockets has been previously measured using CBCT scans (29), and, to our knowledge, this is the first time that the volume of AP lesions has been measured. Using Amira software, the lesion size was calculated as the volume summation of the lesion surface areas across all the segmented slices (Fig. 1). Lesion visibility on each slice is dependent on the slice orientation relative to the lesion (ie, different cuts in different orientation will show different views of the same lesion). The effect of this dependency was minimized by correcting the scan position and by segmenting the slices in three orthographic directions (axial, coronal, and sagittal) in order to reduce bias from single-slice orientation.

In groups 1 through 3, a total of 72 roots was treated. Forty-seven roots presenting unfavorable outcomes were detected by CBCT scans, three times more than those detected by PR (Table 1). PR was unreliable not only in diagnosing the absence of a lesion but also in diagnosing a reduction in lesion size in 24 roots (Table 1). It could be that when lesions expanded in the cancellous bone and in the buccolingual direction, the lesion's enlargement was only revealed by volumetric measurements using CBCT (2–5). One possible reason for the poor outcome in this study would be the short timeframe in animal experiments (30, 31).

The superiority of CBCT scans over PRs in detecting bone lesions has been reported in several articles (15, 19, 21). No AP lesions were detected with PRs at day 14 after root canal infection and 47% could be detected at day 21, whereas CBCT evaluation detected AP in 33% at day 14 and 83% at day 21 (21). Estrela et al (15) showed the absence of posttreatment AP in 65% of teeth using PRs but only in 37% using

CBCT scans. Obviously, the prevalence of posttreatment AP was underestimated by PRs, whereas additional relevant information was obtained through CBCT images.

One controversy in endodontics is whether two-visit therapy is superior to one-visit therapy (32–36). In several studies, no significant difference in periapical healing was found between them (32–34). The outcome was evaluated by PRs, which was not sensitive in diagnosing AP lesions (15). In the current study, the unfavorable outcomes occurred more frequently after one visit than two visits when inspected by CBCT scans ($p < 0.05$). Poor periapical healing after one-visit therapy has been reported in other dog experiments (30, 31), and it could be attributed to the presence of microorganisms that were not properly removed during the cleaning and shaping step of the root canal procedure. Even though it has been reported that the anatomy of the apical portion of the dog root canal differs from that in humans because it consists of a delta of many small canals that cannot be cleaned or filled (37, 38), we attempted to eliminate these small canals by creating a single standardized apical opening. It could be that infection remaining in the apical root canal caused posttreatment AP and the use of $\text{Ca}(\text{OH})_2$ as an antimicrobial root canal dressing did, to a certain degree, lead to a more favorable outcome for the two-visit therapy group.

In conclusion, our findings provide evidences of the superiority of CBCT scans for the detection of periapical disease compared with PR. Furthermore, unfavorable outcomes determined by CBCT occurred more frequently after one-visit therapy compared with two-visit therapy.

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