In vivo detection of external apical root resorption induced by apical periodontitis using periapical radiography and cone-beam computed tomography

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Research Article

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Abstract

Objectives: To investigate sensitivity, specificity, predictive values and accuracy of periapical radiography (PR) and Cone beam computed tomography (CBCT) for detection of external apical root resorption (EARR).

Materials and Methods: Dog's teeth with experimentally induced root resorption underwent or not root canal treatment ($n = 62$ roots). True positives (TP), false positives (FP), true negatives (TN) and false negatives (FN) in PR and CBCT diagnoses were determined using histopathologic findings as gold standard. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and diagnostic accuracy (TP + TN) in the diagnosis of EARR were calculated. Data was compared using chi-squared test ($\alpha = 0.05$).

Results: We found that PR detected EARR in 35% of roots and CBCT, in 47%. EARR was microscopically diagnosed in 50% ($p = 0.03$ comparison between PR and microscopy; $p = 0.67$ comparison between CBCT and microscopy). Overall, CBCT produced more accurate diagnoses than PR (0.93 for CBCT versus 0.70 for PR; $p = 0.008$). Interestingly, when data was stratified into small and large resorptions, PR and CBCT allowed identification of large resorption in 100% of the cases and showed the same accuracy. However, for small resorptions, PR showed an accuracy of 0.83, whereas CBCT showed an accuracy of 0.96 ($p = 0.003$).

Conclusions: We demonstrated that CBCT showed higher accuracy to detect EARR. These findings shed light on the use of CBCT for detection of initial root resorption.

Clinical relevance: Early identification of resorption allows a prompt treatment and reduces the risk of dental structure loss.

Introduction

External apical root resorption (EARR) might be induced by endodontic pathogens in a pathologic process, consequence of a persistent stimulation of inflammatory mediators that triggers a resorptive mechanism, which gradually eliminates cementoblasts, cementum and the dentin area on the external surface of the dental root (1, 2).

Current technology has given access to new adjunct diagnostic tools to perform an adequate diagnosis. Though periapical radiography (PR) remains as one of the most used diagnostic aids in dentistry, Cone beam computed tomography (CBCT) are now available for the practitioner to deliver a better diagnostic and treatment plan. CBCT is a well-established method that compensate for the PR drawbacks such as distortion, anatomic superimposition and magnification, allowing the operator to completely explore the region of interest in a CBCT scan using a computer program (3, 4).

Small field of view (FOV) cone beam computed tomography (CBCT) has increasingly replacing several radiological procedures (5). In cases in which lower dose radiography does not provide adequate or satisfactory diagnostic information, small field of view CBCT has been recommended for assessment and/or management of root resorption when imaging would potentially change or enhance treatment plan (6).

Previously we demonstrated that cone beam computed tomography (CBCT) allows detection of small size apical periodontitis (AP) and that healing rates following root canal treatment were lower than previous radiographic studies have predicted (7-9). Specifically, for investigation of external root resorption, CBCT has a high accuracy in detecting *ex-vivo* artificial dental root surface mineral loss (10-13). Even though previously demonstrated that CBCT portrays an attractive and valuable option to assess periodontal and periapical tissues, its accuracy to detect external root resorption *in vivo* has not been investigated. Therefore, this study aims to investigate sensitivity, specificity, predictive values and accuracy of periapical radiography (PR) and Cone Beam Computed Tomography (CBCT) in diagnosing external apical root resorption.

Materials And Methods

This is a secondary study based on experimental protocols and material generated by the study of Paula-Silva et al. (7, 8), previously approved by the Animal Research Ethical Committee of Ribeirão Preto Dental School of the University of São Paulo (process number 07.1.192.53.6). Briefly, an animal experiment with 12 mongrel dogs (12 months of age, body weight from 10 to 15 kg) was performed and, for that, premolar teeth were used to induce AP (62 dental roots of dogs' teeth). The animals received medication (Drontal Puppy Bayer, São Paulo, SP), vitamins (Glicopan Pet; Vetnil Indústria e Comércio de Produtos Veterinários Ltda, Louveira, SP), and vaccines (Rai-Vac I; Fort; Vanguard HTLP 5 / CV-L; Laboratórios Pfizer Ltda., Guarulhos, SP). The dogs were kept in the vivarium at the School of Dentistry of Ribeirão Preto at the University of São Paulo with free access to water and standardized diet. Dogs were anesthetized and sedated previous every procedure.

Roots with AP were treated either by one-visit, two-visit therapy or left untreated. The animals were followed throughout the experimental period to observe changes in eating habits, development of inflammatory processes or suppuration of tissues, among other abnormalities. After 6 months, the animals were euthanized with a lethal intravenous overdose of sodium pentobarbital. The mandibles were dissected and sectioned to obtain individual roots that were fixed in 10% buffered formalin for 72 hours, demineralized in EDTA, and embedded in paraffin. The specimens were serially sectioned. Longitudinal sections of 5-mm thickness were stained with hematoxylin and eosin (HE).

Periapical radiographs used in this study was performed according to the parallelism technique, using a device for standardizing radiographic takes in dogs (14). Ultraspeed® size 2 periapical films (Eastman Kodak Company, Rochester, USA), Heliodont® dental X-ray machine (Siemens, New York, USA), with 60 kVp and 10 mA and exposure time of 1 second were used. The radiographs were developed manually

using the time / temperature method and filed in plastic cards. The images were digitalized using an optical scanner (Scanjet 7450C, Hewlett-Packard; Palo Alto, CA) with a resolution of 1,200 dpi.

CBCT scans were performed using a NewTom 3G cone beam computed tomography equipment (QR Srl, Verona, Italy). For this study, 120 kv and 3.6 mA were used for standardization of the technique, with 9-inch FOV (field of view) and exposure time of 36 seconds. The NewTom 3G device captures 360 images with an interval of 1 between them, in 36 seconds, with an image reconstruction resolution of 512×512 pixels and 12 bits per pixel (4096 gray scale).

To investigate the presence of EARR in the current report, microscopic slides from 62 roots were collected and examined under fluorescence microscopy using HE stained cuts (excitation at 460-500 nm and emission at 512-542 nm) at $20 \times$ magnification. A skilled and trained observer classified EARR as small external apical root resorption when mineralized tissue loss involved cementum only or large external root resorption when mineralized tissue loss involved cementum and dentin.

Three calibrated examiners ($\kappa = 0.94$) evaluated presence of external root resorption in radiographic and tomographic images. For radiographic analysis, images were assessed using the Image J 1.28 Software (National Institutes of Health, Bethesda, MD) in which brightness, contrast and magnification tools could be used. For CBCT evaluation, the NewTom 3G equipment software was used. In order to allow a direct comparison with the periapical radiography, the use of sections of 1 millimeter thick with 0.5 millimeter spacing between sections was standardized, in sagittal view.

Based on the presence of microscopically detected small external root resorption (involving cementum only) or large external root resorption (involving cementum and dentin), true-positives (TPs), false-positives (FPs), true-negatives (TNs), and false-negatives (FNs) in PR and CBCT diagnoses were determined using microscopy findings as the gold standard. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy (true positives + true negatives) in the diagnosis of AP were calculated. Data was compared using chi-squared test ($\alpha = 0.05$).

Results

After microscopic analyses, we found that external root resorption was present in 50% of the specimens. PR allowed detection of EARR in 35.5% of roots and CBCT in 46.8%. ($p = 0.03$ comparison between PR and microscopy; $p = 0.67$ comparison between CBCT and microscopy) (Table 1). False negative diagnoses were most common after PR evaluation (14.5% of the roots) than CBCT (3.2% of the roots). Both tools presented adequate specificity, yet CBCT presented higher sensitivity (0.93). Results of TP, FP, TN, FN, sensitivity, specificity, PPV, NPV, and diagnostic accuracy for diagnosis of EARR are summarized in Tables 2 and 3. CBCT produced more accurate diagnoses than PR ($p = 0.008$).

When data was stratified into small and large resorptions, we found that for large resorptions, in which microscopically cementum and dentin were damaged, PR and CBCT allowed identification of resorption in 100% of the cases and showed the same accuracy. For small resorptions, in which only cementum was

damaged, PR showed an accuracy of 0.83 whereas CBCT showed an accuracy of 0.96 ($p = 0.003$). PR had a lower sensitivity (0.62) in finding small resorptions, yet its positive predictive value was 100%. Results of TP, FP, TN, FN, sensitivity, specificity, PPV, NPV, and diagnostic accuracy for diagnosis of small EARR and large resorptions are summarized in Tables 2 and 3.

Discussion

Our study showed that CBCT has a higher sensitivity in detecting external apical root resorption than PR. Nevertheless, both techniques presented a similar specificity. Our results are consistent with previous studies that reported CBCT as the most accurate method in finding artificial external root resorption when compared to panoramic or periapical radiography (13, 15, 16). Even though, we observed that PR has been found to be less sensitive, a high specificity of PR was obtained.

In order to obtain detailed information about the degree of mineralised tissue resorption, we classified large and small resorption by analyzing the affected mineralized tissue after histological processing. Large resorption, in which cementum and dentin were damaged, were detected using both radiographic techniques. For small resorption detection, however, where only cementum was affected, PR had a lower sensitivity than CBCT. These results could be explained by a previous study that stated that mineral bone loss could not be detected by the human eye in periapical radiograph until reaching 7,1% of loss (17), indicating that small resorption will not be perceived using conventional radiographic techniques, whereas CBCT will provide a better sensitivity and accuracy in detecting apical external root resorption.

In some cases, cone beam computed tomography (CBCT) has increasingly replacing conventional radiological procedures due to the possibility of arbitrary reconstructions and views free of superimposition (5). Previous studies have reported that CBCT has a high accuracy in detecting EER, however these studies were performed under different methodologies, in *ex vivo* models with artificial or natural EER, that may impair their results after comparison with other radiographic techniques (10-13). Our analysis was performed in teeth that were treated endodontically or not *in vivo*, in which soft tissue thickness as well as other anatomic features that may influence the periapical image are considered. Furthermore, using the microscopic analysis as gold standard assures an accurate diagnosis, as was previously reported by our research group (7).

Imaginologic evaluation is a diagnostic tool of irrefutable importance when needing further and careful assessment; however, previous detailed clinical evaluation should be performed in order to prescribe radiation-based imaginologic tools (18). Several international groups have published statements aiming to provide a recommendation about CBCT indication (19-21). The benefits of using CBCT are widely known and recognized, though the amount of radiation used each scanning time is still a matter of controversy. When in need of a detailed image, optimization of radiation exposure may be performed. In cases of impacted and supplementary teeth, dentoalveolar trauma, orofacial defects dental anomalies and bone pathologies, where there is a justified reason for CBCT prescription, effective dose should be managed (21). Reduction of radiation risk could be achieved by managing X-Ray tube voltage and current

(22), exposure time, FOV, number of projections and patient's shielding devices (19). Considering that the amount of radiation is directly related to the period of image taken and the field of the vision (FOV) (23), diagnostic modalities with smaller field are currently used. Limited cone-beam computed tomography (LCBCT) offers a small FOV (1.6 – 3.1 inch/4 – 8cm) with a high-resolution image with less radiation than a common CT (24, 25). In this study, a 9-inch FOV was used to acquire images of the entire low jaw of the animal because several teeth were used for investigation. Clinically, a smaller FOV could be used if we consider that a single tooth should be examined.

This study has compared CBCT and PR's accuracy in diagnosing EARR in an animal model. Even though an animal model is a more adequate subject of study than *in vitro* specimens, some limitations may arise such as species' difference and sample size. The canine specie has more similarities in perioral and oral tissues to humans than other species such as mice and guinea pigs, however, still exists differences such as teeth morphology that should be considered prior endodontic treatment. Furthermore, radiographs should be taken under complete anesthesia and with a pre-design standardization device to obtain a valuable image in all subjects. Another possible limitation could be our small sample size. Since this research was performed in animals, the sample was the minimum necessary that were needed to prove our hypothesis, following the technical regulations of the International Organization of Standardization. However, this limitation was considered in statistics analysis.

We found that CBCT was more accurate and sensitive when compared to PR in detecting external apical root resorption. These findings shed light on the use of CBCT for detection of initial root resorption that might occurs as a result of a dental trauma, pulp exposition or unmanaged orthodontic forces. Early identification of resorption allows a prompt treatment and reduces the risk of dental structure loss, nevertheless, CBCT should be prescribed under situations of strictly need and following effective dose optimization.

Conclusions

We demonstrated that CBCT showed higher accuracy to detect EARR. These findings shed light on the use of CBCT for detection of initial root resorption. Early identification of resorption allows a prompt treatment and reduces the risk of dental structure loss.

Declarations

Conflict of Interest: Author Stephanie Diaz Huamán declares that she has no conflict of interest. Author Maya Fernanda Manfrin Arnez declares that she has no conflict of interest. Author Fernanda Maria Machado Pereira Cabral de Oliveira declares that she has no conflict of interest. Author Andiará De Rossi declares that she has no conflict of interest. Author Léa Assed Bezerra Silva declares that she has no conflict of interest. Author Francisco Wanderley Garcia Paula-Silva declares that he has no conflict of interest.

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Ethical approval: All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. The study was approved by the Institutional Animal Research Ethics Committee (process #07.1.192.53.6).

Informed consent: For this type of study, formal consent is not required.

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Tables

Table 1. Number of roots with EARR diagnosed by PR, CBCT and microscopy.

Number of roots				
Diagnosis	n	PR	CBCT	Microscopy
External apical root	Present	22	29	31
resorption	Absent	40	33	31

Table 2. True and false positives (TP, FP) and true and false negatives (TN, FN) in diagnosis of EARR.

Diagnosis	Method	TP	FP	TN	FN
External apical root	PR	22	0	31	9
resorption	CBCT	29	0	31	2
Large apical root	PR	7	0	31	0
resorption	CBCT	7	0	31	0
Small apical root	PR	15	0	31	9
resorption	CBCT	22	0	31	2

Table 3. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and diagnostic accuracy (true positives + true negatives) for periapical radiographyy (PR) and cone-beam computed tomography (CBCT), calculated using microscopic findings as gold standard for diagnosis of EARR.

Diagnosis	Method	Sensitivity	Specificity	PPV	NPV	Accuracy
External apical	PR	0.70	1	1	0.77	0.85
root resorption	CBCT	0.93	1	1	0.93	0.96
Large apical root	PR	1	1	1	1	1
resorption	CBCT	1	1	1	1	1
Small apical root	PR	0.62	1	1	0.77	0.83
resorption	CBCT	0.92	1	1	0.93	0.96

Figures

Figure 1

Representative histological view, conventional radiograph, and cone beam computed tomography (CBCT) scans from a tooth without apical root resorption. The CT scan pictures are presented in sagittal and axial views. Numbers inside blue box on sagittal views indicate the position of the section in the sequence presented on axial view.

Figure 2

Representative histological view, conventional radiograph, and cone beam computed tomography (CBCT) scans from a tooth with small apical root resorption. The CT scan pictures are presented in sagittal and axial views. Numbers inside blue box on sagittal views indicate the position of the section in the sequence presented on axial view.

Figure 3

Representative histological view, conventional radiograph, and cone beam computed tomography (CBCT) scans from a tooth with large apical root resorption. The CT scan pictures are presented in sagittal and axial views. Numbers inside blue box on sagittal views indicate the position of the section in the sequence presented on axial view.