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ORIGINAL ARTICLE

In Vivo Detection of External Apical Root Resorption Induced by Apical Periodontitis Using Periapical Radiography and Cone-Beam Computed Tomography

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ABSTRACT

Objective: To compare the accuracy of periapical radiography (PR) and cone-beam computed tomography (CBCT) for the detection of external apical root resorption (EARR) due to root canal contamination. **Material and Methods:** Dog's teeth with experimentally induced root resorption due to root canal contamination underwent or not root canal treatment (n=62). True positives (TP), false positives (FP), true negatives (TN), and false negatives (FN) in PR and CBCT diagnoses were determined using histopathologic findings as the 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 were compared using chi-squared test (α=0.05). **Results:** EARR was detected in 35% of roots by PR, in 47% by CBCT, and in 50% of the roots by microscopy (p=0.03 PR *versus* microscopy; p=0.67 CBCT *versus* microscopy). Overall, CBCT produced more accurate diagnoses than PR (p=0.008). PR and CBCT allowed the 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). **Conclusion:** Cone-beam computed tomography showed higher accuracy in detecting external apical root resorption of endodontic origin.

Keywords: Tooth Resorption; Diagnostic Imaging; Radiography, Dental.

Introduction

External apical root resorption (EARR) might be induced by endodontic pathogens in a pathologic process, resulting from a persistent stimulation of inflammatory mediators that triggers a resorptive mechanism, gradually eliminating 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) is now available for the practitioner to deliver a better diagnostic and treatment plan. CBCT is a well-established method that compensates for the PR drawbacks such as distortion, anatomic superimposition, and magnification, allowing the operator to explore the region of interest in a CBCT scan using a computer program [3,4].

A 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, a small field of view CBCT has been recommended for assessment and/or management of root resorption when imaging would potentially change or enhance the treatment plan [6].

Previously we demonstrated that cone-beam computed tomography (CBCT) allows the 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 the investigation of external root resorption, CBCT has high accuracy in detecting ex-vivo artificial dental root surface mineral loss [10-13]. However, 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 the sensitivity, specificity, predictive values, and accuracy of periapical radiography (PR) and Cone-Beam Computed Tomography (CBCT) in diagnosing external apical root resorption.

Material and Methods

Study Design and Ethical Clearance

This is a secondary study based on experimental protocols and material generated by the study of de 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, Brazil), vitamins (Glicopan Pet, Vetnil Indústria e Comércio de Produtos Veterinarios Ltda, Louveira, SP, Brazil), and vaccines (Rai-Vac I; Fort; Vanguard HTLP 5 / CV-L; Laboratórios Pfizer Ltda., Guarulhos, SP, Brazil). 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 a standardized diet. Dogs were anesthetized and sedated previous to every procedure.

Experimental Procedures

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 six months, the animals were euthanized with a lethal intravenous overdose of sodium pentobarbital. The mandibles were dissected and sectioned to obtain individual roots 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).

Radiograph Procedures

Periapical radiographs used in this study were 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), Heliodent® 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, USA) 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 an 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 × 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 (Figure 1 - A, B, and C).

Three calibrated examiners (κ = 0.94) evaluated the 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, USA), using brightness, contrast and magnification tools. For CBCT evaluation, the NewTom 3G equipment software was used. 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.

Data Analysis

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 were compared using chi-squared test (α= 0.05).

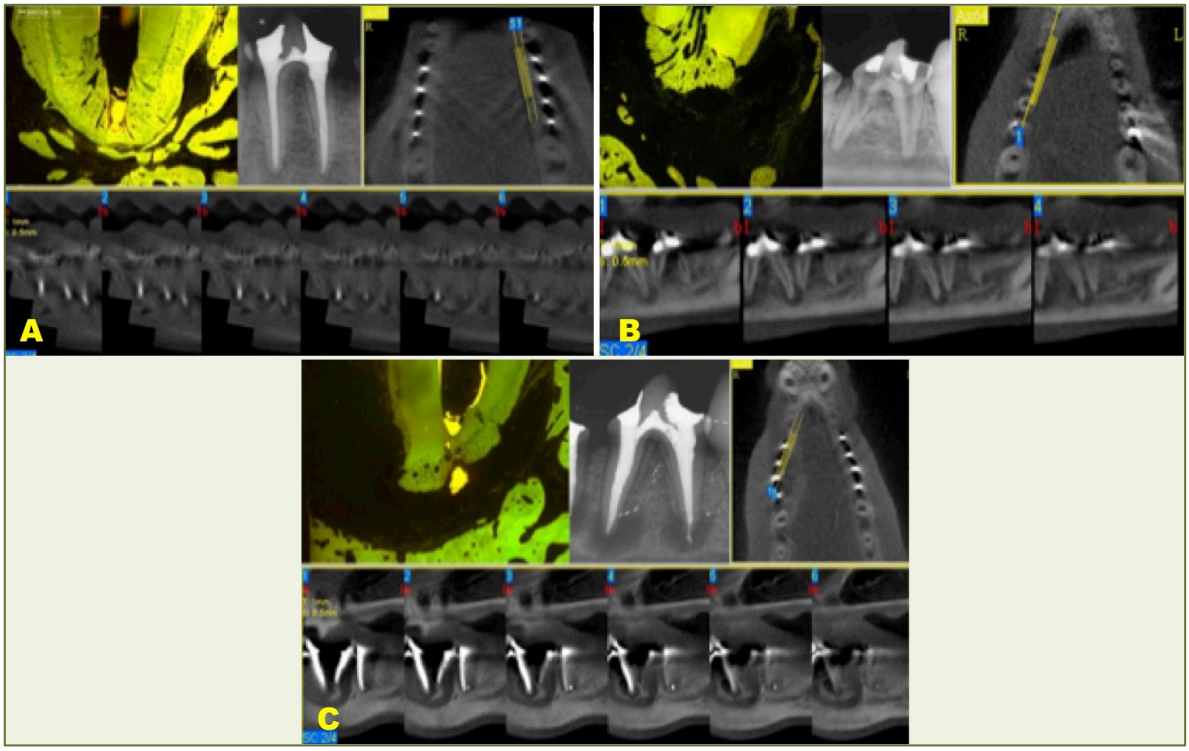

Figure 1. (A): Representative histological view, conventional radiograph, and cone-beam computed tomography (CBCT) scans from a tooth without apical root resorption. The CT scan pictures are presented in sagittal and axial views. Numbers inside blue box on sagittal views indicate the position of the section in the sequence presented on axial view. (B): 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. (C): 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.

Results

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).

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

Diagnosis	N	Number of Roots		
		Periapical Radiography	CBCT	Microscopy
External Apical Root	Present	22	29	31
Resorption	Absent	40	33	31

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 were 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.

Table 2. True and false positives (TP, FP) and true and false negatives (TN, FN) in the 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 radiography (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

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 for finding artificial external root resorption compared to panoramic or periapical radiography [13,15,16]. Even though we observed that PR had been found to be less sensitive, a high specificity of PR was obtained.

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, was 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 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, which may impair their results after comparison with other radiographic techniques [10-13]. Therefore, our analysis was performed in teeth treated endodontically or not in vivo, in which soft tissue thickness and other anatomic

features that may influence the periapical image are considered. Furthermore, using the microscopic analysis as the 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, an 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]. Since 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 fields are currently used. Limited cone-beam computed tomography (LCBCT) offers a small FOV (1.6 – 3.1 inch/4 – 8 cm) 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. For example, 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 was needed to prove our hypothesis, following the technical regulations of the International Organization of Standardization. However, this limitation was considered in statistical 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 to detect initial root resorption that might occur due to 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.

Conclusion

Cone-beam computed tomography showed higher accuracy to detect external apical root resorption. These findings shed light on the use of CBCT for the detection of initial root resorption. Early identification of resorption allows a prompt treatment and reduces the risk of dental structure loss.

Authors' Contributions

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All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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