

Reliability of CBCT and Periapical Radiography Methods to Evaluate External Apical Root Resorption during Early Phase of Orthodontic Treatment

Confiabilidade dos Métodos de TCFC e Radiografia Periapical para Avaliar a Reabsorção Radicular Apical Externa Durante os Estágios Iniciais do Tratamento Ortodôntico

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Recebido em: 20/10/2017; Aceito em: 19/01/2018

Abstract

External apical root resorption (EARR) is an undesirable therapeutic effect associated with induced tooth movement. The aim of this study was to evaluate the reliability of two methods, cone beam computed tomography (CBCT) and periapical radiography (PR), for measuring EARR during early phases of orthodontic treatment. The study included 25 patients (mean age, 18.02 ± 6.06 years) with moderate to severe tooth crowding. Maxillary and mandibular incisors were evaluated in CBCT scans and PR at two different times: T1, at the beginning of orthodontic treatment; T2, 6 months after the treatment initiation. The difference in incisor length T2-T1, as measured by two independent calibrated examiners, represented EARR. Measurements made on the images obtained by I-cat scanner (Hatfield, PA) were performed using the Dolphin program (Chatsworth, Calif.). The PR images were imported to the CorelDraw X5 program (Ottawa, Canada). Intraclass correlation coefficient (ICC) was used to measure intra- and inter-examiner errors. A Student's t-test was used for comparing the results between CBCT and PR, with a significance level of 5%. All teeth showed EARR, using both periapical radiographs (0.92mm) and CBCT (0.25mm). Although the difference between the results of the two techniques was statistically significant, its value was lower than 1mm for all teeth measured. Both radiographic methods are suitable and reliable for assessing EARR after 6 months of initial orthodontic treatment. However, the difference in magnitude between the measurements obtained by the two methods does not justify requesting CBCT merely to assess EARR during orthodontic treatment.

Keywords: Tooth. Orthodontics. Cone-Beam Computed Tomography.

Resumo

A reabsorção radicular apical externa - RRAE é um efeito indesejável associado ao movimento dentário induzido. O objetivo deste estudo foi avaliar a confiabilidade de dois métodos radiográficos, a tomográfica computadorizada de feixe cônico - TCFC e a radiografia periapical (RP), para mensurar a RRAE. A amostra foi composta por 25 pacientes (média de idade de $18,02 \pm 6,06$ anos) com presença de apinhamento de moderado a severo. A RRAE foi verificada em RP e TCFC de incisivos superiores e inferiores em dois tempos (T1 - início do tratamento ortodôntico e T2 - seis meses após início do tratamento). As RRAE foi avaliada através de mensurações da diferença no comprimento dentário (T2-T1) de cada incisivo. Foram realizadas por dois examinadores previamente calibrados. Nas imagens obtidas pela TCFC, as medidas foram realizadas por meio do programa Dolphin (Chatsworth, Calif.), já nas imagens das radiografias periapicais, no programa CorelDraw X5 (Ottawa, Canadá). Os erros de medição intra e interexaminadores foram avaliados pelo Coeficiente de Correlação Intraclasse - CCI. Os valores obtidos foram comparados utilizando o teste t de student com nível de significância de 5%. Os resultados da comparação entre T1 e T2, tanto para a RP (0.92mm) quanto para a TCFC (0.25mm), evidenciaram a presença de RRAE para todos os dentes mensurados, com diferença estatisticamente significativa. Ambos os métodos são confiáveis para avaliar a RRAE aos 6 meses após início do tratamento ortodôntico, contudo a diferença de magnitude entre as medidas obtidas entre os métodos não justifica a solicitação de TCFC somente para este fim.

Palavras-chave: Dente. Ortodontia. Tomografia Computadorizada de Feixe Cônico.

1 Introduction

External apical root resorption - EARR is an undesirable and irreversible therapeutic effect associated with dental trauma, chronic occlusal trauma, chronic periapical lesion, unerupted teeth and induced tooth movement. The forces concentration in the periodontum, especially in the apical region, may cause imbalance in the local homeostasis and result in resorption.¹ Loss of cementum in the apical region characterizes this phenomenon, and can approach 48-66% during orthodontic treatment.² The most affected teeth are the upper incisors,³ particularly the upper lateral incisors.^{2,4} The EARR etiology, although widely discussed in the literature, still remains unclear and controversial, as several contributing

factors have been identified: individual susceptibility; genetic predisposition; anatomical characteristics; malocclusion severity; periapical inflammatory conditions; and systemic factors such as allergies, asthma, arthritis, diabetes, hormonal deficiencies, and orthodontic mechanotherapy.^{5,6}

Root resorption must be diagnosed early because patients who experience this in the first six months of treatment are more likely to experience continued root shortening, which may progress to severe EARR.^{5,7} In severe cases, the success of orthodontic treatment can be compromised, as well as the tooth longevity and the ability to resist to masticatory forces.⁷ Discontinuation of active orthodontic treatment can minimize future damage to the tooth roots.⁸ According to Owman-

Moll,⁹ after seven weeks of active orthodontic treatment, resorption already exists, however, this can only be observed histologically. The early detection of this process is important in order to identify teeth at high risk for developing severe resorption.¹⁰

The radiographic technique most commonly used to detect EARR is periapical radiography.^{1,11} In order to obtain the most accurate images, the radiographic procedure is performed using the paralleling technique with positioners.^{12,13} With the introduction of cone beam computed tomography - CBCT in the late 1990s,¹⁴ several dental specialties have benefited from its greater diagnostic capacity, including orthodontics.

Computed tomography is a noninvasive, fast, reliable method and high-precision diagnosis, being therefore considered the method of choice for bone structure viewing image. The reproduction of the maxillofacial complex in three spatial plans allows observations of the buccal and lingual plates, at the same time that enables cross-sectional measurements in any region of the jawbone. Comparing to conventional radiography it has three important advantages: there is no overlapping by adjacent anatomical structures; allows differentiation of types of tissues, detecting differences in density among them of 1% or less; possibility to manipulate and adjust the image after the scan has been completed.^{6,7,15}

Considering the lack of *in vivo* studies comparing CBCT and periapical radiographs regarding EARR diagnosis, the purpose of this retrospective study was: (1) to evaluate EARR in patients after 6 months of orthodontic treatment, and (2) to verify if CBCT is necessary to evaluate EARR.

2 Materials and Methods

The test power evaluation showed that considering the sample size ($n=25$) and based on the average standard deviation of EARR calculated for measurements carried out in CBCT scans ($SD=0.37\text{mm}$) and periapical radiographs ($SD=0.67\text{mm}$), and adopting a significance level of $p<0.05$, the test power was 99% for CBCT and 82% for periapical radiography.

This study was approved by the ethics committee under protocol number of 250.556. Informed written consent was signed by patient or guardian, as well as, a medical release form for the orthodontic records.

The sample selected for this study consisted of 25 individuals (12 men and 13 women), mean age, 18.02 ± 6.06 years, belonging to the university's patient files. These patients presented Angle Class I or II malocclusion with moderate to severe anterior crowding in the upper and lower arches. Exclusion criteria were craniofacial anomalies, congenitally missing permanent teeth except wisdom teeth, previous orthodontic treatment or history of dental trauma.

The patients were treated with the use of orthodontic preadjusted brackets with a 0.022 x 0.030-inch slot. For the initial stage of treatment, i.e., the first 6 months, the following

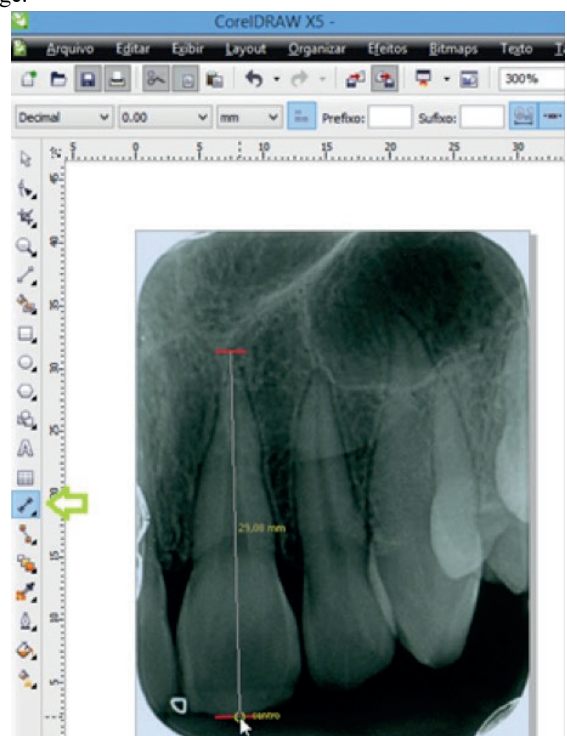
treatment protocol was recommended regarding the sequence of wire: 0.013-inch Nitinol, 0.014-inch Nitinol, and 0.016-inch Nitinol, each wire remaining for 2 months.

CBCT and periapical radiographs were performed in all patients at two different times: T1, before the beginning of treatment, and T2, six months after the orthodontic treatment initiation. All tomograms were performed using the same scanner (I-cat Imaging Sciences International, Hatfield, Pa) according to the following specifications: 22 x 16 FOV, 40 seconds, 120 kVp, 36 mA and voxel 0.4 mm. Periapical radiographs were performed with a radiographic positioner using a paralleling technique with an anode/film distance of 40 cm. For periapical films, Kodak Dental Intraoral E-speed was used, and radiography was performed using the RX Dabi Atlante unit, 70 KV and 8 mA (Dabi Atlante S/A Industries, Ribeirão Preto, Brazil). The exposure time for the incisors ranged from 0.11 to 0.13 seconds.

To evaluate EARR, the upper and lower incisors were measured along the long axis, i.e., from the root apex to the incisal edge, in both radiographic methods. The EARR magnitude in each tooth was calculated by the difference between the tooth lengths in T2-T1.

The images measurement in the Corel Draw X5™ program (Corel corporation, Ottawa, Canada) proceeded as follows: with the aid of the mouse cursor, linear measure was made from the apex to the incisal edge of each tooth. This measurement corresponded to the length of the tooth. This procedure was performed for each incisor, in all patients (Figure 1).

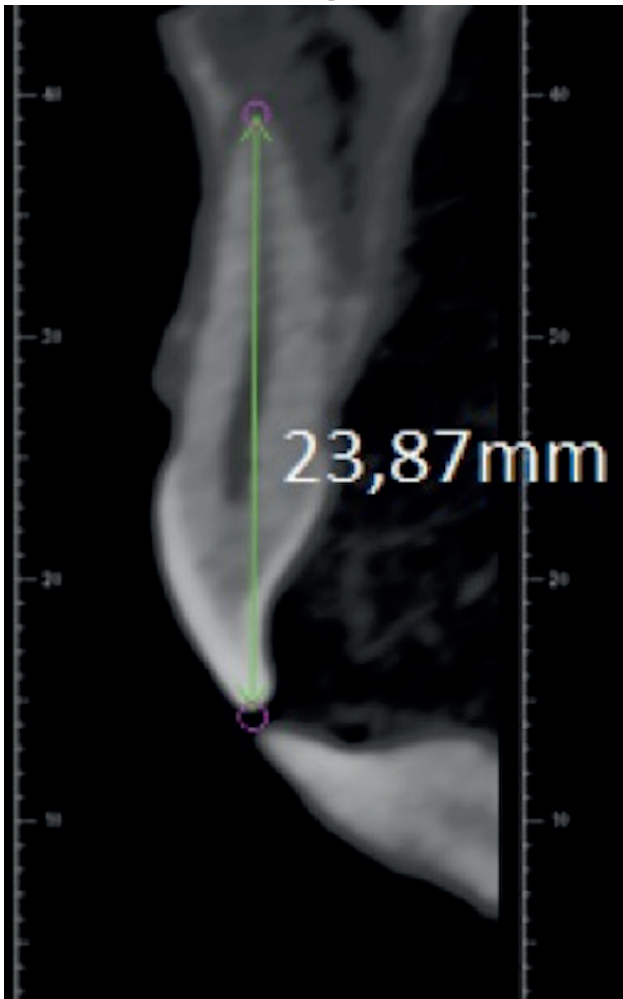
Figure 1 - Measurement of the tooth length in the periapical radiography: Linear measure from the apex to the tooth incisal edge.



Source: The Authors.

For the analysis of EARR using CBCT, the images were handled and positioned using the Dolphin Imaging™ program, version 11.7 (Dolphin Imaging & Managements Solutions, Patterson Dental Supply Inc, Chatsworth, Calif.), with a level of sensitivity fixed at 25%. Sagittal cuts of each incisor were selected and a sectional cut was made in the center of the long axis thereof, which coincided with the incisal border and the root apex (Figure 2).

Figure 2 - Measurement of the tooth length in the CBCT: sectional cut in the center of the long axis, coinciding with the incisal border and the tooth root apex.



Source: The Authors.

Two previously calibrated examiners evaluated CBCT images, as well as scanned periapical radiographs. They performed the measurements on the same computer, with the same mouse and in an appropriate environment using low light to minimize external interference. Thirty days after the initial evaluation, 30% of the patient sample was measured again by the same examiner.

2.1 Statistical Analysis

Intra and interexaminer errors were measured by intraclass correlation coefficient - ICC. Kolmogorov-Smirnov test was applied and since the distributions were normal,

parametric tests could be used. To compare the initial and final measurements, a Student t Test was used. For all tests, a significance level of $p < 0.05$ was set. All statistical procedures were performed with the Statistica software, version 5.1 (StatSoft Inc., Tulsa, USA).

3 Results and Discussion

According to the results for the intra and interexaminers errors, coefficients showed high rates of agreement for the measures with CBCT and periapical radiographs. The ICC values found for interexaminers error varied from 0.95 to 0.99 and for intraexaminers error from 0.90 to 0.99.

The EARR magnitude between T2 versus T1, as determined by periapical radiographs, was statistically significant in all the measured teeth, as described in Table 1.

Table 1 – Comparison of the tooth length (mm) between T1 and T2 (EARR) evaluated by means of periapical radiographs.

	T1		T2		dif.	P	
	mean	SD	mean	SD			
Tooth	12	25.52	2.33	24.54	2.35	-0.97	<0.001*
	11	26.77	2.43	25.92	2.50	-0.85	<0.001*
	21	26.72	2.47	25.69	2.09	-1.03	<0.001*
	22	25.26	2.45	24.27	2.37	-0.98	<0.001*
	42	24.72	1.72	23.76	1.68	-0.96	<0.001*
	41	23.54	1.81	22.52	1.72	-1.02	<0.001*
	31	23.37	1.62	22.54	1.67	-0.83	<0.001*
	32	24.57	1.66	23.81	1.78	-0.76	<0.001*

* - statistically significant difference ($p < 0.05$)

Source: Research data.

Similar statistically significant result was observed when the EARR magnitude was detected by CBCT, in all the measured teeth, as described in Table 2.

Table 2 – Comparison of the Tooth length (mm) between T1 and T2 (EARR) evaluated by means of CBCT scans. (Paired t test)

	T1		T2		dif.	P	
	mean	SD	mean	SD			
tooth	12	22.99	1.78	22.69	1.80	-0.30	<0.001*
	11	24.03	1.98	23.75	1.93	-0.28	<0.001*
	21	23.89	2.01	23.67	1.90	-0.22	0.032*
	22	22.93	1.91	22.73	1.91	-0.21	0.002*
	42	21.94	1.61	21.76	1.57	-0.17	0.029*
	41	21.04	1.45	20.64	1.40	-0.39	<0.001*
	31	20.80	1.42	20.51	1.39	-0.30	<0.001*
	32	21.98	1.63	21.79	1.66	-0.20	0.049*

* - statistically significant difference ($p < 0.05$)

Source: Research data.

When the EARR magnitude was compared between the methods, CBCT and periapical radiographs, a statistically significant difference was found for all teeth (Table 3). The periapical method showed a mean value of 0.92mm of resorption for all teeth (3.69%) while for the CBCT method the value was 0.25mm (1.15%).

Table 3 – Comparison of the EARR degree between the two methods, CBCT and periapical radiographs (PR). (*Paired t test*)

tooth	CBCT		PR		dif.	P
	Mean	SD	mean	SD		
12	-0.30	0.34	-0.98	0.56	0.68	<0.001*
11	-0.28	0.30	-0.85	0.65	0.57	0.002*
21	-0.22	0.49	-1.03	0.74	0.81	<0.001*
22	-0.21	0.30	-0.98	0.80	0.78	<0.001*
42	-0.17	0.37	-0.96	0.67	0.78	<0.001*
41	-0.39	0.38	-1.02	0.72	0.63	0.001*
31	-0.30	0.34	-0.83	0.66	0.53	0.003*
32	-0.20	0.47	-0.76	0.59	0.56	<0.001*

* - statistically significant difference ($p < 0.05$)

Source: Research data.

EARR presents a high incidence and has always been considered an iatrogenic side effect of orthodontic treatment.¹⁶ Its early detection has been challenging for the orthodontist because in the early stages it does not present clinical signs. In this context, several imaging examinations have been used for detecting early EARR, including panoramic radiography, periapical radiography, and CBCT, the latter two being the most suitable to observe apical shortening.^{8,16,17}

In this study, two imaging techniques were used to evaluate the EARR degree: CBCT and periapical radiography. The 0.4mm voxel was used as a protocol for obtaining the CBCT scans. In a previous study, 3 distinct voxel values (0.2, 0.3, and 0.4 mm) were applied to detect the extension of cavities performed in 60 extracted teeth. The authors concluded that all voxel values were reliable to evaluate the injuries in the studied teeth.¹⁸

Upper and lower incisors were chosen in this study to be evaluated, as they are more susceptible to EARR and suffer greater movement during orthodontic treatment.¹⁹ The upper lateral incisors showed the greatest shortening during orthodontic movement, followed by the lower lateral incisors, upper central incisors, and lower central incisors.²⁰

The comparison between T1 and T2 aimed to detect the patient's predisposition for root resorption. It is known that if the patient presents EARR during the first months, he is more susceptible to continued resorption thereafter, when compared to patients without visible EARR at an early stage. The time between T1 and T2 was set at six months because, according to the literature, it is possible to evaluate some degree of EARR in this period.¹⁰ On the other hand, other studies have stated that 6 months are enough to early predict severe magnitude of EARR after treatment.¹⁷

Conventional two-dimensional imaging methods have been commonly used to detect EARR during orthodontic treatment.^{5,21} Three-dimensional imaging, such as CBCT, has been demonstrated to effectively detect EARR during the treatment early phase.^{15,22,23} Therefore, this study aimed to compare the ability of periapical radiographs and CBCT to assess the EARR magnitude during the first six months of orthodontic treatment.

The methods used for evaluating EARR using CBCT scans and periapical radiographs followed previously reported studies.^{11,24} It should be noted that both methods are reliable (Table 3); all measurements obtained for both CBCT and periapical radiographs showed a high degree of inter- and intra-examiner agreement, which support the use of these methodologies in future studies.

In the current study, 200 teeth were measured, and the presence of root resorption of small magnitude was observed in all of them. These results revealed a high incidence of low EARR and corroborate with the results of other studies that assessed EARR.^{11,25} The data obtained in this study demonstrated that EARR values in periapical radiographs were magnified; this may be due to the high sensitivity of this technique and/or to the tipping changes during the alignment of upper and lower incisors, which can result in elongation in radiographic images.^{5,26}

When considering the EARR detected by the conventional method for the upper incisors, our results for the central incisors (0.94mm) were slightly greater to 0.69mm found by Artun et al.⁷ However, the lateral incisors showed similar findings, 0.98mm in our study and 0.86mm by their study.

For the lower incisors, our results showed 0.92 for the central incisors and in the study by Sameshima et al,³ the value was 0.67mm. The findings for the lower lateral incisors were very similar, with 0.86mm found in our study and 0.80mm in their study.³ It should be noted that our results for the EARR detected by periapical radiographs are similar to the results from the literature, and when a small difference was found, it was not clinically significant.

The above-mentioned studies^{3,7} were performed with periapical radiographs, but another study¹¹ using CBCT scans in the same evaluation period found also similar results. Their value found in the EARR of the upper central incisors was 0.36mm and ours was 0.25mm, for the upper lateral incisors, 0.41mm for their study and 0.25mm for ours. The results for the lower central incisors were 0.39mm in their study and 0.34mm for ours, and for the lateral incisors, 0.28mm and 0.18mm, respectively.

A statistically significant resorption was observed for all measured teeth using the two methods. These findings also demonstrated that the measurements obtained by CBCT are more reliable than radiographic examination, which showed increased EARR values, as already mentioned in the literature.²⁶ The CBCT scan shows no overlapping images, and anatomical structures can be viewed in isolation, resulting in less interference when measurements are taken. However, the radiation dose to the patient should be considered, because CBCT, when compared to periapical radiography, exposes patients to significantly more radiation. Therefore, its use should be indicated only when it is likely to offer substantial benefit to the patient.²⁷

Thus, according to the data obtained and discussed in the present study, CBCT was found to be a reliable imaging

method and more accurate than periapical radiography to assess EARR in its early stages (less than 2mm), a fact that is corroborated by the literature.^{28,29} In a systematic review and meta-analysis comparing CBCT and periapical x-rays, the authors concluded that the results from clinical trials can not be considered definitive as there is no gold standard for *in vivo* comparison.²⁹ They also pointed out that, in spite of the greater CBCT accuracy, there was no statistically significant difference between the two techniques regarding the ability to rule out the presence of external resorption.²⁹ Concerning the EARR magnitude findings of our study, even considering the potential magnification of periapical radiography, the mean difference (T2-T1 < 1 mm) was not considered clinically relevant.³⁰

There is a tendency to overuse CT, forgetting the biological costs that this examination may cause to the patient.²⁷ Thus, CBCT should be carefully indicated to assess a patient's degree of EARR, only in specific cases where periapical radiography cannot provide the necessary resolution to accurately assess EARR, specially when the resorption occurred around the tooth root. Considering the root resorption as a possible side effect of the orthodontic treatment, the most common affected area seems to be the root apex, which can be diagnosed in a conventional radiographic image. Periapical radiography is an easy, reliable, and low-cost method for this purpose, with less exposure to ionizing radiation.^{15,27}

Additional clinical studies are recommended, improving the methodology to detect EARR in volumetric analysis. The current study findings are suitable to fill the gap in the literature, because only *in vitro* methodologies^{15,16} have been widely reported to compare the two methods for detecting EARR.

4 Conclusion

- Both radiographic methods were effective to detect EARR during the first six months of orthodontic treatment.
- Although the differences in EARR magnitude between the measurements obtained by the two methods were significant, the small differences (less than 1 mm) do not justify requesting CBCT merely to assess EARR during orthodontic treatment.

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