HU Revista

Is relevant the underestimation of irregular apical root resorption by periapical radiographs?

A subestimativa da reabsorção radicular apical irregular em radiografias periapicais é relevante?

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ABSTRACT

Introduction: Periodic control of root resorption during orthodontic treatment is frequently made by two-dimensional radiographic examinations, in which irregular resorptions are not detected buccolingually. **Objective:** Quantifying the resorbed root area of incisors with irregular apical root resorption underestimated by two-dimensional radiographic methods. **Materials and Methods:** Cone beam computed tomography images of 18 patients whose maxillary incisors presented irregular apical root resorption underestimated by two-dimensional radiographic methods (experimental group) and their contralateral correspondents without resorption (control group) were evaluated. In the control group, a regular apical root resorption was simulated at the same height as that of the irregularly resorbed incisors. The apical and total root surface areas of the incisors with irregular root resorption and simulated regular root resorption were measured and compared. The Student´s t test for paired samples was used at a level of significance of 0.05. **Results:** The apical area of the incisors with irregular root resorption was significantly smaller than that of the incisors with simulated regular resorption ($p<0.001$). There was no significant difference in the comparison between total root surface areas ($p=0.435$). **Conclusion:** Underestimation of the irregular root resorption shown on two-dimensional images was significant when analyzing the apical area of the tooth. However, when considering the total root surface area of the tooth, which is responsible for the most part of the periodontal support, such underestimation was not significant.

Key-words: Root Resorption; Cone Beam Computed Tomography; Periodontal Attachment Loss.

RESUMO

Introdução: O controle periódico da reabsorção radicular durante o tratamento ortodôntico é frequentemente realizado através de exames radiográficos bidimensionais, nos quais as reabsorções irregulares não são detectadas no sentido vestibulolingual. **Objetivo:** Quantificar a área reabsorvida de raízes de incisivos com reabsorção radicular apical irregular subestimada por exames radiográficos bidimensionais. **Material e Métodos:** Foram avaliadas imagens de tomografia computadorizada de feixe cônico de 18 pacientes que apresentavam incisivos superiores com reabsorção radicular apical irregular substimada por exames radiográficos bidimensionais (grupo experimental) e os incisivos correspondentes contralaterais sem reabsorção radicular (grupo controle). No grupo controle foi simulada uma reabsorção radicular apical regular na mesma altura da encontrada nos incisivos com reabsorção irregular. As áreas apical e total das raízes dos incisivos com reabsorção radicular irregular e regular simulada foram avaliadas e comparadas. O teste t de Student para amostras pareadas foi utilizado, sendo considerado um nível de significância de 0,05. **Resultados:** A área apical nos incisvos com reabsorção radicular irregular foi significativamente menor do que nos incisivos com reabsorção radicular regular simulada ($p<0,001$). Não houve diferença significativa entre as áreas radiculares totais ($p=0,435$). **Conclusão:** A reabsorção radicular irregular foi significativamennte subestimada em imagens radiográficas bidimensionais quando a área apical radicular foi analisada. Entretanto, quando a área radicular total é considerada, a qual é responsável pela maior parte do suporte periodontal, esta subestimativa não foi significativa.

Palavras-chave: Reabsorção da Raiz; Tomografia Computadorizada de Feixe Cônico; Perda da Inserção Periodontal.

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INTRODUCTION

Apical root resorption (ARR) is a frequent side effect of orthodontic treatment, showing variable and unpredictable lesion extension.[1,2,3,4] It is characterized by loss of tooth structure due to the disappearance of the cementoblasts from the root surface.[4,5,6,7] This occurs because the force applied to the teeth causes compression of the blood vessels of the periodontal ligament.[3,7,8]

Despite representing tissue and structural damage, apical root resorption limited to 3mm in length is considered as a clinically acceptable biological cost during orthodontic treatment. Nevertheless, it should not be considered as normal, physiological or part of apical remodeling. This reduction in root length leads to less periodontal support.[3,9] The greater the loss of periodontal support, the higher the risk for stability and longevity of the affected tooth. Thus, even more important than knowing how much root length had been lost because of resorption is to determine the amount of loss of periodontal support caused by it.

Since root resorption is asymptomatic, it is generally diagnosed by means of routine periapical and panoramic radiographs.[10,11,12] Both these techniques show limitations in that they yield two-dimensional images of three-dimensional structures.[13,14] Panoramic radiographs, besides overestimating bone loss in 20% when compared to periapical radiographs, yield few details, present many distortions, and should not be used as a diagnostic tool for resorptions.[3] In turn, periapical radiographs do not allow the quantification of resorption in that tooth surfaces are superimposed, underestimating lesion extension,[12] restricting the detection of alterations on the buccal and lingual surfaces of the tooth, and hampering the visualization of initial lesions.[13,15] The main advantage of computed tomography is that it permits the representation of tooth structure in three dimensions, allowing an adequate interpretation of the real defects caused by resorption.16 However, due to the high dose of radiation and high cost, this method is not appropriate for root resorption monitoring during orthodontic treatment.[17]

Cone beam computed tomography (CBCT) is especially indicated for the dentomaxillofacial region,[18,19] having as advantages the reduction of radiation to 1/60 of the usual multislice computed tomography dose, the direction of radiation to the area of interest through the use of a collimator, the possibility of reconstructing the original image with voxels, and the reduction of examination time.[20-23]

The aim of the study was to quantify the resorbed root area of incisors with irregular apical root resorption underestimated by two-dimensional radiographic methods.

MATERIAL AND METHODS

This study has been approved by the Research Ethics Committee of Juiz de Fora Federal University (Approval number 463/2008). All individuals participated voluntarily and informed written consent was obtained after explanation of the procedures had been given.

The sample consisted of 18 patients (8 males and 10 females) with the mean age of 20.82 years (14-41 years) under orthodontic treatment with edgewise appliance, who exhibited irregular apical root resorption in one maxillary incisor (experimental group) and absence of apical root resorption in the corresponding contralateral tooth (control group). In the pre-treatment periapical radiographs, the selected incisors (with and without ARR) should have presented same root length, similar root structures, with no morphological alteration, root resorption, endodontic treatment or history of trauma in the incisors. In the pre-treatment records, the patients showed symmetrical malocclusions that required the same treatment protocol of application of force on both sides of the maxillary arches.

The apical root resorption lesions were only associated with the application of orthodontic forces to the teeth and were diagnosed during orthodontic treatment through follow-up periapical radiographs.

After selecting the sample through pretreatment and follow-up periapical radiographs, the participants were submitted to CBCT performed with an i-CAT scanner (Imaging Sciences International, Hatfield, PA, USA) operated at 120kV and 3-8mA, voxel size of 0.25mm, rotation time of 26.9s, and a field of view (FOV) with a diameter of 160mm and height of 100mm.

For image acquisition, each individual was seated with the chin on the chin rest, with the Frankfurt plane parallel to the floor, the midsagittal plane perpendicular to the floor, and the mandible in maximum habitual intercuspation. The FOV was positioned in a way that the occlusal plane could occupy its vertical center and the anterior nasal spine could be 35mm distant from its anterior border, inside the FOV.[24]

The images were analyzed with the i-CAT Vision (Imaging Sciences International, Hatfield, PA, USA) software in MPR (multiplanar reconstruction) mode, with 2.0mm-thick slices. The 36 incisors (20 lateral and 16 central incisors) were evaluated in a randomized and blind manner by two calibrated examiners (orthodontists with more than 5 years of clinical experience in CBCT imaging). With the purpose of standardizing the images to be analyzed, each incisor was positioned vertically in the image so that the intersection between the sagittal and coronal slices would coincide with the central vertical axe of the tooth and the coronal cut would coincide with the incisal border.

On the sagittal image of the incisor with irregular root resorption, a perpendicular line along the axis of the tooth was drawn, which was positioned equidistant from the labial and lingual enamel-cementum junctions (EC line). On the same image, the most apical point of the root (point AR) and the most cervical point of the irregular root resorption lesion (point CR) were also determined (figure 1).

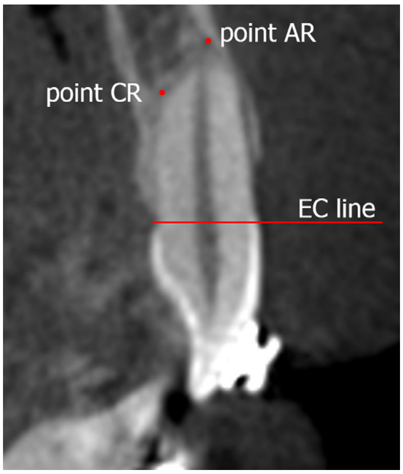

Figure 1: Sagittal cut of a superior incisor showing the points AR and CR and the EC line.

On the sagittal images of the incisors without resorption, the EC line was traced. Points AR and CR of the contralateral incisors with irregular ARR of the same patient were transferred from this line, keeping the distances between them (figure 2A and B). That was possible because the selected incisors had the same root dimension on pretreatment periapical radiographs.

Two horizontal lines parallel to the EC line passing through the points AR (AR line) and CR (CR line) were drawn on the images of all incisors. On the same images, a 2mm x 2mm square was drawn in order to be used as reference for the measurements of the area (figure 2A and B).

The horizontal line passing through the point AR, drawn on the incisors without ARR (figure 2B), simulated regular apical root resorption (type 1) at the same height as the most apical point of the incisor root with irregular ARR (figure 2A).[21]

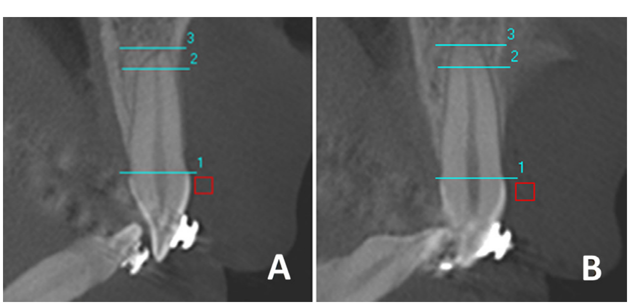

Figure 2: Sagittal cut of superior incisors with ARR (A) and without ARR (B) showing horizontal lines EC line (1), AR line (2) and CR line (3) and the 2mm x 2mm square.

Sagittal cut images were saved in JPEG format using the "Save as JPEG" function of the i-Cat Vision software (332 x 208 pixels and 72 dpi resolution).

Images were open on Image J software (National Institutes of Health, Washington, DC, USA) using zoom of 400%. For the determination of the measurements of the areas of interest, the polygon selection tool was used for marking several points to delineate the contour of three regions of the root as well as the square used as reference scale:

- Sound root area: delineated on the images of all incisors from EC line to CR line, contouring the labial and lingual limits of the roots (figure 3A and figure 4/green);
- Apical area with irregular resorption: root area located apically to CR line on the images of incisors with irregular resorption, contouring the whole apical area and respecting the limits of the root (figure 3B and figure 4/red);
- Apical area with simulated regular resorption: delineated on the images of incisors without resorption between the AR and CR lines, respecting the labial and lingual limits of the root (figure 3C and figure 4/yellow).

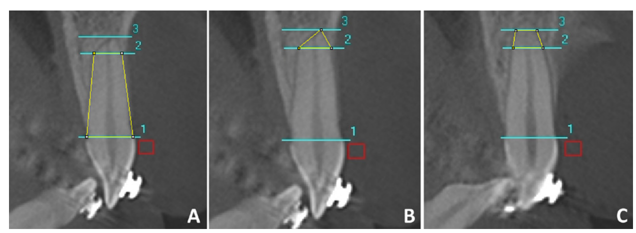

Figure 3: Sagittal cut of superior incisors with ARR (A and B) and without ARR (C): showing sound root area (A), apical area with irregular reabsorption (B) and apical area with simulated regular reabsorption (C).

After contouring each region of the root and the reference scale, the "measure" tool for measuring the delineated area was used. From the measurements of the area provided by the Image J software, the reference scale was used to determine, in millimeters, each one of the root areas.[2]

Total root area was determined by the sum of the sound root area and the apical area of the incisors with irregular resorption (green area + red area in figure 4A) and with simulated regular resorption (green area + yellow area in figure 4B).

Statistical analysis

Intra and interexaminer reliability was analyzed by the determination of the intraclass correlation coefficient (ICC), which was calculated through the values of the sound root area and the apical area of 15 randomly chosen incisors measured twice by both the examiners with a 15-day interval, being that for the interexaminer evaluations the second measurements of each examiner were used.

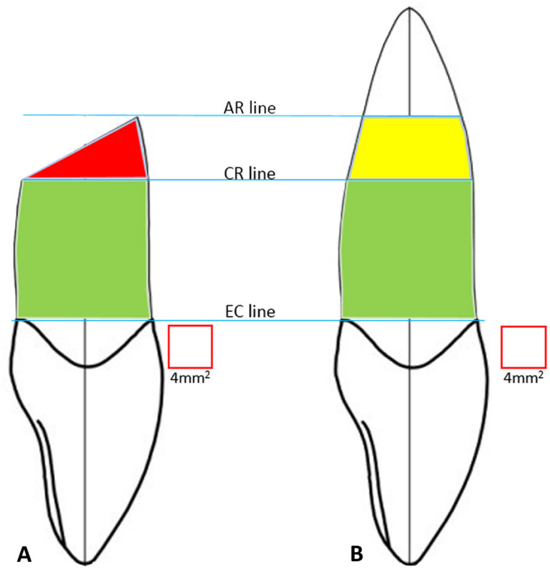

Figure 4: Sagittal section of maxillary incisors with irregular ARR (a) and simulated regular root resorption (b), demonstrating the horizontal lines (AR and CR), the 2mm x2mm reference square, the sound root area in green, the apical area with irregular resorption in red, and the apical area with simulated regular resorption in yellow.

The normality of variables was assessed through the Shapiro-Wilk's test. The comparison of the values of the sound root area, apical area, and total root area between the incisors with irregular ARR and simulated regular ARR was performed with the Student's t test for paired samples. Statistical analysis used a level of significance of a=0.05 and the data were processed with the SPSS Statistics 17.0.0 software (SPSS, Chicago, IL, USA).

RESULTS

The intra and interexaminer agreement tests for the variables exhibited excellent agreement (all above 0.9).[25]

Table 1 shows the values of the normality test of the sound root area, apical area, and total area for the incisors with irregular ARR and simulated regular ARR, where all variables exhibited normal distribution.

Table 1: Normality test of the variables under study.

	Incisors with irregular ARR		Incisors with simulated regular ARR	
	Test*	P	Test*	P
Sound root area	0.980	0.952	0.977	0.912
Apical area	0.950	0.424	0.952	0.452
Total root area	0.985	0.987	0.970	0.792

*Shapiro-Wilk test

Table 2: Mean values of the evaluated areas of the incisors with simulated regular and irregular apical root resorption and the comparison between them.

	Incisors with irregular ARR		Incisors with simulated regular ARR		Paried t test
	Mean (mm^2)	SD	Mean (mm^2)	SD	
Sound root area	62.11	14.63	62.62	13.88	0.837
Apical area	4.51	2.08	6.05	2.97	<.001
Total root area	66.62	14.78	68.68	14.63	0.435

The sound root area (between the lines EC and CR), the apical area (between the lines CR and AR), and the total root area of the incisors with irregular ARR and simulated regular ARR are described in table 2.

The sound root area did not show significant difference (p=0.837) between incisors with irregular ARR and simulated regular ARR, confirming the structural similarity of the roots when the area affected by irregular root resorption was not considered.

The apical area of the incisors with irregular ARR was significantly smaller than that of the incisors with simulated regular ARR (p<0.001). However, incisors with irregular ARR and simulated regular ARR did not show significant difference between their total root areas (p=0.435).

DISCUSSION

Apical root resorption is a frequent, undesired side effect of orthodontic treatment,[1,3,12] affecting particularly the maxillary incisors in that these teeth present single, thin, cone-shaped roots, which transmit the orthodontic force directly to the tooth apex.[9,13,2,26]

Despite not being considered as normal, a 3mm reduction in root length during orthodontic treatment was considered as biologically acceptable by Phillips.[9] Periapical radiographs are routinely used for diagnosis and follow-up of possible resorption lesions. In the present study, incisors with irregular ARR showed a mean reduction of 1.35mm in root length when the most apical point of the root was considered.

Since root resorption occurs in an irregular manner in 92.7% of the incisors,[24] affecting the lingual and labial surfaces in different degrees, two-dimensional radiographic examinations are not capable of demonstrating the real extension of the lesion because of the superimposition of the root structure in the labial-lingual direction.[27,12,24] According to Campos et al24, approximately 11.6% of the root length may be compromised by apical root resorption not diagnosed by two-dimensional radiographic techniques.

In the present study, regular resorption was simulated in the incisors without ARR at the same height of the most apical point of the incisors with irregular ARR (point AR). Point AR was chosen to determine the height of the simulated regular ARR because this point represents the most apical point of the lesion detectable by the two-dimensional radiographic technique such as the periapical radiograph.

The comparison between the roots of the incisors with irregular root resorption and without root resorption was possible due to the similar morphological structure presented by the two roots of each individual in the initial periapical examination. This characteristic was confirmed by the absence of significant difference (0.51mm2, p=0.837) between the sound root areas of the incisors with irregular ARR and simulated regular ARR.

Absence of symptomatology related to root resorption makes its diagnosis to be associated with routine radiographic examinations therefore periapical radiographic is indicated.[10,11,12] However, the bidimensional radiographic images do not show speficity for the diagnosis of RRA injuries; in other words, they can present false-negative results associated to the overlapping of images.[28,12,24] Thus, accurate diagnosis of the presence and extent of the lesion of root resorption is only possible through three-dimensional radiographic examination such as the computed tomography.[16,29] In this study, CBCT scans of the central sagittal section of the roots were evaluated, demonstrating a different perspective of the structures not visualized in periapical radiographs.

The quantification of the reduction of root length has limited clinical significance in that it is more important to determine the reduction of the surface area of the root and the consequent decrease of periodontal support.[3] The relationship between root shortening and loss of periodontal support has been little addressed in the literature. Kalkwarf et al[30] reported that a root shortening of 8mm corresponds to a reduction of 50% of the periodontal support.

The conical format of the roots ensures that the reduction of root length from the apex does not exhibit a linear relationship with the reduction of root area and, consequently, with the reduction of periodontal support, because the transverse section of the root increases in an apical to cervical direction. This characteristic, associated with the morphological variability of the roots, makes it difficult to determine such relationship.

The results obtained in this study demonstrated a significant difference in the apical area between the incisors with irregular ARR and simulated regular ARR. This result suggests that, by considering only the resorbed root area shown in the sagittal cut of the maxillary incisors, an irregular ARR affects significantly more root structure than the regular ARR with the same apical limit in similar root structures. However, there was no significant difference between the total root areas of the incisors with irregular ARR and the incisors with simulated regular ARR, indicating that the root structure affected by irregular ARR, in relation to the simulated regular ARR, did not affect significantly the total root area of the upper incisors in the sagittal cuts. Thus, the underestimation of the longitudinal extension of irregular apical root resorption lesions associated with two-dimensional radiographic methods did not have significant influence on the total root area of the tooth. Therefore it seems reasonable that the periapical radiography is indicated for the periodic control of the condition of the incisors during orthodontic treatment, since its diagnostic limitation is overcome by its advantages in terms of exam complexity, cost and radiation dose.

CONCLUSION

Although the apical root area of the incisors with irregular root resorption was significantly smaller than the area of the incisors with simulated regular root resorption, there was no significant difference between total root areas in both conditions.

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