Journal of the World Federation of Orthodontists 5 (2016) 46–49

Contents lists available at ScienceDirect

Journal of the World Federation of Orthodontists

journal homepage: www.jwfo.org

Research

Assessment of apical root resorptions during orthodontic treatment with digital subtraction and geometric reconstruction

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ARTICLE INFO

Article history:
Received 11 November 2013
Received in revised form
3 March 2015
Accepted 16 March 2016
Available online 25 May 2016

Keywords:
Computer-assisted diagnosis
Dental radiography
Early diagnosis
Root resorption
Subtraction technique

ABSTRACT

Objectives: To assess the severity of external apical root resorptions (EARR) in orthodontic patients by using digital subtraction and image reconstruction.
Materials and methods: Periapical radiographs from 34 individuals were obtained on the beginning (T0), after 6–7 months (T1), and after 12–13 months (T2) of treatment. These individuals had Angle Class I and II malocclusion and were treated with standard edgewise full fixed appliances (0.022 × 0.028-in.). The images were registered and subtracted on Regeemy® Image Registration and Mosaicking v.0.2.43-RCB (DPI-INPE, Sao Jose dos Campos, SP, Brazil). After reconstruction, root loss of the upper central incisors was measured on T1 and T2.
Results: The difference between T1 and T2 was statistically significant for the left central incisor ($P < 0.05$). No statistically significant differences were found for the variables of the orthodontic treatment (extraction of first premolars, use of intermaxillary rubber bands, or type of malocclusion; $P > 0.05$).
Conclusions: The EARR was greater during the first 6–7 months of orthodontic treatment. Extraction of premolars, use of intermaxillary rubber bands, and type of malocclusion did not pose a significant influence to the EARR.

1. Introduction

Histological and radiographic findings have confirmed that the orthodontic treatment is followed by varying extents of root shortening in almost all teeth [1,2], but, when correctly diagnosed, these lesions can be minimized.

Conventional and digital periapical radiography are the most used techniques for the diagnosis of external apical root resorption (EARR). With digital intraoral dental radiography, the radiation dose can be decreased to one-third of that of conventional film–based radiography [3], although, independent of the type of image receptor, the sensitivities of conventional and digital radiographs have been found to be similar [4]. Magnification and geometric distortion, inconsistency in detecting anatomic structures, variations of image processing and interoperator variability, buccolingual position of the resorption, and teeth position on the jaws are factors that affect the images and the comparison between images [5], making the qualitative importance of radiographs questionable as well as geometrically inaccurate.

Therefore, periapical radiography is still an important tool for detecting EARR, and the obstacles involved in the radiographic follow-up of EARR led to the development of methods that provided more precise results, such as geometric reconstruction and digital subtraction radiography (DSR). According to Ono and colleagues [6], EARR of around 0.5 mm and lingual lesions with depth and diameter of greater than 1 mm were detected by the examiners with significantly higher accuracy when using DSR.

Because scientific, diagnostic, prognostic, and treatment planning of orthodontic treatment may require the quantification of tooth loss due to EARR and because of the availability of digital resources for imaging examinations, our aim in the present study is to assess the EARR in orthodontic patients at 6 and 12 months of treatment by using DSR and image reconstruction. Our expectation is to contribute to the study of factors related to the root resorption due to orthodontic treatment using a methodology for its diagnosis.

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.

Authors have obtained and submitted the patient signed consent for images publication.

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2212-4438/$ – see front matter © 2016 World Federation of Orthodontists.
http://dx.doi.org/10.1016/j.ejwf.2016.03.002

2. Materials and methods

The sample consisted of 34 Brazilian patients (14 males and 20 females), with ages ranging between 11 and 16 years, who had Angle Class I or Class II malocclusion and received orthodontic treatment through the Orthodontics Specialization Course at the Associação Odontológica do Norte do Paraná (Londrina, Paraná, Brasil). The assortment of patients was sequential and aleatory among those who volunteered to participate in the study after providing informed consent.

All the patients had well-preserved permanent dentition in good state of hygiene. They had no history of dental trauma, self-immune systemic diseases, radiographic signs of periodontal disease, periapical lesions, or previous orthodontic treatment. Also, they were not regular users of drugs that could interfere with the bone metabolism.

Lateral cephalometric analyses were used in conjunction with the dental casts to select Angle's Class I and II patients with small maxillomandibular discrepancies (ANB angle 2°, and Wits Appraisal between −3 mm and 1 mm for males and −2 mm and 2 mm for females) [7,8].

Patients were treated with the "edgewise" directional forces technique using 0.022 × 0.028-in. slot brackets.

Periapical radiographs of each patient were obtained using parallel technique on the following stages of the treatment:

- Stage 1 (T0): before the treatment began
- Stage 2 (T1): between 6 and 7 months after the treatment began
- Stage 3 (T2): between 12 and 13 months after the treatment began

The radiographs were obtained on conventional film (Kodak Ektaspeed; Eastman Kodak Co., Rochester, NY) with a Spectro intraoral x-ray tube (DabiAtlante; Ribeirão Preto, SP, Brazil) operating at 70 kVp, 10 mA. Exposure time was set to 0.7 second for all patients. Image processing was carried out manually with fresh chemicals (Eastman Kodak Co.), following the manufacturer's instructions of time/temperature technique.

The radiographs were digitized on a flatbed scanner with transparency device and its software for image capture (HP Scanjet G4050; Hewlett-Packard, Palo Alto, CA). Digitizing factors were set to 300 dpi, 100% scale. The digitized images were saved in Tagged Image File Format (TIFF) and imported to Regeemy® Image Registration and Mosaicking v.0.2.43-RCB; (DPI-INPE, Sao Jose dos Campos, SP, Brazil; http://regima.dpi.inpe.br/download.html). Regeemy® has algorithms for image reconstruction, with which differences in geometric projections, brightness, and contrast between 2 images can be corrected. T0 images were always selected as the baseline (reference for the reconstruction of the subsequent image). T1 or T2 images were selected as follow-up images (reconstructed image), when stage 1 or 2 was compared with stage 0, respectively. Between 9 and 15 reference points were manually selected for each pair of images (baseline and follow-up). These points served as coordinates for the software to align the pairs and correct the geometry of the follow-up images according to its baseline.

After image reconstruction, the images were subtracted. Image subtraction was the tool to check the success of image reconstructions. These were considered as successful if the crown could not be visually distinguished from the root on the resultant subtracted image [9] (Fig. 1). If successful, the reconstructed follow-up images were saved in TIFF. Both baseline and follow-up images were imported to UTHSCSA Image Tool (University of Texas Health Science Center at San Antonio; ftp://maxrad6.uthscsa.edu), where the root lengths were measured on T0 (L0), T1 (L1), and T2 (L2) images of each patient. A line between the mesial and distal cementoenamel junction (CEJ) was traced, and its geometrical center was determined. The root length on each image was the measurement between the geometric center of the inter-CEJ line and the middle point of the radicular apex. The loss of root length was calculated in percent using the formula $((L1 - L2)/L1) * 100$, where L1 = root length on T1 and L2 = root length on T2 or T3.

Each measurement was repeated twice on a 30-day interval by a single experienced examiner for the error of the method.

The variations of root length induced by the orthodontic treatment were compared between stages 1, 2, and 3.

2.1. Statistical analysis

To evaluate the error of the method, the readings of each measurement were compared using a simple linear regression model $Y = aX + b$, where X and Y correspond to the first and second reading, respectively, and a and b are the angular and linear coefficients of the regression model, respectively. The absence of random and systematic errors is indicated by a not being statistically different from 1 and b not being statistically different from 0. The Student t test ($\alpha = .05$), was used to analyze if the hypothesis "$H_0 = a$ is not statistically different from 1" can be accepted. The same test is used to verify if the hypothesis "$H_0 = b$ is not statistically different from zero" is true. The third condition to be verified on the analysis of the error is the correlation coefficient $r \geq 0.90$.

Repeated-measures analysis of variance was used for the comparison between the stages of orthodontic treatment (T0–T1, T1–T2, and T0–T2). Mann–Whitney U test was used to compare the amount of root resorption considering the variables related to the orthodontic treatment (extraction of first premolars, use of intermaxillary rubber bands, type of malocclusion). The level of significance for both tests was .05.

3. Results

The mean and standard deviation (SD) of the percentages of EARR for the upper right central incisors and upper left central incisors after 6–7 months of treatment (phase 1 = T1–T0) and 12–13 months of treatment (phase 2 = T2–T1) are represented on Table 1.

The sample was split according to the variables related to the orthodontic treatment in order to detect their influence over the amount of EARR during the orthodontic treatment. Mean and SD values for the amount of EARR in Angle Class I and Class II groups and the P value for the comparison between groups are shown in Table 2. Mean, SD, and P values for the amount of EARR in groups with or without the use of intermaxillary rubber bands are represented in Table 3. Mean, SD, and P values for the amount of EARR in groups treated with and without the extraction of first premolars are represented in Table 4.

4. Discussion

Although most of the teeth with EARR due to orthodontic forces present less with than 1 mm of root shortening, around 8% of the orthodontic patients will have radicular resorptions of more than 3 mm after 12 months of treatment [9], with the possibility of reaching an extension that may damage the stability of the occlusion.

In this manner, after 6 months of treatment, periapical radiographs of the teeth involved in this treatment should be obtained [4,10], and for teeth with severe resorption, follow-up radiographic examinations are recommended until EARR is no longer evident [10]. Because in most published reports the incisors are the teeth