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Original Research Article

Digital radiographic evaluation of root resorption during orthodontic treatment. An *in vivo* study

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Abstract

Objective: To present two null hypothesis: (1) The absence of orthodontically induced inflammatory root resorption (OIEARR) in maxillary incisors during orthodontic treatment indicates that it does not occur in other teeth. (2) The teeth that don't present root resorption at the first 6 months of orthodontic treatment, they will not present until the end of treatment. **Material and methods:** Digital periapical X-rays of 37 patients. The periapical radiographs were evaluated following phase alignment and leveling (time 1), and at the end of orthodontic treatment (time 2). **Results:** Despite OIEARR was not evident in the maxillary incisors, Grade 4 resorption was evident in the maxillary and mandibular teeth. The only teeth which showed statistical significance for the incidence of OIEARR were the maxillary lateral incisors and the mandibular incisors during both periods ($p<0.05$). **Conclusion:** The null hypothesis (1) was rejected, because there was OIEARR in the other teeth despite it doesn't occur in the maxillary and mandibular incisor. The second hypothesis (2) was also rejected because there were teeth that did not

present OIEARR at 6 months after the beginning of treatment and presented at the end. There was no relationship among root shape, sex, age and OIEARR; but the greater degree of crowding, the greater tendency of OIEARR.

Introduction

Resorption is described as the physiologic or pathologic dissolution of mineralized tissues in bone, dentin or cementum by osteoclastic type cells [1]. The resorption that occurs during orthodontic treatment can be called inflammatory root resorption concurrent with orthodontics (IRRCWO) [3] or orthodontically induced inflammatory root resorption [4] (OIEARR) and it is defined as the loss of dental hard tissues caused by clastic activity [11]. It has a multifactorial etiology resulting from a complex interaction between individual biology and the effect of mechanical forces, being an undesirable and often unpredictable side effect of orthodontic tooth movement [4]. It was suggested that the irreversible lacunar resorption along the roots' surfaces is a mechanism that may defend against the loss of teeth with resorbed short roots by increasing their surface areas [3].

The prevalence of OIEARR in patients treated orthodontically is high [6], so the detection of OIEARR at the beginning of the treatment is essential for identifying teeth at risk of severe resorption at the end of it, and to re-establish goals [7]. But this is difficult because the majority of these cases are asymptomatic and are found during routine radiographic or clinical examination [1]. To be detected radiographically it is necessary a certain amount of tissue lost, as well as the need for all teeth to be radiographed, and with the limitations of 2D exams. Despite this, periapical radiographs continue to be widely used because of the ease of access in the clinics and the low doses of radiation, when compared with other radiographic and mainly tomographic exams [12, 18].

The main reasons for using the maxillary incisors to determine OIEARR is that it most commonly occurs in these teeth, which are easily visualized on images exams, and that the mechanical factor, such as in movements as tipping, torque and incisor intrusion, the root surface is directly compressed against the alveolar bone resulting in root resorption [13].

Therefore, the purpose of this investigation was to evaluate the following null hypothesis: 1) absence of OIEARR in maxillary incisors during orthodontic treatment indicates that it does not occur in other teeth; 2) the teeth that do not present root resorption at the first 6 months of the therapy, they won't present anymore. The study also aimed to find out if there is any relationship among the root shape, treatment time, and degree of dental crowding, as indicated with the Little Irregularity Index [8], in order to assist the clinic in the identification of patients at higher risk.

Material and methods

After the approval by the research ethics committee CAAE – 0035.0.213.000-09, an initial sample of 50 patients from a private practice setting was consecutively invited to participate in the study and all subjects signed informed consent. After apply eligibility criteria a selection of 37 patients (mean age: 22.9 years, SD 9,378), 12 males (32,4%) and 25 females (67,6%), were included in this observational cohort study.

The inclusion criteria were caucasian with all permanent teeth present (except third molars), absence of open or deep bite, posterior and anterior crossbite. The exclusion criteria were dental intrusion movement, retraction of the anterior teeth, need for tooth extraction, trauma history, change in the portion of the incisor crowns, malformation or defect in the teeth, agenesis, supernumerary, and endodontic or impacted incisor treatment.

The prevalence of malocclusion in this study was: Class I 29,7%, Class II 48,7% and Class III 21,6%. Treatment was carried out by the same orthodontist for all patients with total complete fixed appliances 0.022 x 0.028-in pre-adjusted brackets (Abzil, 3M Unitek, Monrovia, California, USA) using the following wire sequence: 0.014-in nickel-titanium (NiTi), placed in the arc for one month and 0.016-in SS, 0.018-in SS for at least two months and 0,017 x 0,025-in SSwere placed for an average of three months before debonding. The Class II and sagittal discrepancy was corrected with Class II or Class III elastics on both sides for at least 6 months, 15 to 18 hours a day, with mean force of 200g measured with strain gauge (Dentaurum, Ispringen, Germany). Devices such as extra-buccal, lip bumper or springs were not used at any stage of treatment.

The periapical radiographs were obtained in the beginning of the treatment (time 0), 6 to 9 months from the beginning of treatment (time 1), and at the end of treatment (time 2), 12 to 24 months after the end of aligment and leveling phase.

The Heliodent 70 Dental X-Ray (Sirona-The Dental Company, Bensheim-Germany) was used to acquire the radiographic images at 70 kVp and 10 mA. The radiographic evaluation was performed on a monitor (Dell 23 inch, Round Rock, Texas, USA) in a room with low light using the imaging software program Adobe Photoshop (version CS5) by two expert (AGDS e FRM) evaluators in Dental Radiology after training and calibration of the resources of *software* tools. Each image was evaluated twice at an interval of one week and there was a high level of agreement between the methods of the two evaluators, with 97.8% agreement (Kappa).

The total longitudinal length of the teeth on the radiographic image was obtained using *software* program, from the measurement of the distance of the coronary incisal points (IC) and the root apical (RA). The IC point was obtained as the midpoint of the mesiodistal length incisal edge of the incisors, while the RA point was located in the apical portion of the root apex (figure 1).

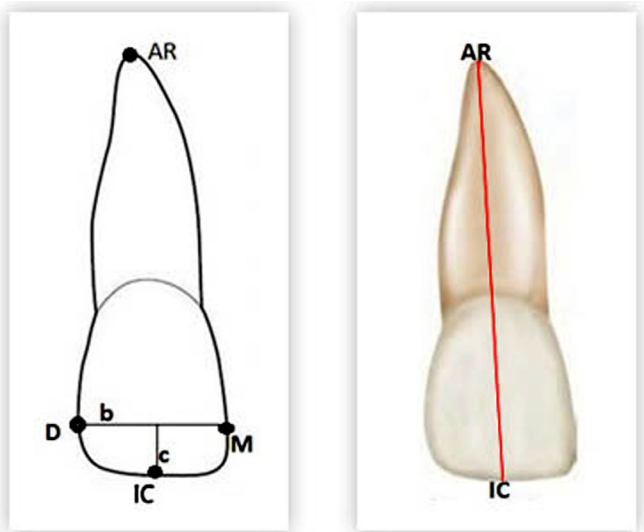

Figure 1 – A schematic drawing of the points and lines that were used: mesial point (M), distal point (D), line b (formed by the union of M and D), and line c (perpendicular to half of line b, focusing on the incisal tooth edge), coronary incisal point (CI), and the root apical point (RA)

To correct the possible distortion between one radiograph and another, the distance between the incisal edge and the cement enamel junction, which would remain unchanged, was also measured at both moments, so a simple three-rule was performed to calibrate the second radiography.

The root resorption index [6] was graded as follows: no resorption, grade 0; irregular root contour to 1-mm resorption, grade 1; resorption<2.0-mm, grade 2; resorption apically from 2 mm to one third of the original root length, grade 3; and resorption>3-mm exceeding one third of the original root length, grade 4 (figure 2).

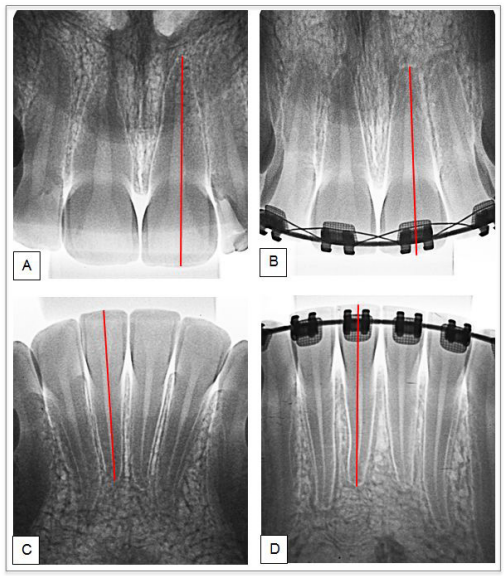

Figure 2 – The points and lines used to standardize the tooth length measurements for the digital radiographic images. This length is given by the union of coronary incisal point (CI) and the root apical point (RA)

When OIEARR was greater than 2 mm in the intermediate phase, the applied force would be decreased and more time between one appointment and other was done, and periapical radiography would be performed in intervals of 6 months.

The root form was classified in normal, blunt, sharp root, apically bent root and pipette shaped root [6]. And the Little Irregularity Index, as previous described, was done in the mandibular model.

The data were tabulated and the SPSS statistics program (version 22; IBM, Armonk, NY) was used for statistical analysis. Fisher exact and Chi-square tests were used to determine whether were any statistically significant differences in the data.

Results

Based on the results of time 1, the patients were divided into the following groups: (1) with OIEARR in the incisors (8 maxillary and 12 mandibular) and (2) those without OIEARR (29 maxillary and 25 mandibular). It is possible to observe in table I, the patients who showed no signs of OIEARR in the incisors instead showed signs of the condition in other tooth types.

Table I – The relationship between the incidence of OIEARR in the maxillary incisors and that of other maxillary and mandibular teeth during both evaluation periods. (* indicates a statistical difference). The incidence of OIEARR is indicated accordingly

	Frequency of EARR cases at time 1				**Frequency of EARR cases at time 2**			
	WITHOUT EARR 11/21		WITH EARR 11/21		WITHOUT EARR 11/21		WITH EARR 11/21	
	NO EARR	EARR	NO EARR	EARR	NO EARR	EARR	NO EARR	EARR
16/26	8	8	30	28	9	11	25	29
15/25	7	9	19	39	14	6	34	20
14/24	13	3	30	28	13	7	32	22
13/23	8	8	24	34	8	12	25	29
12/22	14*	2*	15*	43*	12*	8*	13*	41*
36/46	10	14	28	22	21	11	19	23
35/45	18	6	30	20	18	14	20	22
34/44	17	7	31	19	17	15	23	19
33/43	14	10	29	21	12*	20*	29*	13*
32/42	24*	0*	21*	29*	25*	7*	12*	30*

In figure 3A e 3B, the behavior of the teeth to orthodontic forces can be observed, sorted according to severity.

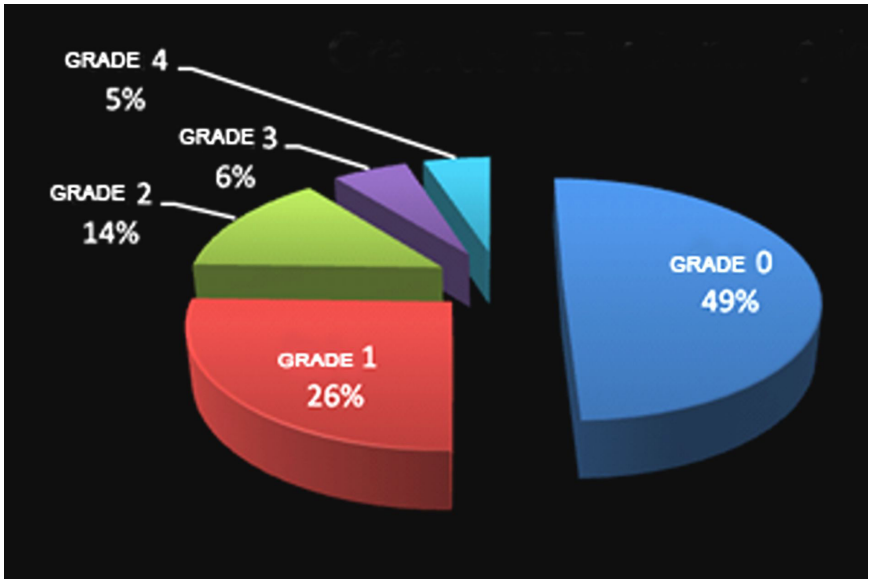

Figure 3A – The distribution of the severity grades for the incidence of OIEARR at time 1 in patients unaffected by the condition in the maxillary incisors

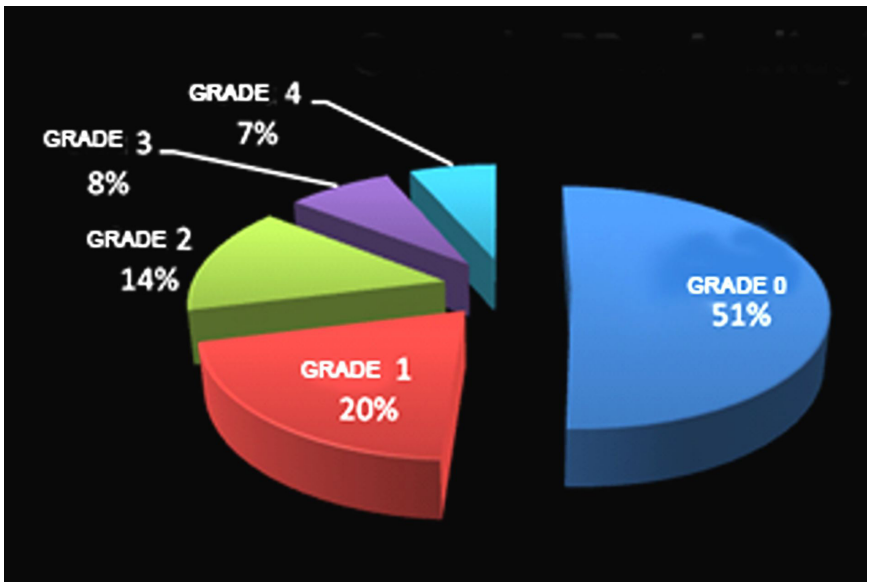

Figure 3B – The distribution of the severity grades of OIEARR at time 2 in patients unaffected by the condition in the maxillary incisors.

The distribution of OIEARR in the sample (888 teeth) is shown in table II.

Table II – The relationship between the OIEARR and tooth type for both evaluation periods (time 1 and time 2). (* indicates a statistical difference). The incidence of OIEARR is indicated accordingly

Time 1		**Time 2**		Total
		WITHOUT EARR	WITH EARR	
WITHOUT EARR	Maxillary central incisor	7	15	22
	Maxillary lateral incisor	11	18	29
	Maxillary canine	13	19	32
	Maxillary premolar	41	28	69
	Maxillary molar	13	16	29
	Mandibular central incisor	17	16	33
	Mandibular lateral incisor	26	19	45
	Mandibular canine	24	19	43
	Mandibular premolar	46	50	96
	Mandibular molar	16	20	36
	Total	214	220	434
WITH EARR	Maxillary central incisor	23	29	52
	Maxillary lateral incisor*	14	31	45
	Maxillary canine	20	22	42
	Maxillary premolar	50	29	79
	Maxillary molar	12	33	45
	Mandibular central incisor	24	17	41
	Mandibular lateral incisor	13	16	29
	Mandibular canine	17	14	31

To be continued...

Continuation of table II

Time 1	Time 2		Total
	WITHOUT EARR	WITH EARR	
Mandibular premolar	31	21	52
Mandibular molar	18	20	38
Total	**222**	**232**	**454**
Total	**436**	**452**	**888**

The incidence of OIEARR was not significantly associated with the following patient parameters: root shape, sex, age, treatment time, incidence of malocclusion. Nonetheless, a relationship was evident between OIEARR and the degree of tooth crowding for the mandibular incisors and canines (table III). The Little Irregularity Index had the lower value 3,20mm, the upper value 15,50mm, the average 7,1451 (SD 3,86998).

Table III – Logistic regression analysis showing the factors that most influence OIEARR

	B	E.P.	Wald	gl	Sig.	Exp(B)	95% C.I. to EXP(B)	
							Lower	Upper
Sex	-,168	,151	1,237	1	,266	,846	,629	1,136
Age	,098	,142	,480	1	,488	1,104	,835	1,458
Dental group			41,501	9	,000			
Maxillary lateral incisor	-,454	,351	1,666	1	,197	,635	,319	1,265
Maxillary canine	-,699	,353	3,929	1	,047	,497	,249	,992
Maxillary premolar	-,884	,314	7,909	1	,005	,413	,223	,765
Maxillary molar	-,606	,361	2,815	1	,093	,546	,269	1,107
Mandibular central incisor	-,418	,362	1,333	1	,248	,658	,324	1,339
Mandibular lateral incisor	-1,131	,358	9,966	1	,002	,323	,160	,651
Mandibular canine	-1,348	,357	14,277	1	,000	,260	,129	,523
Mandibular premolar	-1,627	,318	26,223	1	,000	,197	,105	,366
Mandibular molar	-,992	,357	7,707	1	,006	,371	,184	,747
Malocclusion			,005	2	,998			
Malocclusion (1)	-,011	,165	,005	1	,944	,989	,716	1,366
Malocclusion (2)	-,005	,197	,001	1	,979	,995	,676	1,464
Root form (1)	,493	,225	4,801	1	,028	1,638	1,053	2,545
Constant	,558	,320	3,041	1	,081	1,747		

Discussion

The incidence of OIEARR is cited as a common complication of orthodontic treatment [2, 17] and in this study it was present in all tooth types, which was consistent with a study that indicated it occurred in teeth submitted to orthodontic forces.

According to Levander and Malmgren [7], the diagnosis of OIEARR can be established after 6 months from the date of treatment, and if the patient didn't present OIEARR in this period, it will be difficult to present it in there maining treatment [4, 6]. We evaluated this hypothesis and showed that the clinical manifestation of OIEARR at time

1, tended to stay the same by the end of treatment. But, when observing by dental group, the maxillary lateral incisors went from 7 teeth without OIEARR in time 1 for 15 teeth in time 2, and the lateral incisors from 11 teeth for 18 teeth, being the last one statistically significant.

In the past, authors have attempted to determine whether the incidence of OIEARR of the incisors was indicative of OIEARR in other teeth [10]. In this study, OIEARR was evident in all teeth and approximately half of the maxillary canines had OIEARR, despite the lack of reports indicating maxillary incisor involvement at time 2, maybe because their single-rooted nature, and their role as supportive structures for the use of rubber bands during orthodontic treatment [16].

On the other hand the Little Irregularity index was positively related to the OIEARR, that is, the greater the initial dental crowding the greater the frequency of RR at the end of the treatment.

Cases involving EARR, of up to 3 mm in the apical third, should not warrant special care as they have low clinical significance and do not compromise the success of the treatment [17]. In this study, only 5% of the cases evaluated at time 1 (figure 3A), and 7% of the cases evaluated at time 2 (figure 3B) showed OIEARR equal to or greater than 3mm when incisor involvement was not evident, which was less frequent than other study.

The root form has also been cited as a predisposing factor to EARR; the blunt shape and the presence of root morphology with an apical bend or with an apical pipette are reportedly more susceptible to the incidence of resorption [15, 17]. Here, the apical root shape did not influence the prevalence and severity of OIEARR.

The prolongation of treatment was associated with a higher prevalence of OIEARR [9, 14]. Nonetheless, here, the duration of the treatment time had no influence on the incidence of OIEARR. Furthermore, malocclusion type and patient age had no influence on the incidence of OIEARR either.

Therefore, the acquisition of radiographs at regular intervals is a good precautionary measure since it is possible for OIEARR, over 3 mm, to occur even without the incidence of resorption in the incisors. It is not possible to reliably predict the risk of OIEARR prior to orthodontic treatment as appropriate risk stratification involves the use of radiographic controls during treatment [5, 15, 18].

Limitations

A comparative evaluation of most studies on OIEARR is difficult because the different methodologies and radiographic imaging modalities used. The ideal would be to use three-dimensional exams, but this becomes difficult due to the higher dose of radiation when compared to periapical radiography [11].

Another limitation of this study was we had patients with different malocclusion, it would be better to have just one kind of malocclusion to evaluate the OIEARR to avoid vies of different biomechanics.

Conclusion

Both null hypothesis was rejected, 1) because there was OIEARR in the other teeth despite it doesn't occur in the maxillary and mandibular incisor and 2) because there were teeth that did not present OIEARR at 6 months after the beginning of treatment and presented at the end.

After analyzing the results of this study, the orthodontists should consider the use of radiography not only for the maxillary and mandibular incisors, but also for all other teeth and should be careful with the use of radiography during evaluation of OIEARR.

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