LETTER TO THE EDITOR

EXTERNAL APICAL ROOT RESORPTION AMONG THE SAUDI POPULATION: A PROSPECTIVE RADIOGRAPHIC STUDY OF MAXILLARY AND MANDIBULAR INCISORS DURING ORTHODONTIC TREATMENT

I. ALSHAHRANI[1], M. AJMAL[2], T. ALAM[2], M. LUQMAN[2], M.A. KAMRAN[1] and H. AL MOHIY[3]

[1]Department of Paediatric Dentistry and Orthodontic Sciences, King Khalid University College of Dentistry, Abha, Saudi Arabia; [2]Department of Diagnostic Sciences, King Khalid University College of Dentistry, Abha, Saudi Arabia; [3]Department of Radiologic Sciences, College of Applied Sciences, King Khalid University College of Dentistry, Abha, Saudi Arabia

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To the Editor,

Resorption of roots is an inevitable and relatively common side effect of orthodontic tooth movement. The term 'orthodontically-induced inflammatory root resorption' (OIIRR) is mainly used in orthodontics to differentiate from other causes of root resorption in permanent teeth (1). External apical root resorption (EARR) is an undesirable sequel that can significantly compromise the success of orthodontic treatment. It is usually common in the apical region because of the concentration of orthodontic forces and an increased accumulation of stress at the root apex (2). It is believed to occur as a response to altered alignment of periodontal fibers at the apical end due to the presence of cellular cementum at the apex (with patent vasculature), rendering the periapical cementum more friable and susceptible to trauma and concomitant vascular stasis (3, 4). Although clinically inconsequential, a relatively small percentage of patients express EARR severe enough to cause undesirable and irreversible damage to the roots (5).

Orthopantomogram (OPG) and periapical views are the most widely used diagnostic technique. A two-dimensional image underrates the actual amount of root resorption as compared to computerized tomography (6). Despite limitations, the periapical paralleling technique is the most preferred because it has the most favorable benefit to risk ratio in detecting the degree of apical root material loss. It provides the most appropriate information with the least irradiation when used for teeth that are most likely to exhibit blunting of roots: maxillary and mandibular incisors. Also, distortion and superimposition errors are less as compared to the OPG or the lateral head film. Therefore, the purpose of this study was to measure the amount of EARR of maxillary and mandibular incisor teeth and to evaluate its clinical significance during 9 months of active orthodontic treatment.

MATERIALS AND METHODS

The study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, King Khalid University, Abha, Saudi Arabia (SRC/ETH/2018-19/024). The study sample consisted of a total of 320 teeth from 40 patients, recruited by convenience sampling, and divided into two groups with mean age 15.6 (range: 14-18) years. The patients undergoing treatment in the Department of Orthodontics were randomly selected and only

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Corresponding Author:
Dr Ibrahim Al Shahrani,
Department of Paediatric Dentistry and Orthodontic Sciences,
King Khalid University College of Dentistry,
Abha, Saudi Arabia
e-mail: resperioprof@gmail.com

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those cases of Angle Class I malocclusion with upper and lower anterior crowding were divided into two groups: Group 1 (n=20) extraction cases, and Group 2 (n=20) non-extraction cases. All patients' parents or guardians were required to sign informed consent.

Cases with a previous history of orthodontic or endodontic treatment involving incisors, cases with bimaxillary protrusion, impacted maxillary canines, traumatic injuries, crown or root fractures, genetic or developmental anomalies of teeth, severely dilacerated roots, congenitally missing laterals, incomplete root formation at the start of treatment, maxillary incisors with caries and/or periodontal disease and patients with systemic disorders, hormonal imbalance were duly excluded from the study.

All the patients were treated with pre-coated bracket pre-adjusted appliances (Roth brackets) with 0.022″ bracket slots and edgewise mechanics were used during the treatment. The archwire used initially was 0.013" Nickel-Titanium followed by 0.014 Ni-Ti, 0.018 Ni-Ti, and 0.016x 0.022 Ni-Ti wires. All the cases were treated by the same clinician to avoid inter-personnel errors.

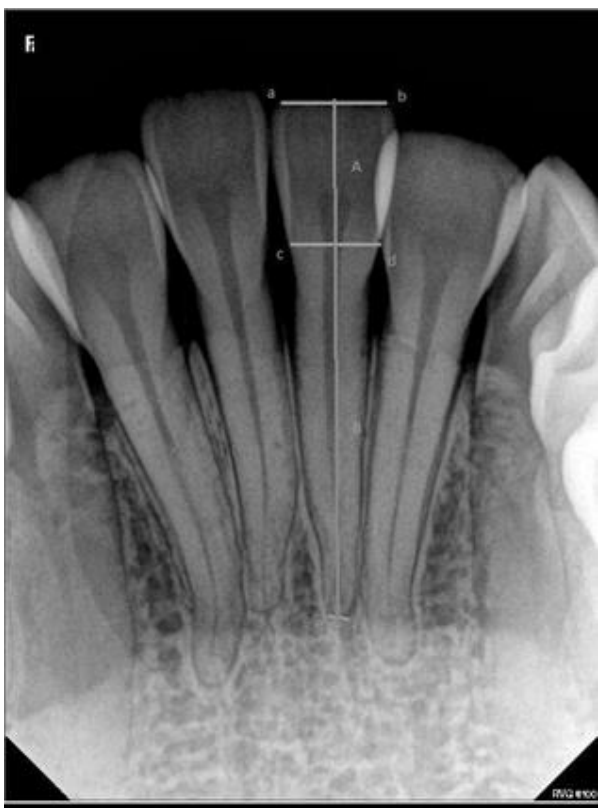

Fig. 1. *Mesial and distal edge points* ***a****) Mesial incisal edge point;* ***b****) distal incisal edge point;* ***c****) mesial cementoenamel junction point;* ***d****) distal cementoenamel junction point;* ***e****) mesial edge point of the apical foramen;* ***f****) distal edge point of the apical foramen;* ***A****) crown height;* ***B)*** *root length;* ***C****) (A+B) total tooth length.*

Periapical radiographs of both maxillary and mandibular incisors (right and left central and lateral incisors) were obtained at the following time-points: at the beginning of treatment (T0), 3 months (T1), 6 months (T2), and 9 months (T3) after the treatment, by using Dentsply Rinn XCP paralleling devices. Single rooted teeth were selected to avoid errors with multiple roots and differential resorption. Radiographic examination was conducted carefully to ensure good quality images for interpretation and determination of root length. Radiographs were analyzed by two observers using CS Imaging software 7.0.3 under 100% magnifications on an LCD monitor. EARR was measured and calculated in the following manner. Mesial and distal edge points (a, b, c, d, e, and f) were identified and marked at the region of incisal edge, cementoenamel junction and apical foramen respectively on both the pre-treatment and post-treatment periapical radiographs. Horizontal lines (a-b, c-d, and e-f) were drawn to connect the edge points and the central point on these lines were connected vertically. The distance between the horizontal lines (a-b and c-d) was measured as "crown height" (A) and the distance between the horizontal lines (c-d and e-f) was measured as the "root length" (B) (Fig. 1).

In the present study, the "root length" of each tooth was used to measure apical root resorption in millimeters (mm) using CS imaging software to a precision of 0.1 mm. The crown length (unaffected by EARR) was used as a reference to correct potential differences in geometric projection in subsequent radiographs. The averages of the pre-treatment and post-treatment crown lengths were computed by the following formula:

Cx = (C1+C2)/2, where Cx= average crown length, C1= pre-treatment crown length and C2= post-treatment crown length.

Following the calculation of the average crown length, the following formula was used to adjust the pre-treatment and post-treatment root lengths:

R1 (adjusted) = R1 x (Cx/C1) where R1= Average root length.

The resultant difference between the second (post-treatment) and first (pre-treatment) root length measurements were quantified as EARR. Root length assessment was carried out for a total of 320 radiographs by 2 examiners.

Statistical analysis

Data were analyzed using SPSS software (VERSION 20) and mixed-method ANOVA was used to analyze the data, and an interclass correlation coefficient analysis was carried out to assess the inter-examiner reliability. The independent variable in this analysis was time and dependent variable was the treatment (non-extraction and extraction) and its influence on root resorption. Mauchly's sphericity test was performed to validate the repeated measures analysis of variance.

Table I. *Mean root length of maxillary and mandibular incisors at different time intervals.*

(A) Maxillary incisors					
Group-1 (Extraction)	T0 (mean±SD)	T1 (mean±SD)	T2 (mean±SD)	T3 (mean±SD)	P-value
Tooth #11	16.56±0.27	16.09±0.56	15.77±0.69	15.73±0.66	0.00
Tooth #12	16.56±0.27	16.06±0.56	15.71±0.71	15.68±0.68	0.00
Tooth #21	16.46±0.24	16.16±0.44	15.60±0.60	15.45±0.45	0.00
Tooth #22	17.11±0.34	16.35±0.37	16.00±0.43	15.90±0.41	0.00
Group-2 (Non-extraction)					
Tooth #11	16.66±0.42	15.76±0.43	15.36±0.69	15.32±0.49	0.00*
Tooth #12	16.77±0.63	15.89±0.59	15.57±0.61	15.42±0.59	0.00*
Tooth #21	16.77±0.54	15.80±0.52	15.36±0.66	15.30±0.59	0.00*
Tooth #22	17.25±0.59	16.43±0.68	15.95±0.75	15.88±0.76	0.00*
(B) Mandibular incisors					
Group-1 (Extraction)					
Tooth #31	14.56±0.20	14.09±0.56	13.77±0.69	13.73±0.66	0.00*
Tooth #32	15.11±0.34	14.38±0.39	14.04±0.47	13.94±0.46	0.00*
Tooth #41	14.64±0.26	14.10±0.57	13.79±0.69	13.75±0.67	0.00*
Tooth #42	15.11±0.34	14.35±0.37	14.00±0.43	13.90±0.41	0.00*
Group-2 (Non-extraction)					
Tooth #31	14.76±0.60	13.85±0.70	13.47±0.77	13.43±0.77	0.00*
Tooth #32	15.28±0.70	14.48±0.88	13.91±0.70	13.85±0.67	0.00*
Tooth #41	14.80±0.76	14.04±0.98	13.49±0.77	13.44±0.75	0.00*
Tooth #42	15.29±0.74	14.53±0.93	13.92±0.67	13.83±0.59	0.00*

*NS: Non-significant; * Statistically significant at p<0.05*

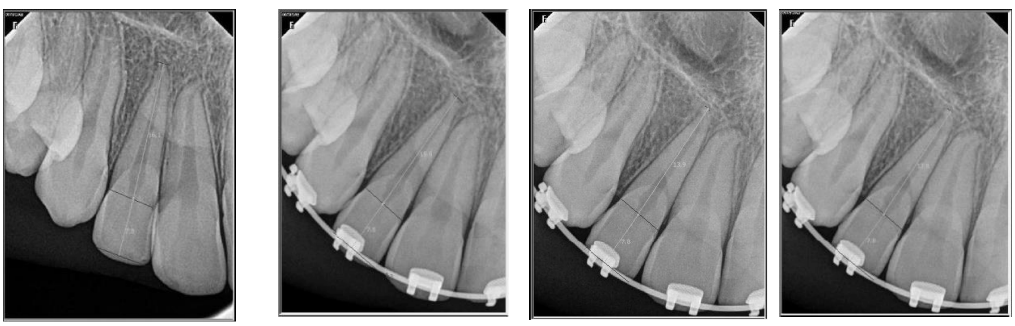

Fig. 2. *Periapical radiographs of a patient showing the progressive resorption in maxillary lateral incisor.*

RESULTS

A total of 320 teeth from 40 patients were divided into two groups of 20 cases each. The mean age of the subjects was 14-18 years and consisted of 20 females and 20 male patients. In the present study, there was progressive resorption of roots with the time that was significant for all the eight incisors.

In the maxillary central incisor teeth (11 and 21) there was significant resorption of roots observed in both the treatment groups with time (Mauchy's test of Spehericity<0.005, within-subjects effect <0.005, *F*- Value 268.625 for 11 and *F*- Value 155.457 for 21). In the maxillary lateral incisor teeth (12 and 22) there was significant resorption of roots observed in both the treatment groups with time (Fig. 2) (Mauchy's test of Spehericity<0.005, within-subjects effect <0.005, *F*- Value 268.625 for 12 and *F*- Value 168.503 for 22) (Table I).

In the mandibular central incisor teeth (31 and 41) with time there was significant resorption of roots observed in both the treatment groups (Mauchy's test of Spehericity<0.005, within-subjects' effect <0.005, *F*- Value 178.707 for 31 and *F*- Value 182.708 for 41). In the Mandibular lateral incisor teeth (32 and 42) with time there was significant resorption of roots observed in both the treatment groups (Mauchy's test of Spehericity<0.005, within-subjects effect <0.005, *F*- Value 282.105 for 32 and *F*- Value 150.907 for 42) (Table II).

Comparison of root resorption between treatment intervals (T0, T1, T2, and T3), showed that the amount of resorption was statistically significant for all maxillary and mandibular incisors except treatment interval T2-T3 for right maxillary lateral incisors (12) and mandibular central incisors (31 and 41), which was non-significant..

A comparison of mean root resorption among the groups based on extraction or non-extraction of cases revealed overall root resorption in both the groups. However, the extent of root resorption was relatively lesser in Group 1 but was statistically insignificant. The inter-examiner reliability and correlation between the two examiners was 97.5%.

DISCUSSION

The average apical root resorption in maxillary incisors, especially the maxillary lateral incisors, is found to be consistently more than any other analyzed tooth, followed by mandibular incisors and mandibular first molars (7, 8). In this study, there was a progressive resorption of roots over time that was significant for all the eight incisors and the extent of resorption was relatively more for lateral incisors, particularly the mandibular lateral incisors. It is reasoned that maxillary incisors are most subjected to orthodontic treatment either due to esthetic or functional reasons and the conical shape of these roots makes them susceptible to the resorption (9). Studies have also reported a consistent association between anatomical factors commonly seen in maxillary lateral incisors such as greater tooth length, narrow, pointed and deviated roots to exhibit more root resorption during orthodontic treatment (10).

Tooth extraction is a known risk factor for

Table II. *Maxillary and mandibular root resorption time trend analysis.*

	T0-T1		T0-T2		T0-T3		T1-T2		T1-T3		T2-T3	
Maxillary teeth	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value
Tooth #11	0.77±0.52	0.00*	1.23±0.69	0.00*	1,30±0.71	0.00*	0.77±0.52	0.00*	0.46±0.39	0.00*	0.70±0.14	0.00*
Tooth #12	0.68±0.67	0.00*	0.68±0.67	0.00*	1.07±0.78	0.00*	0.38±0.43	0.00*	0.43±0.42	0.00*	0.45±0.18	NS
Tooth #21	0.72±0.74	0.00*	0.60±0.67	0.00*	1.02±0.77	0.00*	0.48±0.42	0.00*	0.46±0.42	0.00*	0.67±0.14	0.00*
Tooth #22	0.79±0.81	0.00*	1.20±0.90	0.00*	1.29±0.88	0.00*	0.41±0.30	0.00*	0.30±0.32	0.00*	0.82±0.20	0.01*
Mandibular teeth	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value	Mean±SD	P-value
Tooth #31	0.69±0.05	0.00*	1.04±0.76	0.00*	1.08±0.74	0.00*	0.35±0.37	0.00*	0.39±0.03	0.00*	0.04±0.01	NS
Tooth #32	0.76±0.05	0.00*	1.22±0.06	0.00*	1.29±0.06	0.00*	0.45±0.03	0.00*	0.53±0.04	0.00*	0.07±0.16	0.00*
Tooth #41	0.64±0.63	0.00*	1.08±0.07	0.00*	1.12±0.06	0.00*	0.43±0.04	0.00*	0.47±0.04	0.00*	0.04±0.01	NS
Tooth #42	0.77±0.08	0.00*	1.24±0.09	0.00*	1.33±0.09	0.00*	0.46±0.04	0.00*	0.56±0.05	0.00*	0.09±0.02	0.00*

*NS: Non-significant; * Statistically significant at p<0.05*

EARR during orthodontic tooth movement because extraction cases require longer treatment time and are associated with increased and/or extensive movements and retraction of the apex. In the present study, overall root resorption was appreciated in both extraction and non-extraction cases in respect to both time and time intervals. However, the extent of root resorption was relatively lesser in Group 1 but was statistically insignificant. This is in sharp contrast to various studies that have noted more severe EARR among extraction cases (11, 12). This contrasting finding could be due to mechanisms that are likely to be independent of known factors causing EARR or due to genetic causes.

Our study demonstrated EARR in almost all the teeth expressed as root shortening. This does not mean 100% root resorption in our study because none of them demonstrated EARR more than 2 mm, as we sought to identify change in root length as expressed only as a slight change in apical contour with/without actual root shortening as a result of resorption, whereas few authors consider EARR only when root resorption of more than 4mm or 1/3 of the original root length occurs, which essentially means that any EARR of less than 4 mm could be a transient change involving remodeling of roots during active tooth movement.

It should be noted that root resorption associated with orthodontic treatment ceases with the termination of active treatment and usually does not affect the functional capacity or periodontal integrity of the teeth. Considering the consistent occurrence of EARR, progress radiographs obtained every 3-months during treatment is of great clinical significance in identifying EARR early in the process so that the orthodontist takes necessary precaution to reduce the extent of resorption.

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