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Risk factors associated with external apical root resorption of the maxillary incisors: a 15-year retrospective study

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Aim: To determine the possible risk factors for external apical resorption (EARR) of the maxillary incisors.
Methods: Panoramic radiographs of 132 orthodontic patients with a mean age of 16.9 ± 3.6 years were selected from two practice centres in Tehran. The radiographs were taken between 1990 and 2005 and 63.6% of the subjects were female. Mean, standard deviation and distribution of EARR for various variables were assessed. Prevalence significance, as well as differences between frequency distributions of clinical EARR (≥ 1.2 mm) between genders, treatment plans (extraction/non-extraction), initial overjet and overbite magnitude, and incisor types (centrals/laterals) were evaluated by the chi-squared test. The mean resorption rates on central and lateral incisors were compared using the independent-samples *t*-test. Associations between EARR with the age, duration of treatment, pretreatment overjet and overbite were assessed by the Pearson's correlation test. The reliability of the method was determined by remeasuring 117 randomly selected incisors and determining the associations between both sets of measurements with the Pearson's correlation coefficients.
Results: The prevalence of EARR, and clinical EARR (≥ 1.2 mm) were 91.8% and 44.78% respectively. The average of EARR was 1.377 ± 1.214 mm, or 8.165 ± 8.021% of pretreatment root lengths. The prevalence of clinical EARR was significantly higher in extraction cases, cases with greater initial overjet and on lateral incisors. Using the *t*-test, significant differences ($p < 0.05$) were observed between the extent of resorption between genders (higher in females), treatment plans (higher in extraction cases) and incisor types (greater on lateral incisors). Longer treatment times and excessive initial overjet were correlated with higher EARR levels ($p < 0.05$, $r < 0.2$).
Conclusions: Factors related to premolar extraction, initial ovejet size, treatment time and being female may be correlated with higher EARR. Clinically significant resorption did not occur more in females.
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Introduction

External apical root resorption (EARR) is a common and unwelcome iatrogenic sequela of orthodontic treatment.[1] The occurrence of EARR following orthodontic treatment has been reported to be greater than 90% in histologic studies, whereas, lower prevalence rates have been observed by diagnostic radiographic methods.[1,2] The amount of root shortening attributed to EARR varies from 0.20 mm to a maximum of 3 mm.[3,4] Although a number of factors have been cited as risks for EARR (e.g., genetics,[1,2,5] thyroid disorders,[1,2,6] hormonal imbalances,[2] allergies,[1,7] previous root canal or orthodontic therapy,[1,2,6] periodontitis,[1,2,6] trauma,[1,2] and oral habits),[7] the evidence is by no means clear.[1,2,8] Nishioka et al.[7] stated that root anomalies and allergies might correlate to higher rates of EARR; however, no significant associations were identified in patients experiencing apical resorption together with asthma, gingivitis, trauma, or oral habits. Baumrind et al.[9] regarded treatment duration, gender and apical displacement as predictors of EARR. Brin et al.[10] observed significant correlations between apical root resorption with elapsed treatment time and overjet but not with previous trauma. In addition, a meta-analysis performed by Segal et al.[11] confirmed the role of increased treatment time in root resorption. Mohandesan et al.[12] concluded that premolar extraction, gender and treatment time were significantly associated with EARR, but Årtun et al.[13] failed to find any significant links to treatment duration. A further systematic review carried out by Weltman et al.[2] concluded that comprehensive orthodontic treatment coupled with heavy or intrusive forces might increase the incidence and intensity of EARR, while previous trauma and root morphology were unlikely causative factors. Consistent in the literature is the tenuous association and wide variation in response to overjet,[10,14-20] overbite,[14,21] treatment duration,[3,9,12,13,17,18,20,22-26] extraction/non-extraction,[7,8,12,15,17,18,21,25,27,28] age,[6,16,17,21-23,25,27] and gender.[3,4,9,12,25,29]

The aim of the present study was to assess the prevalence of EARR occurring in the maxillary incisors in a group of Iranian orthodontic patients and to determine the possible relationship of a number of occlusal and treatment factors.

Materials and methods

The subjects in this cross-sectional study were 132 orthodontic patients treated in a private dental surgery (N = 54) and a university clinic (N = 78) between 1990 and 2005. The mean pretreatment age of the subjects was 16.9 ± 3.6 years (Range: 13-24 years); 63.6% were female. All subjects were treated with fixed appliances for 28.54 ± 9.71 months (Range: 11-70 months). In 48.5% of the subjects, two upper premolars were extracted while the remainder were treated by a non-extraction treatment plan. The mean pretreatment overjet and overbite were 2.81 ± 2.69 mm (Range: -4 mm to 16 mm) and 1.864 ± 2.452 mm (Range: -10 mm to 8 mm), respectively.

Following ethical approval, the subjects' pretreatment and post-treatment panoramic radiographs were examined. The radiographs obtained from the university clinic were taken on the same panoramic unit (Odontorama PC, Trophy Radiologie, Marne La Vallee, France), but those obtained from the private dental surgery were taken by units in various and different radiology clinics in Tehran. The details of these units were not available. Of the 416 records obtained, 284 were not considered in accordance with exclusion criteria which comprised inadequate patient information, poor radiograph quality, the presence of pretreatment root resorption, crown fracture, impacted canines, cysts or tumours in the anterior maxilla, dental anomalies or root elongation observed in the films. Also excluded were patients of an age greater than 24 years or less than 13 years, the presence of trauma history, periodontal disease, a history of previous orthodontic treatment, oral habits, known systemic disorders, syndromes, or recorded allergies. The remaining 132 pairs of pre- and post-treatment radiographs were scanned with a ScanMaker 6400XL (Microtek, Husinchu, Taiwan) at 300 dpi spatial resolution.

Of the 264 panoramic radiographs examined, 77 incisors out of a potential total of 528 were excluded because 69 had illegible landmarks, 4 had been root-filled and 4 incisors were missing. Of the final sample, 53.22% were central incisors (right: 26.16%; left: 27.06%) and 46.78 were lateral incisors (right: 22.39%; left: 24.39%).

Determination of EARR

EARR was assessed by comparing the lengths of the roots of the upper incisors on the pre- and post-treatment panoramic radiographs. The measurements were corrected for differences in the X-ray source, film or patient's head position by using radiographic measurements of crown length.

The enhancement tools of an image editing program were used to measure the lengths of the roots and crowns on the pre- and post-treatment radiographs (Figure 1). Changes in crown length were used to calculate a correction factor (CF),[3,10,12,14,16,20] where CF = crown length on pretreatment image (C_1) / crown length on post-treatment image (C_2). Changes in root length change (RLC) were then calculated for each maxillary incisor using the following formula, $RLC = R_1 - (R_2 \times CF)$. The percentage changes in the root lengths of the maxillary incisors were calculated.[28,29] Using Copeland and Green's criteria, EARR ≥ 1.20 mm was regarded as clinical EARR.[12,30]

The scanned images of the incisors were remeasured by the same observer one week later and the means

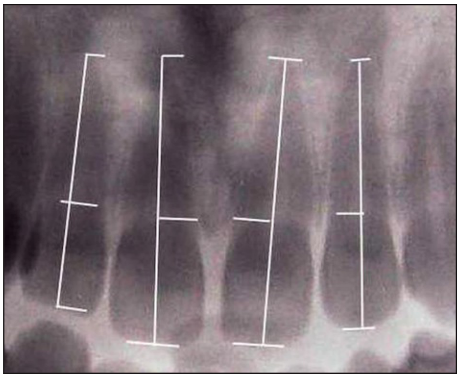

Figure 1. Identifying the landmarks and long axis. Image colours have been reversed for the observer's convenience.

of the measurements were used in all subsequent calculations. Data for the maxillary right and left central incisors, and the maxillary right and left lateral incisors were combined.

Reliability of the method

To assess the reliability of the method, radiographs of 30 randomly selected subjects were remeasured three weeks later and the Pearson's correlation coefficients calculated. The correlation between the two sets of measurements was 0.93 ($p < 0.05$), which was regarded as acceptable.

Statistical analysis

The distributions of EARR in the groups (gender, treatment plan, overbite, overjet, and incisor types) were calculated and compared with chi-squared tests. The unpaired *t*-test was used to compare the resorption rates in males and females, the influence of the treatment plan on EARR (extraction vs non-extraction) and tooth type (central and lateral incisors). Associations between root resorption and treatment duration, age, pretreatment overjet and overbite were assessed with the Pearson's correlation coefficients. The significance level for all tests was set at $p \leq 0.05$.

Results

The distributions of clinical root resorption (RLC ≥ 1.20 mm) in males and females, in subjects treated with premolar extraction and non-extraction treatment plans, with different extents of overbite and overjet and in the maxillary central and lateral incisors (Table I). There were no significant differences in the distributions of gender and overbite on the occurrence of clinical EARR. The distributions of extraction/non-extraction treatment plan ($p = 0.009$), overjet ($p = 0.021$) and incisor type ($p = 0.000$) were significantly different.

A significantly greater number of maxillary lateral incisors revealed evidence of root resorption compared with central incisors. The mean root resorption was 1.377 ± 1.214 mm, or 8.165 ± 8.021% of each incisor's pretreatment root length (Table II). According to the independent-samples *t*-test and comparing means of EARR (Table II), the lateral incisors underwent significantly higher resorption rates compared with central incisors. The probability value for RLCp became 0.000. The *t*-test showed a significant correlation between a higher resorption rate and the female gender (Table II). EARR was significantly greater in extraction cases (Table II). According to the correlation test, the pretreatment overjet and treatment time were correlated with the root resorption (Table III).

Discussion

Longer treatment time, pretreatment overjet and premolar extractions were correlated with greater EARR and greater prevalence of clinical EARR. Root resorption occurred more on lateral incisors, and overbite and pretreatment age factors were not significantly correlated with EARR. Being female did not significantly affect the prevalence of clinical EARR, but was associated with its severity. When incisor EARR was noted in females, it occurred to a greater extent.

The maxillary incisors were selected for examination in the present study because of their apparent increased susceptibility to resorption and that resorption might be observed more conveniently.[1,2,6,31] The finding that lateral incisors underwent greater resorption was consistent with the results of previous studies.[1,2,6,8,27] This is likely to be a multifactorial phenomenon related to morphological features involving apical curvatures, different root shapes and root surface areas. When applying orthodontic forces equally to all teeth, a tooth with a smaller root surface area bears relatively higher pressure.

Table I. Percentage of subjects with clinical root resorption (RLC ≥ 1.20 mm).

Variable		RLC ≥ 1.2 mm	p*
Gender	Male	33.3	0.360
	Female	41.1	
Treatment plan	Extraction	49.2	**0.009**
	Non-extraction	27.9	
Overbite	≥ 2 mm	44.6	0.657
	1 - 2 mm	30.3	
	0 - 1 mm	38.2	
	< 0 mm	41.7	
Overjet	≥ 3 mm	48.6	**0.021**
	1 - 3 mm	36.1	
	0 - 1 mm	34.8	
	< 0 mm	10.0	
Incisor	Central	32.9	**0.000**
	Lateral	58.3	

*Chi-squared test
Significant values in bold

Table II. Comparisons of root resorption as a percentage of total root length (RLCp).

Variable	Mean ± SD (Per cent)	p*
Central	6.39 ± 6.80	**0.000**
Lateral	7.15 ± 7.15	
Male	7.25 ± 9.02	**0.006**
Female	8.66 ± 7.38	
Extraction	9.89 ± 7.74	**0.000**
Non-extraction	6.45 ± 7.94	

*Unpaired t-test
Significant values in bold

Table III. Associations between RLCp and four risk factors.

Variable	r	p value
Age	.043	0.382
Duration	.131	**0.015**
Overjet	.148	**0.022**
Overbite	.025	0.595

r = Pearson's correlation coefficient.
Significant values in bold

Previous studies have also reported that females experience significantly higher EARR rates.[3,4,9,25] This has been attributed to the maturation of root apices of female subjects at a younger age and increased sensitivity to orthodontic trauma due to female hormonal differences.[3,4,25] Higher levels of EARR related to premolar extraction have also been noted by previous studies.[8,12,15,17,18,21,27,28] It is possible that, following extraction, teeth may move greater distances and perhaps at a greater rate and therefore become more susceptible to increased periodontal hyalinization.[1,8,15] Although researchers have stated that patient age may affect resorption,[6,17,22] the present study is consistent with others who did not determine a significant association.[16,17,22,23,25,27] From the present and supporting studies, it may be expected that more resorption may have occurred on other root areas rather than at the apex. This would leave little radiographic sign until it became significant.[22]

The current study observed a clear and significant correlation between longer treatment time and higher resorption levels (p = 0.015, Table III). As reported by previous studies,[3,9,12,18,20,23-25] this might result as a consequence of extended exposure to presumed causative factors.[13] Nevertheless, the correlation coefficient of RLC percentage (RLCp) was very small (=

0.131), indicating the non-linearity of this relationship. Considering that a meaningful correlation value should be greater than 0.4, this was a minor finding and treatment time therefore considered to have a low relevance.[13] Excessive pretreatment overjet was significantly related to increased EARR[10,14,15,17,18,20] and greater torque requirements may be a possible reason.[14] Harris and Butler[19] claimed that the magnitude of the pretreatment overjet was the best and the only predictor of the likelihood of EARR. However, the correlation coefficient indicated by the present study was very small (= 0.148) which suggested a non-linear correlation. The low correlation might be related to the low mean and standard deviation of the initial overjet, indicating low disparity across the sample and possibly reduced overjet impact. In agreement with other studies, no significant evidence was seen to associate overbite with resorption.[14,21] Although controversy exists, certain dental movements such as incisor intrusion might increase EARR risk.[1,2,6,8]

The assessment of EARR from radiographs remains controversial and concerns arise from differences in radiography technique (panoramic, cephalometry, periapical),[22,25,30] treatment or follow-up times and differences in sample size,[14] the nature of the investigator's experience and care, and finally, differences in classification methods (quantitative/qualitative, or different thresholds for determining clinical resorption).[22,23,27] In addition, comparative studies examining treatment plans (extraction/non-extration),[7,25] treatment duration[17,22,26] and overjet and overbite[14] had not used radiographic assessment correction factors, nor accuracy features of image-editing programs. Uncertainties and EARR outcome distortions may be produced by, as yet, unidentified factor(s).[1]

The present study was constrained by the limitation of 2D radiographic images representing 3D objects, as well as measuring bias, labiolingual apical curvatures, and lower reliability of panoramic images compared with periapical images.[32] However, it has been reported that periapical and panoramic images may be similarly accurate in the anterior maxilla.[31] As another limitation, it was unlikely that radiologists would be able to take both radiographs in exactly similar manner (e.g. head position).[33] The films obtained from private surgeries were taken using a variety of radiographic systems which had the potential to compromise validity. However, excluding images of low-quality, as well as using a correction factor was considered to increase the reliability and normality of the measurements.[3,10,12,14,16,20] Of concern was the possibility that several patients with traumatised incisors, but appearing intact, may have forgotten their trauma history. Incisor crown height may be shortened by a fracture which therefore rendered the correction factor inaccurate. As there was awareness of this possibility, the films were carefully scrutinised for visible and obvious fractures.

The exact type of fixed orthodontic technique and dental movements were unknown. Much has been reported on the influence of various appliances and their effect on EARR[1-4,7,8,10,12-14,21,27,29] and this knowledge in the present study may have been useful in evaluating the effects of intrusion or other particular incisor movements.

The strengths of the present study consisted of the use of a correction factor and higher accuracy of panoramic images compared with cephalometric films.[7,25] RLCp, which was calculated per length of individual roots, may be more accurate than RLC.[28,29] The reproducibility of measurements was excellent (93%).[12] The digital zoom of the image editing program increased accuracy while reducing eye fatigue.[13] Moreover, mean treatment time was greater than previous studies.[12,13]

Conclusions

A considerable clinical experience of EARR was observed. Within the limitations of the present study, females, premolar extractions and lateral incisors were associated with a greater severity of EARR, but overbite and age were not. Clinical EARR was not more frequent in females compared with males. The associations between EARR with overjet and treatment duration were statistically significant but not linear, and not necessarily clinically meaningful.

Monitoring periapical radiographs of maxillary incisors in cases of large overjet, longer treatment time and maxillary premolar extraction can be useful in early detection of external apical root resorption.

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