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COMPARISON BETWEEN THE EXTENT OF APICAL ROOT RESORPTION IN VITAL AND ENDODONTICALLY TREATED TEETH FOLLOWING ORTHODONTIC TREATMENT: A PROSPECTIVE SPLIT-MOUTH STUDY

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ABSTRACT

Aim: The aim of this study was to assess the amount of external apical root resorption (EARR) in endodontically treated anterior teeth and their vital counterparts following orthodontic treatment, using Cone-Beam Computed Tomography (CBCT scans.

Methodology: This prospective split-mouth study consisted of 25 patients that were selected from the outpatient clinic of the department of Orthodontics, Cairo University. The patients had full permanent dentition and Class I occlusion with moderate crowding. They were non-syndromic with no history of orthodontic treatment. Each patient included had at least one maxillary anterior endodontically treated tooth (ETT) and its vital contralateral tooth (VCT) acted as the control. There was no difference in root lengths before orthodontic treatment. Non-extraction orthodontic treatment was done for the patients. CBCT scans were taken for each patient before (T0) and immediately after orthodontic debonding (T1). Teeth lengths at T0 and at T1 were measured in order to evaluate the amount of root resorption.

Results: After orthodontic treatment, tooth lengths measured in the ETT were significantly higher (23.83±1.99) than those of their VCT (23.12±1.80) ($p<0.001$). When comparing endodontically treated and vital teeth, there was a significant reduction of measured length after orthodontic treatment ($p<0.001$). Apical root resorption measured in VCT was significantly higher (1.69±1.14) than in ETT (1.01±0.63) ($p<0.001$).

Conclusion: Endodontically treated teeth (ETT) showed significantly less EARR following orthodontic treatment than their vital contralateral teeth (VCT). This suggests that probable complication of root resorption in root-filled teeth is not regarded as an important consideration during orthodontic treatment planning.

KEYWORDS: Apical root resorption, root canal treatment, endodontic treatment, orthodontic treatment

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INTRODUCTION

External apical root resorption (EARR) is a serious and irreversible occurrence characterized by a permanent loss of hard tissue on the root apex of a tooth.[1] It occurs due to clast cellular activity and is identified radiographically by shortening of the root from the apex.[2] Its etiology is multifactorial. It may occur from infection, pressure, trauma or orthodontic treatment.[3] It is a significant complication of orthodontic treatment and has high incidence levels.[4-6] Massler and Malone [7] reported EARR incidence rate of 86.4% in orthodontic patients. Mild EARR does not affect the tooth function or longevity, however in some cases of severe EARR, where more than one-third of the original root length is lost, orthodontic treatment should be discontinued. [5,8]

Mechanical factors related to orthodontic force direction, duration and magnitude contribute to EARR. [9] Several studies have found a relationship between orthodontic treatment and root resorption, whereby age, sex, duration of orthodontic treatment, magnitude of orthodontic force,tooth extraction, type and distance of tooth movement may significantly contribute to apical root resorption.[10-15] Biological factors may also contribute to apical root resorption and include presence of periapical pathology, traumatic injury, root morphology and genetic predisposition as well as individual susceptibility. [9,16-19]

Many studies have questioned the effect of pulpal status on root resorption and whether endodontically treated teeth (ETT) may differ in terms of root resorption compared to vital teeth after being subjected to orthodontic forces. There has been a lack of consensus among earlier clinical studies with respect to the level of EARR following orthodontic treatment in root-filled and contralateral vital teeth. [20] Some studies found no significant differences in the amount of root resorption between vital and contralateral ETT. [20, 21,22] Others revealed less root resorption in root-filled teeth compared to their vital contralateral teeth. [23,24] In contrast, a higher incidence of root resorption was reported in ETT in an uncontrolled clinical study.[25]

The aim of this study was to investigate the prevalence and severity of EARR in endodontically treated teeth (ETT) compared to vital contralateral teeth (VCT) following orthodontic tooth movement using cone beam computed tomography (CBCT).

MATERIALS AND METHODS

Ethics Approval

This prospective study was approved by the Research Ethics Committee of the Faculty of Dentistry, Cairo University. Written informed consent was signed by the patients after they had received detailed information about the planned study.

Initially, 400 patients above 18 years old seeking orthodontic treatment were randomly screened and clinically examined at the outpatient clinic of the department of Orthodontics, Faculty of Dentistry, Cairo University for the presence of or the need to undergo endodontic treatment for at least one maxillary anterior tooth, full permanent dentition and having Class I malocclusion (Angle Class I canine and molar relationship) with moderate dental crowding. Any necessary endodontic treatment was performed by a trained endodontist and the quality was checked for any previous endodontic treatment. A total of 25 (11 males, 14 females) patients with a mean age of 23.28±3.54 years were included in the study and had endodontically treated maxillary anterior teeth (ETT, n=25) and a vital contralateral tooth (VCT, n=25) available as control group that also fits the inclusion criteria. A total of 50 teeth were investigated.

Sample Size Calculation

A power analysis was designed to have adequate power to apply a two-sided statistical test of the null hypothesis that there is no difference between different tested groups regarding root resorption. By adopting an alpha (α) of (0.05) and a beta (β) level of (0.2) (i.e. power=80%); the total required sample size (n) was found to be (21) cases. Sample size was increased to compensate for possible dropouts during different follow up intervals to be (25) cases. Sample size calculation was performed using R statistical analysis software version 4.3.2 for Windows*.

The inclusion criteria were:

1- Permanent dentition.

2- Root-filled maxillary anterior teeth with good quality endodontic treatment, vital contralateral teeth with radiographically normal periapical structures (intact lamina dura and periodontal ligament space) and no clinical signs or symptoms/untreated dental caries or history of trauma.

3- Intact incisal edges confirmed by stone model.

4- Absence of craniofacial syndromes.

5- No history of orthodontic treatment.

The exclusion criteria were:

1- Root Fractures

2- History of trauma

3- Ankylosed or impacted teeth

4- Teeth with periapical pathology

5- Periodontal disease

6- Patients with teeth grinding habits

7- History of orthodontic treatment

8- Craniofacial syndromes or skeletal deformity

9- Temporomandibular joint disorders

Complete orthodontic records including CBCT images were acquired for all participants before and immediately after orthodontic appliance debonding to avoid any image distortion due to metal orthodontic brackets. All the scans were taken using the CBCT scanner Planmeca Promax® 3D Mid (Planmeca, Helsinki - Finland), and the exposure parameters were set to 90 kVp and 8 mA, with an exposure time of 10.5 and voxel size of 0.4mm3 with the patients seated stationary in an upright position and the Frankfort horizontal plane parallel to the ground. Non-extraction orthodontic treatment was provided for all the patients using conventional fixed orthodontic appliance (Roth prescription, slot size 0.022 x 0.028 inch (Ormco, West Collins, Ca-Usa). Dental crowding was relieved by interproximal stripping and dental arch expansion. All patients were treated with the archwire sequence starting 0.016-in nickel titanium reaching 0.019 x 0.025-in stainless steel (6 weeks for each archwire). Treatment duration lasted for an average of 20 months.

Utilizing the CBCT software, the ETT and VCT lengths were measured before orthodontic treatment and immediately after orthodontic debonding from the CBCT images using the axial guided navigation technique (Figure 1). A fully reconstructed three-dimensional image with sagittal, coronal and axial slices was generated. The teeth were measured in their maximum linear lengths from a point on the incisal edge to another point at the root apex. This was done using the most suitable filter that enabled the ideal visualization such bone filter, grey scale filter and teeth filter. For slanted apical root resorption, 3 measurements were taken for the axial length and the mean value was calculated. Measurements were recorded in tenths of millimeters. The reference points and lines for measurements pre (T0) and post-

* R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

orthodontic treatment (T1) are shown in Figures 2 and 3. The amount of EARR for ETT and VCT was calculated as the difference in tooth length as follows: (Tooth length before orthodontic treatment - Tooth length after orthodontic treatment). All measurements were performed by an orthodontist and 10 were randomly repeated after 2 weeks by the same operator to assess intra-observer agreement and evaluate measurement reliability.

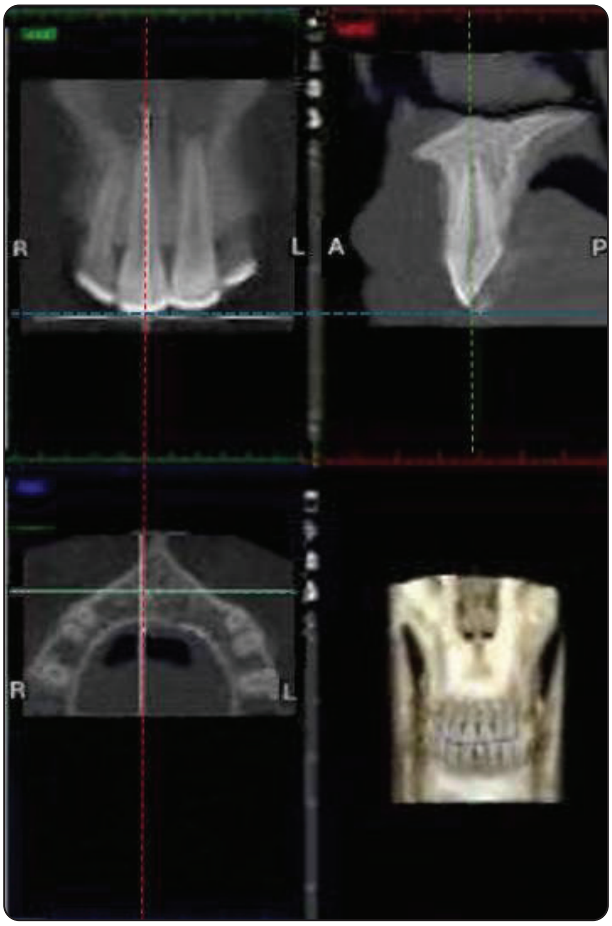

Fig. (1): Volumetric orientation to ensure the axial slice is perpendicular to the incisor long axis. Rotation of the coronal and sagittal slices was done to ensure that tooth length measurements were made parallel to the long axis of the incisor for accuracy and consistency. The length of the tooth was measured as the maximum linear distance between the incisor edge and root apex parallel to the long axis of the tooth.

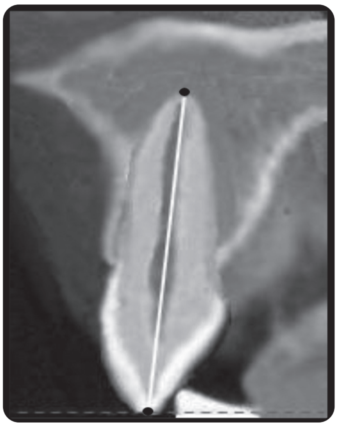

Fig. (2a): Sagittal section: Maxillary central incisor (MxCI)-Vital contralateral tooth length at T0 (VCT-T0)

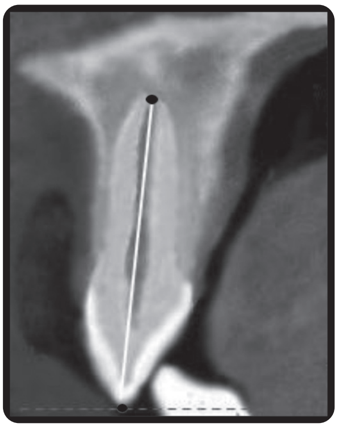

Fig. (2b): Sagittal section: Maxillary central incisor (MxCI)-Vital contralateral tooth length at T1 (VCT-T1)

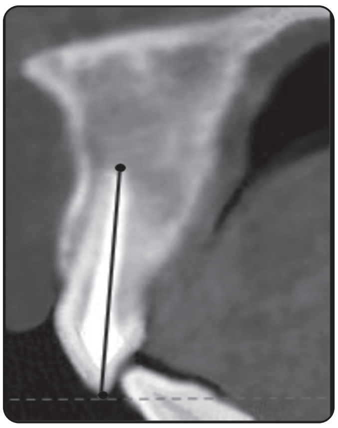

Fig. (3a): Sagittal section: Maxillary central incisor (MxCI)-Endodontically treated tooth length at T0 (ETT-T0)

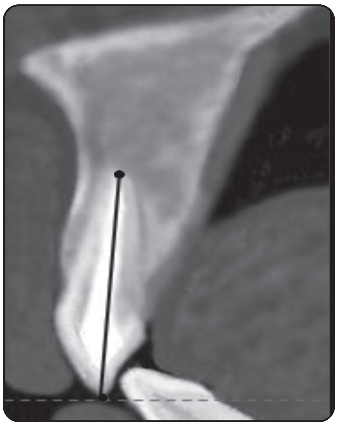

Fig. (3b): Sagittal section: Maxillary central incisor (MxCI)-Endodontically treated tooth length at T1 (ETT-T1)

STATISTICAL ANALYSIS

Categorical data were presented as frequency and percentage values. Numerical data were represented as mean and standard deviation (SD) values. They were tested for normality by viewing distribution and using Shapiro-Wilk's test and were found to be normally distributed. They were analyzed for different comparisons using paired t-tests. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.4.0 for Windows (R Core Team (2024). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.)

RESULTS

This split-mouth study was conducted on 25 patients (11 males (44%) and 14 females (56%)) with a mean age of (23.28±3.54) years. Every patient had or needed endodontic treatment for at least one maxillary incisor tooth (total n=25) while its contralateral tooth remained vital (total n=25, 50%) and served as control. The total number of teeth under investigation was 50 teeth (n=50). Non-extraction orthodontic treatment was performed for all patients. Tooth lengths of both endodontically treated teeth (ETT) and their respective vital contralateral teeth (VCT) were measured and compared before and after the orthodontic treatment using CBCT. The amount of apical root resorption (ARR) was also evaluated and compared between both groups of teeth. The mean treatment duration was 20.6±4.5 months.

Demographic data are presented in Table (1). Tooth length data are presented in Table (2) and in Figures (1) to (3). Before orthodontic treatment, there was no significant difference between the lengths measured in both teeth (ETT (24.84±1.91) mm and VCT (24.81±1.92) mm ($t=0.96$, $p=0.347$). After treatment, lengths measured in ETT (23.83±1.99) mm were significantly higher than those of their VCT (23.12±1.80) mm ($t=3.45$, $p<0.001$). Within ETT and VCT, there was a statistical significant reduction of measured length after treatment ($t=7.99$, $p<0.001$) and ($t=11.48$, $p<0.001$), respectively. Apical root resorption (ARR) measured in VCT (1.69±1.14) mm was significantly higher than in ETT (1.01±0.63) mm ($t=3.89$, $p<0.001$).

Table (3) and Figure (4) present associations with gender. No statistical significance was found for any of the measurements between males and females. For both endodontically treated (ETT) and vital teeth (VCT), males had slightly longer pre-treatment tooth lengths than females (24.96 ± 2.01 mm; 24.73± 1.34 mm; $p=0.231$) and (24.98 ± 2.02mm ; 24.69 ± 1.37mm; $p=0.321$) respectively with no statistical significance. Regarding post-treatment tooth lengths, no statistical significant difference was found between males and females within both groups of teeth. Regarding apical root resorption, in ETT males had less resorption (0.99 ± 0.55 mm) than females (1.02± 0.64 mm) respectively but it was not statistically significant ($p=0.216$). In VCT males had more apical root resorption (1.77±1.17mm) than females (1.64± 1.11mm) respectively with no statistical significance ($p=0.328$).

Correlations with other factors are presented in Tables (4) and (5). Pretreatment and post-treatment tooth lengths as well as external apical root resorption were not significantly correlated with age of the patient (Table 4). EARR was not significantly correlated with treatment duration or pre-treatment tooth lengths (Table 5).

TABLE (1) Demographic data

Parameter		Value
Sex [n (%)]	Male	11 (44%)
	Female	14 (56%)
	Age (Mean±SD) (years)	23.28±3.54
Number of teeth {n (%)}	Maxillary incisor endodontically treated tooth (ETT)	25 (50%)
	Maxillary incisor vital contralateral tooth (VCT)	25 (50%)

TABLE (2) Pre-treatment / post-treatment tooth lengths and EARR in ETT and VCT

Time	Tooth length (mm) (Mean±SD)		t-value	p-value
	ETT	VCT		
Before treatment	24.84±1.91	24.81±1.92	0.96	0.347
After treatment	23.83±1.99	23.12±1.80	3.45	<0.001*
t-value	7.99	11.48		
p-value	<0.001*	<0.001*		
Apical root resorption	1.01±0.63	1.69±1.14	3.89	<0.001*

**** Significant (p<0.05)***

EARR: External apical root resorption, ETT: Endodontically treated teeth, VCT: Vital contralateral teeth

TABLE (3) Pre-treatment / post-treatment tooth lengths and EARR in males versus females in ETT and VCT

Group	Measurement	Tooth length (mm) (Mean±SD)		t-value	p-value
		Male (n=11)	Female (n=14)		
ETT	Before treatment	24.96 ±2.01	24.73 ±1.34	1.68	0.231
	After treatment	23.97±1.09	23.71±1.61	1.51	0.145
	Apical root resorption	0.99±0.55	1.02±0.64	1.79	0.216
VCT	Before treatment	24.98±2.02	24.69±1.37	1.23	0.321
	After treatment	23.21±1.91	23.05±1.71	1.42	0.284
	Apical root resorption	1.77±1.17	1.64±1.11	1.00	0.328

**** Significant (p<0.05)***

TABLE (4) Correlations of Tooth lengths and EARR with patients' age.

		Correlation coefficient with age	
Group	Measurement	r-value	p-value
ETT	Before treatment	0.404	0.246
	After treatment	0.330	0.107
	Apical root resorption	0.130	0.534
VCT	Before treatment	0.404	0.246
	After treatment	0.434	0.137
	Apical root resorption	0.311	0.321

**** Significant (p<0.05)***

TABLE (5) Correlations of external apical root resorption (EARR) with treatment duration and pretreatment tooth length

	Endodontically treated teeth (ETT)		Vital contralateral teeth (VCT)	
Pretreatment tooth length	r-value	p-value	r-value	p-value
	0.41	0.82	0.33	0.76
Treatment duration	0.29	0.35	0.15	0.42

*** Significant ($p<0.05$)***

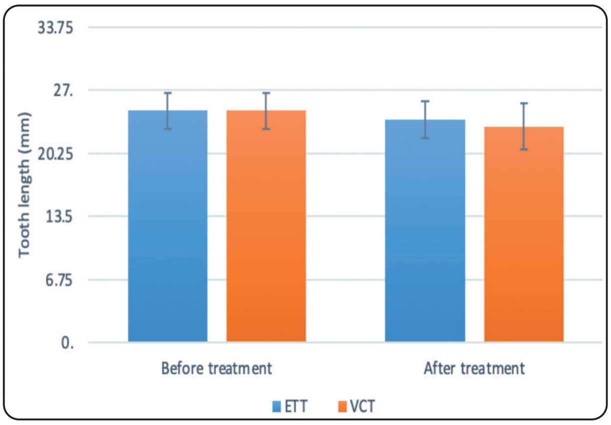

Fig. (1) Bar chart showing mean and standard deviation values (error bars) for tooth length in ETT and VCT

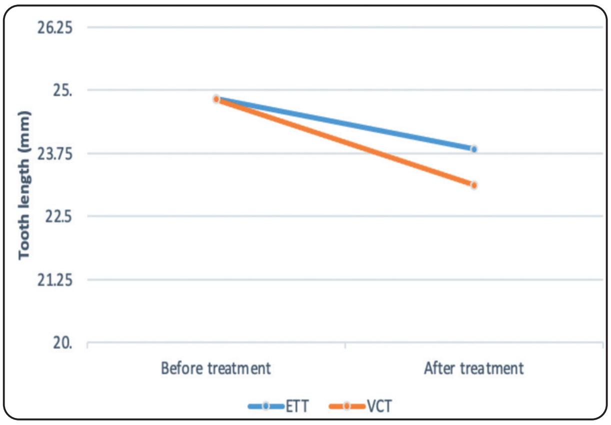

Fig. (2) Line chart showing pre-treatment and post-treatment mean tooth length in ETT as well as VCT

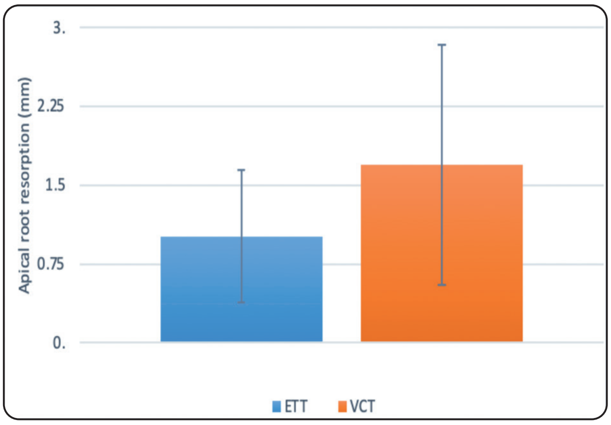

Fig. (3) Bar chart showing mean and standard deviation values (error bars) for EARR in ETT and VCT

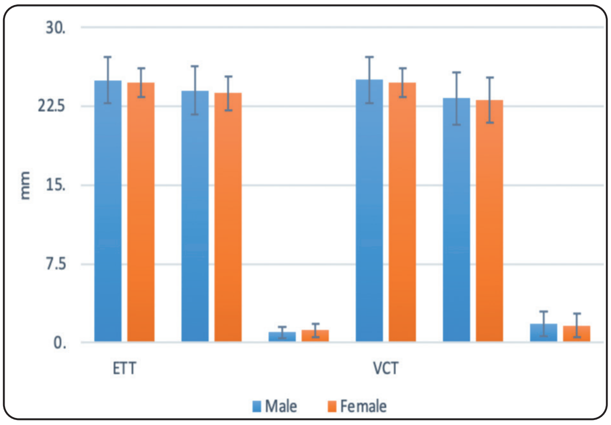

Fig. (4) Bar chart showing mean and standard deviation values (error bars) for tooth lengths and EARR for different genders.

DISCUSSION

EARR is initiated through contact between the root and the alveolar bone during orthodontic tooth movement. A relationship between EARR and pulp has also been reported.[26,27] Orthodontic tooth movement can cause damage to pulpal tissues. Due to connections between pulp vessels and alveolar bone vessels, apical vessels can be injured by heavy orthodontic forces. Moreover, pulpal disturbances result from stretching the apical vessel by light orthodontic tipping force due to decreased blood flow.[28,29,30,31] Previous studies have shown that the maxillary incisors are the most susceptible to EARR, followed by the mandibular incisors and first molars.[6,9,32,33]

CBCT scans have been utilized in this study as they provide a more accurate 3-dimensional image of root resorption along the root surfaces of anterior teeth [31,34,35] compared to conventional radiography such as panoramic and periapical x-rays which provide 2-dimensional images only thus can have limitations on the accuracy of detection and measurement of apical root resorption.[36,37] Common errors in panoramic radiographs are related to head positioning. They also have disadvantages such as errors due to magnification. These errors may result in incorrect interpretation of root resorption [31,37]

The incisal edge was used as a reference landmark for measuring the root length since no remarkable occlusal abrasion would be expected during the orthodontic treatment period [31]. Contrary to other studies [38] the cementoenamel junction was not used as an occlusal landmark as it significantly varies throughout the cervical region especially at the labial and palatal sides which will reduce the accuracy of measurement of root length. To avoid the effects of any confounding variables, only good-quality root canal treatments were evaluated such as proper obturation length (0-2 mm short of radiographic apex) as well as adequate tapered shape and uniform density of root canal filling.[37] In a similar perspective, also to limit the effects of confounders, patients who had a history of teeth trauma, ankylosis or those with periapical lesions were excluded from the study.[31]

Our results revealed that EARR was less in ETT than in VCT. This is in agreement with previous studies [23,24,31,32,39,40,41] Spurrier et al[23] and Mirabella and Artun[24] explained this occurrence by the presence of resorption protector effect in teeth with root canal fillings compared to vital teeth. The mechanism of root resorption is similar to bone resorption whereby dentin and cementum resorption occurs through odontoclasts[31]. The tensile forces from orthodontic treatment reach the pulp cells through the apical foramen and result in the expression of factors such as macrophage colony stimulating factor (M-CSF), tumor necrosis factor-alpha, receptor activator of nuclear factor kappa-B ligand (RANKL) and interleukin 1B (Kaku) in stretch-activated channels.hence leading to inflammatory root resorption [31,42] Endodontic treatment prevents the blood supply to the tooth and therefore prohibits the inflow of these inflammatory factors into the canal space. [42,43] Furthermore, the alkaline medium created by the materials used in endodontic treatment on the external root surface arrests apical root resorption and promotes repair of the hard tissue at the involved location. [44,45,46]

Different from our results were the study by Mattison et al [47], who reported no significant differences in the amount of resorption between root-filled teeth and contralateral vital teeth when both were subjected to orthodontic forces. Similar results were reported by Esteves et al [21] and Llamas-Carreras et al. [38] Studies in animal models also revealed similar EARR in both groups.[48,49] On the other hand, Steadman[50] found more apical root resorption in endodontically treated teeth than vital teeth. But their sample included patients with overfilled teeth therefore it could act as a foreign body that evokes chronic irritation and subsequent root resorption. Wickwire et al [25] also revealed that EARR takes place more frequently in root-filled teeth than in vital teeth; however, their methods included teeth with a history of trauma which could have contributed to the resorption process.

In this study, there was no significant differences between males and females in the amount of apical root resorption in ETT and VCT. This was in agreement with previous studies[9,31] who also did not report any association between gender and root resorption. Our results did not agree with those of Llamas-Carreras[22] and Khan et al [51] who found more EARR in females than males. In another systematic review [10], thirteen articles were reviewed to evaluate association between gender and apical root resorption. Out of these studies, five reported no association while seven found more apical resorption in females than males. Only one study reported more apical root resorption in males. That could be explained due to different amount of orthodontic forces or genetic dimorphism. Female sexual hormones may be a factor in causing more root resorption.[9]

There was no significant correlation between treatment duration and apical root resorption since all patients were treated for approximately the same duration of time with minor differences due to missed appointments or appliance breakage. Other studies have found a positive correlation between EARR in vital teeth and longer treatment duration such as in extraction cases because the orthodontic forces would affect the root for a longer period of time.[31.] This would lead to more release of neuropeptides from the pulp tissue which causes root resorption. However, this correlation was not seen in root-filled teeth. [9,11,31,52]

Additionally, in our study there was no correlation between age and EARR in both ETT or VCT. This was in disagreement with other studies [31] which found positive correlation of EARR in root-filled teeth with increased age. Other studies reported less EARR in younger patients because they had incomplete root formation hence offered more resistance to resorption than teeth with complete roots. [27]

In agreement with the study by Khan et al [51], external apical root resorption (EARR) was not significantly correlated with the pretreatment tooth length in both ETT and VCT. This implies that longer or shorter teeth lengths do not influence the amount of apical root resorption.

CONCLUSION

The results of this study suggest that ETT are less susceptible to EARR than VCT following orthodontic tooth movement. Hence, the possible complication of EARR in ETT may not be accounted for during the treatment planning stage of orthodontic treatment. Accordingly, no elongation in orthodontic treatment intervals or biomechanics modification is necessary. There was no statistical significance difference between males and females regarding EARR in both groups of teeth. Factors such as patient age and pre-treatment tooth lengths were not significantly correlated with EARR in either ETT or VCT.

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