Original Article

Comparison of orthodontic root resorption of root-filled and vital teeth using micro–computed tomography

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ABSTRACT

Objective: To evaluate the difference in orthodontic root resorption between root-filled and vital teeth.

Material and Methods: Sixteen individuals who required bilateral premolar tooth extraction due to orthodontic treatment and had a previously root-filled premolar tooth on one side were included in the study. The experimental group consisted of root-filled premolar teeth, and the control group consisted of contralateral vital premolar teeth. A 150-g buccally directed force was applied to these teeth using 0.017 $\times$ 0.025-inch TMA cantilever springs. The premolars were extracted 8 weeks after the application of force. Images were obtained using micro–computed tomography. Resorption measurements were obtained using the Image J program.

Results: The mean values for resorption were 0.08869 mm^3 for the root-filled teeth and 0.14077 mm^3 for the contralateral teeth, indicating significantly less resorption for the root-filled teeth compared with the contralateral teeth after the application of orthodontic force ($P = .003$). In both groups, the most resorption was seen on the cervical-buccal and apical-lingual surfaces. The mean resorption value of the cervical region was 0.06305 mm^3 in the control group and 0.0291 mm^3 in the experimental group, and the difference was statistically significant ($P = .002$).

Conclusions: Root-filled teeth showed significantly less orthodontic root resorption than vital teeth. (*Angle Orthod.* 2020;90:56–62.)

KEY WORDS: Orthodontic treatment; Root resorption; Root canal treatment

INTRODUCTION

Orthodontically induced external apical root resorption (OIEARR) is defined as surface resorption with loss of cementum that is irreversible when involving dentin.[1] Studies have demonstrated OIEARR in 90% of teeth treated orthodontically.[2,3] The etiology of OIEARR is single or multifactorial, including patient variables such as genetics, systemic diseases, nutrition, and age and mechanical variables such as the amount of tooth movement, the magnitude of applied force, and the duration of orthodontic treatment.[4,5] It is not clear exactly which etiological factor is most influential and how it can be prevented.

The likelihood of encountering root-filled teeth has increased with the higher incidence of caries in the population and the increased demand for orthodontic treatment among adult patients.[6–8] The prognosis of root-filled teeth after orthodontic treatment and their resistance to root resorption is vital for orthodontic treatment planning. In the literature, the results of studies investigating OIEARR in root-filled teeth are controversial. Some studies[9–11] reported that root-filled teeth are a risk factor for OIEARR, whereas others[12–17] concluded there is no difference in terms of OIEARR between vital and root-filled teeth. In contrast, there are also many studies[18–25] reporting less OIEARR in root-filled teeth than in vital teeth. The current general opinion is that the root-filled teeth managed with a successful endodontic procedure can be moved orthodontically without the risk of significant root resorption.[26,27]

In the literature, studies on orthodontic root resorption of root-filled teeth mostly used 2-dimensional radiographs or histological examination methods. No

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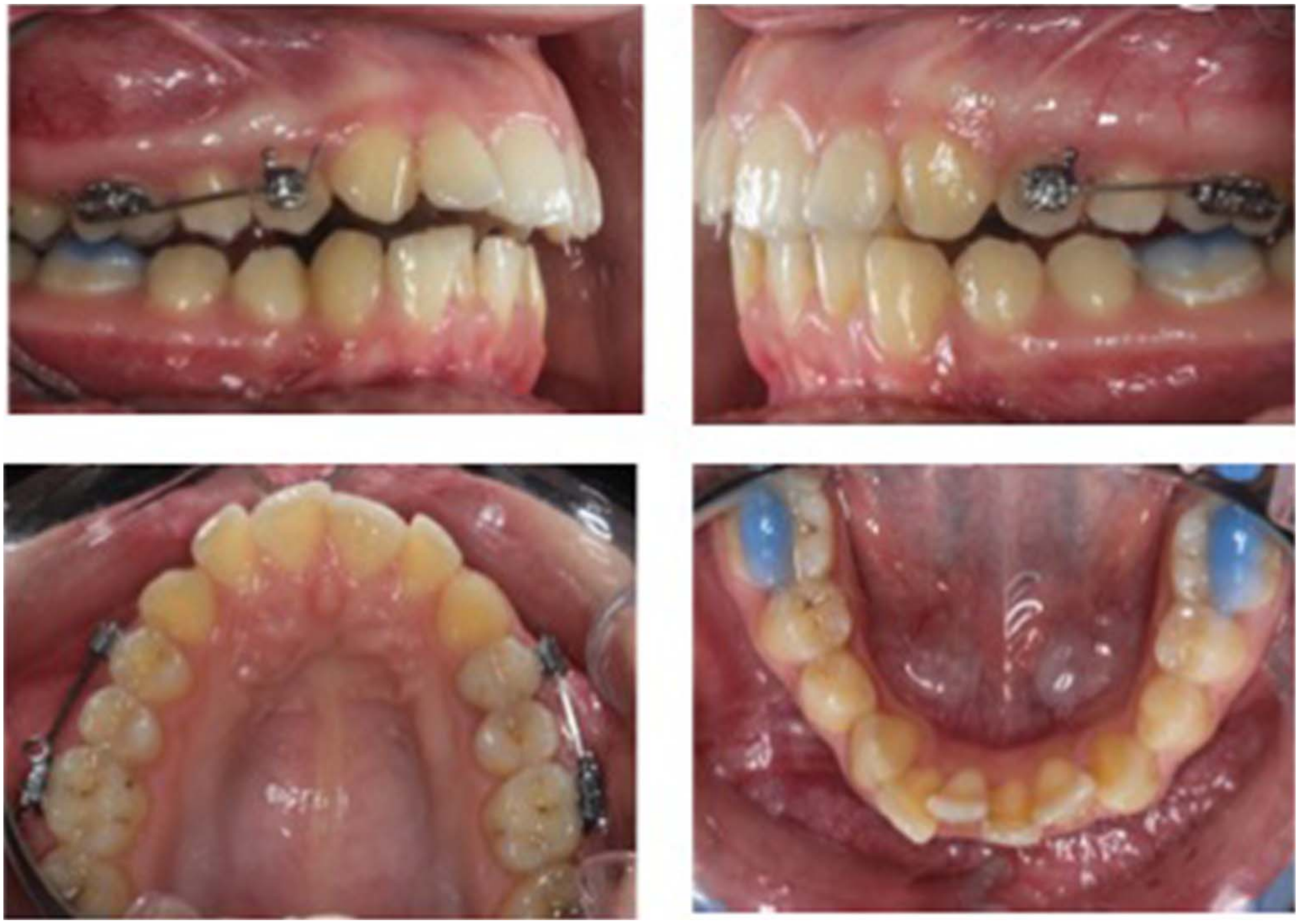

Figure 1. Intraoral images of the application of the orthodontic force.

studies that evaluated resorption of root-filled teeth using the micro–computed tomography (CT) method were found in the literature. The aim of the present study was to evaluate the difference in root resorption status between root-filled and vital teeth after the application of orthodontic force by imaging with micro-CT.

MATERIALS AND METHODS

This study was approved by the regional ethics committee (OMÜ KAEK 2016/382). The subjects were 16 patients with a mean age of 18.8 years (8 male, 8 female). They were selected according to the following criteria: (1) maxillary and/or mandibular premolar extraction treatment planned, (2) one of the premolar teeth that needs to be extracted underwent previous endodontic treatment, (3) no clinical or radiological symptoms in the root-filled tooth, and (4) no systemic diseases.

All premolars and molars were cleaned and polished with pumice. The premolar teeth were bonded with 0.022-inch slot self-ligating brackets ((H4 brackets, Ortho Classic, McMinnville, Ore), and the molar teeth were bonded with standard tubes. A 150-g buccally directed force was applied to the premolar teeth with 0.017 $\times$ 0.025-inch TMA cantilever springs (Beta III Titanium, 3M Unitek, Monrovia, Calif). The occlusion was opened with light-cured band cement placed on the occlusal surfaces of the mandibular first molars to allow buccal tipping of the premolars (Figure 1).

After 8 weeks, all premolars were extracted and stored in 10% formalin solution. All samples were scanned using X-ray microtomography (1172; Sky-Scan, Aartselaar, Belgium). Digital sectional images were obtained using 100-kV accelerating voltage, 100-mA beam current, and a 0.5-mm aluminum filter. Each scanning procedure was conducted using 11-mega-pixel cameras over 50–60 minutes. The images were scanned with a voxel size of 2.56 lm, and 800–900 cross-sectional images were recorded in DICOM (Digital Imaging and Communications in Medicine) file format. The volume of resorption craters was measured using the software Image J (ImageJ 1.43, Wayne Rasband, National Institutes of Health, Bethesda, Md;

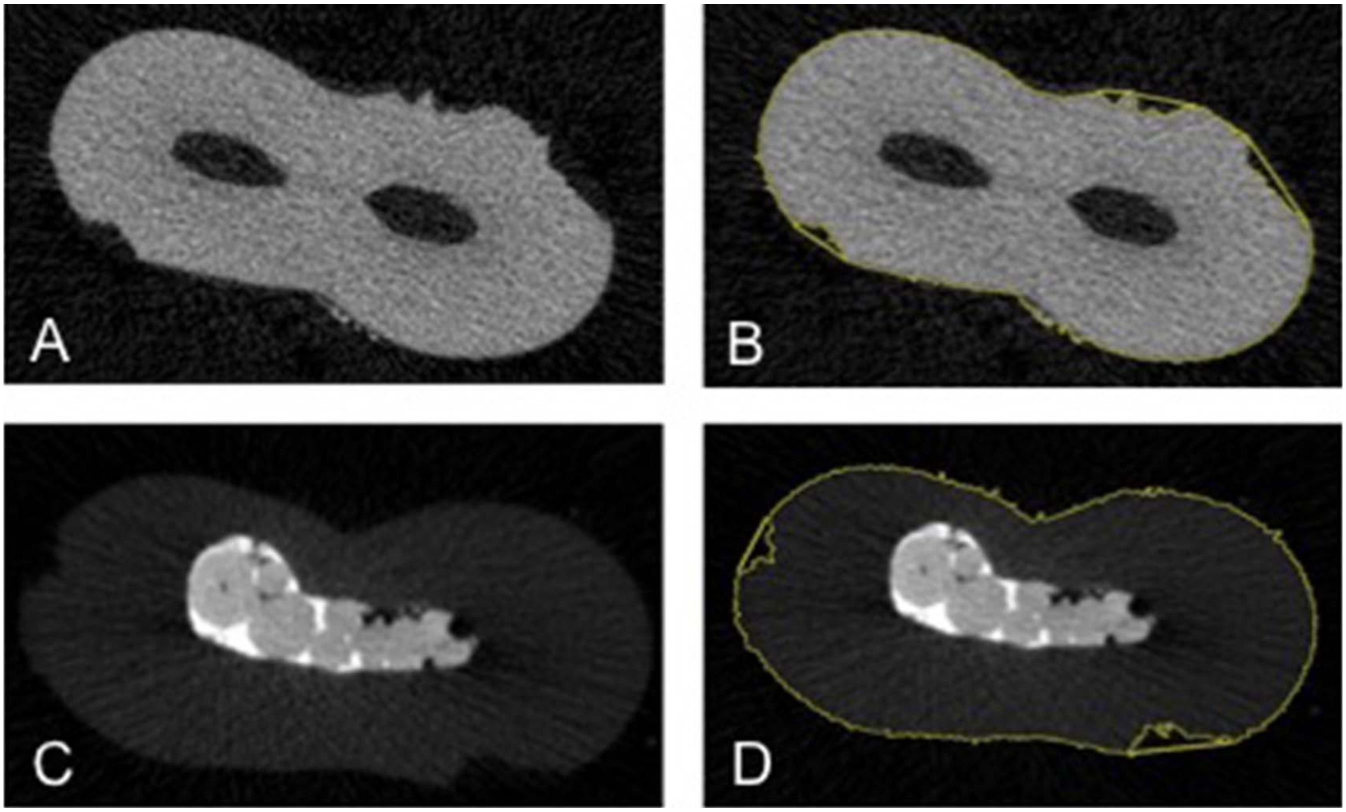

Figure 2. Measurements of resorption of the vital teeth (A, B) and root-filled teeth (C, D).

Figure 2). The roots were divided into cervical, medial, and apical thirds in the vertical aspect and buccal, lingual, mesial, and distal surfaces in the axial aspect. Thus, each root was divided into the following regions: cervical-buccal, cervical-mesial, cervical-distal, cervical-lingual, middle-buccal, middle-mesial, middle-distal, middle-lingual, apical-buccal, apical-mesial, apical-distal, and apical-lingual. Total resorption volumes were calculated for each group. All measurements were made by the same researcher (Dr Kolcuoğlu).

Statistical Analysis

The data were analyzed with IBM SPSS V23. Compliance with the normal distribution was examined using the Shapiro-Wilk test. The independent-sample *t*-test and Mann-Whitney *U*-test were used to compare the data. In addition, the Friedman test was used for intragroup comparisons.

RESULTS

In 13 patients, the root-filled premolars were in the maxillary arch, and in three patients, they were in the mandibular arch. A total of 32 premolar teeth were evaluated.

Comparison of the resorption volumes of different root surfaces and thirds between the study and control groups is seen in Table 1. There was a statistically significant difference between the groups in the total mean resorption volume (MRV). The total MRV for the control group (0.11831 $\pm$ 0.06537) was higher than that for the study group (0.09300 $\pm$ 0.02509). The MRV for the control group at the cervical third (0.06305 $\pm$ 0.03637) was also higher than that for the study group (0.02910 $\pm$ 0.01333). The differences were statistically significant ($P < .05$).

When comparing the resorption volumes of different surfaces of the root, there was a statistically significant difference between the groups on the cervical-distal surface. In the control group, 0.00652 $\pm$ 0.01658 mm^3 MRV was observed, with 0 $\pm$ 0.00456 mm^3 MRV in the study group (Table 2).

Intragroup comparisons among the different root regions for the control group and study groups are shown in Tables 3 and 4, respectively. The cervical-buccal region in the control group had the highest MRV, while the cervical-lingual region had the lowest MRV. Similarly, MRV in the cervical-buccal region was higher than in the other regions. Among the middle third measurements, there was no statistically significant difference for either group. The intragroup comparison of the apical MRV measurements showed that the highest MRV was in the apical-lingual region in both groups.

Table 1. Comparison of Mean Resorption Volumes (mm³) in the Different Root Thirds and Surfaces Between the Control and Study Groups[a]

	Control Group			Study Froup				
	Mean	Median	SD	Mean	Median	SD	Statistics	*P*
Cervical	0.06305	0.06417	0.03637	0.02910	0.02677	0.01333	$t = 3.5$	**.002**
Apical	0.04430	0.03287	0.03793	0.03619	0.03254	0.01626	$U = 128$	1.000
Middle	0.03342	0.03335	0.01928	0.02340	0.02360	0.01383	$t = 1.7$	.101
Mesial	0.04011	0.01948	0.04108	0.01444	0.01333	0.01066	$U = 87$	.122
Distal	0.02651	0.01634	0.02941	0.01671	0.01576	0.01202	$U = 105$	.386
Buccal	0.04423	0.04104	0.02315	0.03308	0.03108	0.01728	$t = 1.5$	.133
Lingual	0.02992	0.02872	0.02404	0.02446	0.02194	0.01215	$t = 0.8$	.424
Total	0.14077	0.11831	0.06537	0.08869	0.09300	0.02509	$U = 48$	**.003**

[a] *t* indicates independent-samples *t* statistics; *U*, Mann-Whitney *U* statistics.

The intragroup comparison of the different vertical third levels and surfaces of the roots did not show a statistically significant difference for either group (Tables 5 and 6).

DISCUSSION

In the present study, root resorption of root-filled and vital premolar teeth was measured on micro-CT images. In studies evaluating orthodontic root resorption, two-dimensional radiographs such as periapical radiographs,[28,29] panoramic radiographs,[15,21] and lateral cephalometric radiographs[30] can detect only shortening of the root length. Histological studies indicate that minor resorption craters on the apical or root surface cannot be determined radiographically. To detect craters in two-dimensional radiographs, there should be more than 7.1% mineral loss along the X-ray direction.[22] The efficacy of micro-CT, which allows full examination of root resorption, has been tested in many studies.[31–35] The absence of any limitation on radiation dose and scanning time on devital samples provides better-quality images. In this study, micro-CT was chosen for imaging the resorption because the patients needed premolar extractions according to their orthodontic treatment plans.

The results of the present study showed that less OIEARR occurred in root-filled teeth compared with vital teeth. This finding was in accordance with previous studies that evaluated the root resorption of root-filled teeth.[18,21–23,36] Mirabella and Årtun[19] performed a study to determine the risk factors for OIEARR in adult orthodontic patients. Radiographs of maxillary incisor teeth were examined before and after orthodontic treatment in 343 adult patients. Less root resorption was observed in root-filled teeth than in contralateral control teeth. Spurrier et al.[18] recorded similar findings demonstrating that vital incisors resorbed more than root-filled incisors after orthodontic treatment in a sample of 43 patients. Lee and Lee[21] evaluated the digital panoramic radiographs of 35 patients with at least one tooth that had undergone root-canal treatment. They reported significantly less resorption in root-filled teeth. If there was a periapical lesion in the root-filled tooth, they emphasized that resorption due to orthodontic treatment would be added to the inflammatory resorption and resorption to the same extent as in vital teeth would occur.

Castro et al.[12] conducted a study similar to the present study. In their study, 30 subjects with at least one root-filled tooth and cone-beam computed tomography (CBCT) images before and after treatment were

Table 2. Comparison of the Mean Resorption Volumes (mm³) on the Different Root Regions Between Control and Study Groups[a]

	Control Group			Study Group				
	Mean	Median	SD	Mean	Median	SD	Statistics	*P*
Cervical-buccal	0.03502	0.02838	0.02284	0.02192	0.01906	0.01445	$t = 1.9$	.062
Cervical-mesial	0.01680	0.00532	0.02266	0.00461	0.00352	0.00498	$U = 89.0$	.140
Cervical-distal	0.01122	0.00652	0.01658	0.00217	0.00000	0.00456	$U = 63.0$	**.010**
Cervical-lingual	0.00000	0.00000	0.00000	0.00040	0.00000	0.00127	$U = 112$	.151
Middle-buccal	0.00658	0.00308	0.00761	0.00778	0.00533	0.00927	$U = 122.5$	.833
Middle-mesial	0.01016	0.00416	0.01327	0.00612	0.00253	0.00736	$U = 107$	.422
Middle-distal	0.00927	0.00201	0.01306	0.00533	0.00345	0.00545	$U = 120.5$	.774
Middle-lingual	0.00741	0.00515	0.00756	0.00417	0.00368	0.00375	$U = 104.5$	.368
Apical-buccal	0.00263	0.00014	0.00720	0.00338	0.00002	0.00764	$U = 127$	.968
Apical-mesial	0.01314	0.00369	0.02590	0.00371	0.00220	0.00414	$U = 103$	.345
Apical-distal	0.00602	0.00459	0.00604	0.00920	0.00647	0.00773	$U = 93$	.187
Apical-lingual	0.02251	0.01813	0.01845	0.01989	0.01829	0.01178	$t = 0.5$	.636

[a] *t* indicates independent-samples *t* statistics; *U*, Mann-Whitney *U* statistics.

Table 3. Comparison of Resorption Volumes in the Control Group Within Vertical Thirds of the Roots[a]

	Median	Minimum	Maximum	Statistics	*P*
Cervical-buccal	0.02838b	0.00096	0.07374	$\chi^2 = 33.3$	<.001
Cervical-mesial	0.00532bc	0.00000	0.07878		
Cervical-distal	0.00652ac	0.00000	0.06612		
Cervical-lingual	0.00000a	0.00000	0.00000		
Middle-buccal	0.00308	0.00000	0.01975	$\chi^2 = 0.1$	.987
Middle-mesial	0.00416	0.00000	0.04063		
Middle-distal	0.00201	0.00000	0.04044		
Middle-lingual	0.00515	0.00000	0.01884		
Apical-buccal	0.00014a	0.00000	0.02894	$\chi^2 = 18.3$	<.001
Apical-mesial	0.00369ab	0.00000	0.10337		
Apical-distal	0.00459ab	0.00000	0.02036		
Apical-lingual	0.01813b	0.00050	0.07141		

[a] χ^2 indicates Friedman test statistics. a,b,c: There is no difference between the measurements with the same letter within the group.

included. The changes in root length on the CBCT images were examined, and no difference were found between the two groups. However, it is possible that this result was due to the patient population selected. All the teeth evaluated were in the posterior region, and the amount of shortening in the root was minimal since they were not exposed to orthodontic forces that could cause resorption. In addition, a difference in evaluation methods may have been responsible for the difference in results between the studies. With micro-CT, very small resorption areas that may be missed by CBCT can be measured.

Intragroup comparisons revealed that the greatest resorption was observed in the cervical-buccal region in the cervical third and the apical-lingual region in the apical third in both groups. This can be explained by the concentration of force on the buccal surface in the coronal part of the root and on the lingual surface in the apical part of the root during buccal tipping movement at the crown.[33,35] Resorption on the mesial and distal surfaces of the cervical and apical regions was caused by rotation occurring simultaneously with the tipping movement.

It is noteworthy that vital teeth showed more resorption in the cervical third than root-filled teeth. The hardness and the elastic modulus of cementum in the premolar teeth decrease from the cervical to the apical third.[37] In this respect, greater resorption in the apical third can be expected. However, the anatomical location, direction, and type of force would be more influential in the localization of resorption. Rudolph et al.,[38] in their finite element analysis study, showed that the force is concentrated in the cervical third during tipping movement. In the current study, the presence of more resorption in the cervical third of the control group than in the study group may be explained by the concentration of force in this region.

Odontoclastic activity associated with root resorption is similar to that of osteoclastic activity associated with bone resorption.[39] Previous studies showed that macrophage colony stimulating factor, receptor activator of nuclear factor kappa-B ligand, and inflammatory cytokines derive from the injured pulp cells under orthodontic force, and odontoclastic activity starts.[23] In addition, existing neuropeptides in teeth with vital pulp play a role in root resorption.[22] Bender[22] suggested that the decrease in the calcitonin gene-related peptide immunoreactive nerve fibers occurs because of the absence of neuropeptides released from pulp, and less resorption can be seen in root-filled teeth. On the other

Table 4. Comparison of Resorption Volumes in the Study Group Within Vertical Thirds of the Roots[a]

	Median	Minimum	Maximum	Statistics	*P*
Cervical-buccal	0.01906a	0.00433	0.05210	$\chi^2 = 31.1$	<.001
Cervical-mesial	0.00352ab	0.00000	0.01550		
Cervical-distal	0.00000b	0.00000	0.01708		
Cervical-lingual	0.00000b	0.00000	0.00498		
Middle-buccal	0.00533	0.00000	0.03409	$\chi^2 = 1.2$	.755
Middle-mesial	0.00253	0.00000	0.01950		
Middle-distal	0.00345	0.00000	0.01676		
Middle-lingual	0.00368	0.00000	0.01042		
Apical-buccal	0.00002a	0.00000	0.02876	$\chi^2 = 26.2$	<.001
Apical-mesial	0.00220ac	0.00000	0.01316		
Apical-distal	0.00647bc	0.00120	0.02719		
Apical-lingual	0.01829b	0.00176	0.04111		

[a] χ^2 indicates Friedman test statistics. a,b,c: There is no difference between the measurements with the same letter within the group.

Table 5. Resorption Volumes of the Control Group Among the Different Root Thirds and Different Root Surfaces[a]

	Median	Minimum	Maximum	Statistics	*P*
Cervical	0.06417	0.01325	0.14405	$\chi^2 = 6.1$	.050
Apical	0.03287	0.00486	0.15123		
Middle	0.03335	0.00680	0.06086		
Mesial	0.01948	0.00059	0.11675	$\chi^2 = 3.2$	.369
Distal	0.01634	0.00477	0.12292		
Buccal	0.04104	0.00106	0.08206		
Lingual	0.02872	0.00050	0.08673		

[a] χ^2 indicates Friedman test statistics.

Table 6. Resorption Volumes of the Study Group Among the Different Root Thirds and Different Root Surfaces

	Median	Minimum	Maximum	Statistics	*P*
Cervical	0.02677	0.01148	0.06138	$\chi^2 = 5.4$	.068
Apical	0.03254	0.01593	0.07230		
Middle	0.02360	0.00586	0.04873		
Mesial	0.01333	0.00000	0.03679	$\chi^2 = 7.5$	.058
Distal	0.01576	0.00235	0.04102		
Buccal	0.03108	0.01070	0.05927		
Lingual	0.02194	0.00526	0.04491		

hand, calcium hydroxide–based root canal materials have been shown to have a positive effect on periapical tissue healing and repair of orthodontic root resorption in the teeth of endodontically treated dogs.[24] These factors may explain the lower OIEARR observed in root-filled teeth.

CONCLUSIONS

- Total resorption volume due to orthodontic force in root-filled teeth was significantly lower than in vital teeth.
- When the groups were evaluated within themselves, the most resorption in the vital teeth was seen in the cervical third and in the apical third in the root-filled teeth.
- In both groups, more resorption was seen in the cervical-buccal and apical-lingual regions than in the other regions, and this was compatible with the direction of movement.
- Based on these results, it is thought that during orthodontic treatment, root-filled teeth are more resistant to root resorption and can be moved safely.

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