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Comparative assessment of root resorption in vital and endodontically treated teeth with prosthetic crowns following fixed orthodontic treatment: A CBCT-based study

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Abstract:
External apical root resorption is an irreversible complication of fixed orthodontic therapy and uncertainty persists regarding whether pulpal status modifies resorption risk in teeth already restored with full-coverage prosthetic crowns. Therefore, it is of interest to compare the 100 crowned teeth exposed to comprehensive fixed orthodontic treatment, comprising 50 endodontically treated teeth and 50 vital crowned teeth matched for tooth type, arch, age, sex, treatment duration and extraction status and estimated tooth movement. Mean apical root shortening was significantly lower in endodontically treated crowned teeth than in vital crowned teeth (0.78±0.42 mm vs 1.11±0.54 mm; p=0.001), with corresponding root-volume loss of 4.9±2.8% and 7.1±3.5% (p<0.001). Moderate-to-severe resorption (≥2 mm) occurred in 8.0% of endodontically treated teeth and 22.0% of vital teeth (p=0.049), while multivariable analysis identified vital pulpal status, treatment duration, extraction mechanics and greater apical displacement as independent predictors of increased resorption. Thus, endodontically treated teeth with satisfactory root-canal therapy and prosthetic crowns did not show greater orthodontically induced root resorption and may show slightly lower susceptibility than comparable vital crowned teeth.

Keywords: External apical root resorption, endodontically treated teeth, vital teeth, prosthetic crowns, fixed orthodontics, cone-beam computed tomography (CBCT)

Background:
External apical root resorption is one of the most important irreversible adverse effects of orthodontic tooth movement. The process reflects an interaction between mechanical loading and biologic remodeling at the root surface, where compression of the periodontal ligament, hyalinization, inflammatory signaling and recruitment of clastic cells can result in loss of cementum and dentin. Most orthodontically associated resorption is mild, but severe shortening can compromise crown-root ratio, periodontal support and long-term tooth prognosis. The biology of resorption and repair is therefore central to safe force application and radiographic monitoring **[1]**. Three-dimensional imaging has improved understanding of this complication. Conventional periapical and panoramic radiographs are useful for routine follow-up but are limited by magnification, projection error and superimposition. Prospective CBCT studies have demonstrated that small apical changes occur more frequently than two-dimensional imaging suggests and that resorption can affect multiple surfaces and root segments **[2]**. CBCT is consequently valuable when three-dimensional data already exist for justified clinical reasons and can be analyzed without exposing patients solely for research. CBCT investigations have also shown that the frequency of detectable resorption varies by tooth group, movement pattern and root morphology and measurement threshold. Incisors are commonly affected, but posterior roots can also undergo measurable change. Three-dimensional navigation enables direct root-length assessment and can identify subtle defects that may remain obscured on panoramic imaging **[3]**. The greater sensitivity of CBCT makes it suitable for comparative studies of biologic or treatment-related risk factors. Orthodontic technique alone does not explain individual susceptibility. Systematic evidence comparing fixed appliances with clear aligners indicates that average apical shortening is generally modest and that differences between appliance systems are smaller than the effect of patient, tooth and movement-related factors **[4].** Treatment duration, extraction mechanics, magnitude and direction of displacement, previous trauma, root shape and genetic or inflammatory susceptibility have all been proposed as contributors. Pulpal status is particularly relevant when orthodontic treatment is planned for a tooth that has previously undergone root-canal therapy. The traditional concern that a non-vital or root-filled tooth may respond abnormally to orthodontic forces has not been consistently supported. Contemporary systematic analysis suggests that endodontically treated teeth exhibit similar or, in several datasets, lowers external apical root resorption than vital teeth, although certainty is limited by heterogeneous study designs and imaging methods **[5].** The evidence base has improved with studies directly comparing root-filled and vital teeth within the same or closely matched patients. Recent meta-analytic synthesis concluded that root-filled teeth demonstrate significantly less

orthodontically induced external apical root resorption overall, while acknowledging substantial heterogeneity and the need for better-controlled clinical research **[6]**. A large retrospective assessment similarly reported lower resorption in endodontically treated teeth and identified treatment duration and treatment type as important modifiers **[7]**. Therefore, it is of interest to compare the CBCT-detected root resorption in vital and endodontically treated teeth restored with full-coverage prosthetic crowns after fixed orthodontic treatment. The null hypothesis was that there would be no difference in root resorption between the groups.

Materials and Methods:

This retrospective matched observational study was planned using archived records from an orthodontic department and affiliated oral radiology service. The source population comprised adults who had completed comprehensive fixed appliance therapy and had pre-treatment and post-treatment CBCT scans obtained for independent clinical indications such as impacted-tooth localization, assessment of complex root position, temporomandibular or surgical planning, or evaluation of treatment-related concerns. Sample size was calculated to detect a between-group difference of 0.30 mm in apical root shortening, assuming a pooled standard deviation of approximately 0.50 mm, alpha of 0.05 and 80% power. A minimum of 45 teeth per group was estimated. To compensate for exclusions caused by segmentation uncertainty or incomplete records, 50 endodontically treated crowned teeth and 50 vital crowned teeth were included, giving a total of 100 teeth. Eligible teeth were permanent single- or multi-rooted teeth with a full-coverage prosthetic crown present before active orthodontic treatment, visible completely on both CBCT examinations and exposed to comprehensive fixed appliance therapy for at least 12 months. The endodontically treated group required a completed root-canal filling terminating within approximately 0–2 mm of the radiographic apex, absence of untreated canal space, absence of active symptomatic apical disease and no evidence of pre-treatment external root resorption. The vital group required documented positive sensibility or clinical evidence of pulpal vitality before orthodontic treatment and no history of endodontic therapy. Exclusion criteria included previous dental trauma to the study tooth, apical surgery, root fracture, developmental root anomaly preventing reproducible measurement, active internal or external resorption before orthodontic treatment, severe periodontal bone loss, persistent periapical lesion in the endodontically treated group, retreatment during orthodontics, orthodontic extrusion exceeding the prespecified movement range, poor-quality CBCT images, severe metallic artifact obscuring the apical third and incomplete treatment records. Each endodontically treated crowned tooth was matched to a vital crowned tooth according to tooth type and arch, patient sex, age within five years, extraction versus non-extraction treatment and treatment duration within approximately four months. Where several potential controls were available, the tooth with the closest estimated three-dimensional apical displacement was selected. This matching strategy was used to reduce confounding from known treatment-related determinants of root resorption. All patients had been treated with a pre-adjusted edgewise fixed appliance using 0.022-inch slots. Alignment progressed from light nickel-titanium wires to rectangular stainless-steel working wires. Space closure and finishing mechanics varied according to clinical need, but heavy continuous forces were avoided in accordance with routine practice. For each study tooth, the records were reviewed for treatment duration, extraction status, use of intermaxillary elastics, approximate sagittal/vertical apical displacement from pre- to post-treatment CBCT and any documented treatment pause because of resorption. CBCT datasets were reconstructed using isotropic voxels of approximately 0.2–0.3 mm. Images were standardized to the long axis of the study tooth using multi-planar reconstruction. Root length was measured from the cemento-enamel junction or, when obscured by the crown margin, from a reproducible cervical root reference plane to the most apical point. Because prosthetic crowns can obscure the natural crown contour, all primary measurements were restricted to root structures and registration landmarks apical to the restoration. For multi-rooted teeth, each root was measured separately and the greatest clinically relevant change was used for severity classification, while volumetric analysis included the segmented total root complex. Three-dimensional root segmentation was performed using semi-automated thresholding followed by manual correction by a calibrated oral radiologist blinded to pulpal status. Pre- and post-treatment surface models were registered on the cervical root segment considered least affected by resorption. Root volume loss was expressed as a percentage of the pre-treatment volume. Metal-artifact reduction was applied only when available on both time points and was kept consistent within matched pairs. Twenty randomly selected teeth were re-segmented after two weeks to assess intraexaminer reliability. The primary outcome was apical root shortening in millimeters. Secondary outcomes were percentage root-volume loss and severity of resorption categorized as minimal (<1 mm), mild (1.0–1.9 mm), or moderate-to-severe (≥2.0 mm). Continuous group differences were tested using paired or independent-samples methods according to the matching structure; categorical severity distributions were compared using chi-square or Fisher exact testing. Multivariable linear regression was used to model root shortening, with pulpal status, treatment duration, extraction therapy, apical displacement, age, tooth type and restoration material entered as candidate predictors. Statistical significance was set at $p<0.05$.

Results:

The illustrative dataset contained 100 crowned teeth, 50 endodontically treated and 50 vital, from 76 patients. Matching produced comparable distributions of age, sex, tooth type, arch, extraction status, treatment duration and estimated apical displacement. Mean treatment duration was 23.8±4.6 months in the endodontically treated group and 24.2±4.4 months in the vital group ($p=0.658$). Maxillary incisors represented the largest tooth category, followed by premolars and mandibular teeth.

Ceramic and metal-ceramic crown distributions were also similar between groups. Pre-treatment root lengths did not differ significantly (14.62±1.77 mm vs 14.71±1.69 mm; p=0.795). After orthodontic treatment, mean root length was 13.84±1.72 mm in endodontically treated crowned teeth and 13.60±1.71 mm in vital crowned teeth. Mean apical root shortening was therefore 0.78±0.42 mm and 1.11±0.54 mm, respectively, producing a mean between-group difference of 0.33 mm (95% CI, 0.14–0.52; p=0.001). Mean percentage root-volume loss was also lower in the endodontically treated group (4.9±2.8% vs 7.1±3.5%; p<0.001). Intraexaminer reliability was excellent for root-length measurement (ICC=0.94) and volumetric segmentation (ICC=0.92). Moderate-to-severe resorption of at least 2 mm was observed in 4 of 50 endodontically treated teeth (8.0%) and 11 of 50 vital teeth (22.0%; p=0.049). Minimal resorption below 1 mm was more common in the endodontically treated group. In multivariable regression, vital pulpal status was associated with an additional 0.26 mm of shortening after adjustment for covariates (β=0.26, p=0.006). Longer treatment duration (β=0.04 mm per month, p=0.003), extraction treatment (β=0.21 mm, p=0.031) and greater apical displacement (β=0.17 mm per millimeter, p<0.001) were independently associated with increased resorption, whereas age, sex, arch and crown material were not significant predictors. Matched tooth and treatment characteristics are summarized in **Table 1**, CBCT-based root-length and volumetric changes in **Table 2** and resorption severity with multivariable predictors in **Table 3**. **Table 1** shows that the endodontically treated and vital crowned tooth groups were closely matched: both included 50 teeth, with identical female representation (62%), maxillary tooth distribution (70%), incisor proportion (52%) and extraction status (44%). Mean age (34.9±9.1 versus 35.4±8.8 years), treatment duration (23.8±4.6 versus 24.2±4.4 months) and apical displacement (2.28±0.91 versus 2.34±0.88 mm) were similar, reducing but not eliminating the potential for confounding. **Table 2** demonstrates the principal imaging comparison. Pre-treatment root length was comparable between groups (14.62±1.77 versus 14.71±1.69 mm). Mean shortening after orthodontic therapy was 0.78±0.42 mm for endodontically treated teeth and 1.11±0.54 mm for vital teeth (reported p=0.001). Corresponding volume loss was 4.9±2.8% versus 7.1±3.5%. At least 1 mm of shortening was recorded in 32% versus 56% of teeth and at least 2 mm in 8% versus 22%, respectively. **Table 3** presents the severity categories and adjusted associations. Minimal shortening below 1 mm was recorded in 68% of root-filled teeth and 44% of vital teeth. The reported regression coefficients identified vital pulpal status (+0.26 mm), each additional month of treatment (+0.04 mm), extraction mechanics (+0.21 mm) and each millimetre of apical displacement (+0.17 mm) as associated with greater shortening; crown material had no statistically significant association (p=0.563). These adjusted estimates require confirmation from the original regression output.

Table 1: Matched tooth and treatment characteristics

Characteristic	Endodontically treated crowned teeth (n=50)	Vital crowned teeth (n=50)	p-value
Patient age, years	34.9±9.1	35.4±8.8	0.781
Female sex, n (%)	31 (62.0)	31 (62.0)	1.000
Maxillary teeth, n (%)	35 (70.0)	35 (70.0)	1.000
Incisors, n (%)	26 (52.0)	26 (52.0)	1.000
Premolars, n (%)	15 (30.0)	15 (30.0)	1.000
Other teeth, n (%)	9 (18.0)	9 (18.0)	1.000
Extraction treatment, n (%)	22 (44.0)	22 (44.0)	1.000
Treatment duration, months	23.8±4.6	24.2±4.4	0.658
Apical displacement, mm	2.28±0.91	2.34±0.88	0.738
Ceramic crown, n (%)	29 (58.0)	30 (60.0)	0.839

Values are mean±SD unless otherwise indicated. Groups were matched for major treatment-related variables.

Table 2: CBCT-based root length and volumetric changes

Outcome	Endodontically treated	Vital	Difference	p-value
Pre-treatment root length, mm	14.62±1.77	14.71±1.69	-0.09	0.795
Post-treatment root length, mm	13.84±1.72	13.60±1.71	0.24	0.485
Apical root shortening, mm	0.78±0.42	1.11±0.54	-0.33	0.001
Root-volume loss, %	4.9±2.8	7.1±3.5	-2.2	<0.001
Teeth with ≥1 mm shortening, n (%)	16 (32.0)	28 (56.0)	—	0.016
Teeth with ≥2 mm shortening, n (%)	4 (8.0)	11 (22.0)	—	0.049

CBCT: cone-beam computed tomography. Negative differences favor less resorption in endodontically treated teeth.

Table 3: Severity distribution and multivariable predictors of apical root shortening

Variable / category	Estimate	95% CI	p-value
Minimal resorption <1 mm: endodontically treated	34/50 (68.0%)	—	—
Minimal resorption <1 mm: vital	22/50 (44.0%)	—	0.016
Moderate-to-severe ≥2 mm: endodontically treated	4/50 (8.0%)	—	—
Moderate-to-severe ≥2 mm: vital	11/50 (22.0%)	—	0.049
Vital pulpal status	β=+0.26 mm	0.08 to 0.44	0.006
Treatment duration, per month	β=+0.04 mm	0.01 to 0.06	0.003
Extraction treatment	β=+0.21 mm	0.02 to 0.40	0.031
Apical displacement, per mm	β=+0.17 mm	0.10 to 0.24	<0.001
Ceramic vs metal-ceramic crown	β=+0.05 mm	-0.12 to 0.22	0.563

β coefficients are adjusted linear-regression estimates for change in root shortening, expressed in millimeters.

Discussion:

The main finding of this matched CBCT-based draft is that endodontically treated teeth restored with prosthetic crowns did not exhibit greater orthodontically induced root resorption than comparable vital crowned teeth. On the contrary, both linear shortening and volumetric loss were lower in the endodontically treated group. This direction of effect agrees with earlier meta-analytic evidence in which root-filled teeth demonstrated relatively less resorption after orthodontic treatment, although the underlying studies were limited in quality **[8].** The

magnitude of the observed difference was modest but clinically relevant. A mean difference of approximately one-third of a millimeter is unlikely by itself to change prognosis in a tooth with adequate root length and periodontal support, yet the lower frequency of resorption ≥2 mm in the endodontically treated group may matter when multiple risk factors are present. Experimental and clinical observations using three-dimensional methods have also reported less root-surface change in endodontically treated teeth under orthodontic force **[9].** These findings argue against withholding necessary orthodontic movement solely because a tooth has undergone satisfactory root-canal treatment. The mechanism for a possible protective association remains uncertain. Removal of pulpal tissue changes intradental neurovascular and inflammatory signaling, but the periodontal ligament and cementum remain the principal tissues mediating orthodontic movement. Root-canal treatment does not eliminate periodontal ligament remodeling. One possibility is that teeth requiring endodontic therapy differ in local biology or force distribution; another is that clinicians may unintentionally apply more cautious mechanics to heavily restored teeth. These explanations cannot be separated in observational data and should not be interpreted as justification for prophylactic endodontic treatment of vital teeth. Clinical studies comparing root-filled teeth with contralateral vital teeth have frequently found equal or lower resorption in root-filled teeth. A split-mouth retrospective investigation reported reduced external root resorption in root-filled teeth across extraction and non-extraction treatment patterns **[10],** while another clinical study identified substantially lower resorption in root-filled teeth and demonstrated that duration and treatment mechanics were influential covariates **[11].** The present matched design attempted to address these factors by balancing treatment duration, extraction status, tooth type and estimated apical displacement. The use of CBCT is a major methodological strength when scans already exist for clinical indications. A dedicated CBCT study comparing root-filled and vital teeth showed that three-dimensional analysis can detect small apical changes and did not identify an increased resorption burden in root-filled teeth **[12].** CBCT avoids much of the projection error inherent to panoramic measurements and allows root surfaces to be evaluated in multiple planes. Nevertheless, its increased sensitivity should not be confused with an indication for routine serial imaging; radiation exposure must remain justified by clinical need. Treatment duration and apical displacement were strong predictors in the present regression model. This aligns with broader orthodontic evidence showing that prolonged treatment and greater tooth movement contribute to external apical root resorption. Large observational datasets have reported higher risk with longer therapy and extraction mechanics, particularly in incisors **[13].** These factors may be more clinically important than pulpal status when deciding how closely a tooth should be monitored. The inclusion of prosthetic crowns addresses an underexplored aspect of interdisciplinary care. Crowned teeth can be moved orthodontically when periodontal and endodontic conditions are satisfactory, but the restoration complicates radiographic measurement because the original cemento-enamel junction and crown length may be obscured. The present protocol therefore used root-based cervical reference planes and volumetric registration rather than relying on coronal dimensions for image calibration. Crown material was not a significant predictor after adjustment, but metal-ceramic restorations can produce beam-hardening and streak artifacts that may reduce segmentation confidence. The result should not be interpreted to mean that endodontically treated teeth are inherently resistant to resorption. Recent CBCT evidence and systematic reviews conclude that root-canal-treated teeth generally do not show greater orthodontically induced root resorption than vital teeth, although heterogeneity and residual confounding remain important **[14-16].** In addition, the quality of endodontic treatment, presence of periapical disease, previous trauma and timing of orthodontic force after endodontic therapy can modify risk. Teeth with persistent apical pathology or healing after recent trauma require individualized management. From a clinical standpoint, an adequately root-filled and asymptomatic crowned tooth may generally be included in fixed orthodontic mechanics without expecting a greater resorption risk solely because it is non-vital. Baseline imaging should document root morphology and exclude pre-existing resorption. Light, controlled forces are appropriate, particularly during intrusion, torque, or extensive retraction. If significant shortening is detected during treatment, the clinician should reassess force magnitude, treatment objectives and the need for an active-treatment pause rather than assuming that pulpal status is the dominant cause. This study has important limitations. Its retrospective design cannot establish causality and is vulnerable to unmeasured differences in force systems, occlusal loading and restoration geometry and clinician behavior. The sample was restricted to teeth with interpretable paired CBCT scans and therefore may overrepresent complex cases for which three-dimensional imaging was clinically justified. Although matching reduced confounding, patients could contribute more than one tooth and residual clustering may remain. Metallic artifacts may influence volumetric thresholds, especially around posts or dense crown substructures. Finally, the numerical results are simulated for article construction and must be replaced or confirmed with authentic CBCT measurements and valid ethical approval before submission. Recent 2026 clinical and systematic-review evidence also indicates that adequately endodontically treated teeth show resorption that is comparable to or lower than that of vital teeth during orthodontic treatment **[17-19].** The direction of the reported comparison is consistent with the meta-analysis of root-filled versus vital teeth and a subsequent mandibular-molar radiographic study; both support discussing pulpal status as a possible modifier while acknowledging observational confounding and differences between panoramic and CBCT measurements **[20, 21]**.

Conclusion:

Endodontically treated teeth restored with prosthetic crowns showed no increase in CBCT-detected root resorption after fixed orthodontic treatment and showed slightly less linear and

volumetric loss than matched vital crowned teeth. Treatment duration, extraction mechanics and greater apical displacement were more consistent predictors of resorption severity than crown material. Thus, data support cautious orthodontic movement of adequately treated, asymptomatic endodontic teeth while emphasizing individualized force control and radiographic monitoring for all teeth at elevated resorption risk.

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