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Cervical dentin thickness and root-to-crown ratio in endodontically treated versus healthy teeth: a retrospective cone-beam computed tomography study

Ahmet Bölük

aboluk@ankara.edu.tr

Ankara University

Cansu Yavuz

Ankara University

Hilal Okyar

Ankara University

Işıl Onat

Ankara University

Sevde Naz Gökdağ

Ankara University

Gizem Hanoğlu

Ankara University

Meltem Dartar Öztan

Ankara University

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Abstract

Background

Cervical dentin thickness (CDT) and root-to-crown ratio (RCR) are anatomical parameters associated with structural stability and fracture susceptibility in endodontically treated teeth. Population-specific cone-beam computed tomography (CBCT) data comparing treated teeth with structurally intact healthy teeth remain limited. This study compared CDT and RCR between endodontically treated teeth and healthy controls in a Turkish population and identified predictors of CDT.

Methods

This retrospective CBCT study analyzed 794 endodontically treated teeth and 200 healthy controls from scans obtained at Ankara University Faculty of Dentistry (January 2020–December 2025). Images were acquired using Planmeca ProMax 3D and analyzed with Synapse 7.1. CDT was measured as the shortest distance between the root canal wall and the external root surface at the cementoenamel junction; RCR was calculated as root length divided by crown length.

Results

Mean CDT was significantly lower in endodontically treated teeth than in healthy controls (1.427 ± 0.522 mm vs. 1.781 ± 0.529 mm; $p < 0.001$; mean difference 0.354 mm; Cohen's $d = 0.68$). Overall, 20.0% of treated teeth had CDT ≤ 1.0 mm versus 4.0% of controls. Mandibular incisors showed the lowest CDT among treated teeth (77.8–85.7% ≤ 1.0 mm). Tooth type explained a modest proportion of CDT variance in the study group ($\eta^2 = 0.072$) but a large proportion in controls ($\eta^2 = 0.722$). Sex predicted CDT in controls ($B = -0.201$, $p < 0.001$; females approximately 0.2 mm thinner) but not in the study group ($p = 0.284$). Mean RCR did not differ between groups (1.409 ± 0.466 vs. 1.502 ± 0.382; $p = 0.082$).

Conclusions

Endodontically treated teeth showed significantly lower CDT than healthy controls, with the largest reductions in molars; after Bonferroni correction, only molar tooth types retained significant between-group differences. Mandibular incisors showed CDT below the 1.0 mm threshold regardless of endodontic status. Given the retrospective design and absence of pretreatment scans, these differences represent associations rather than causal effects. The findings support conservative access preparation, cautious instrumentation, and individualized restorative planning in structurally vulnerable teeth.

Background

Endodontically treated teeth are generally considered structurally vulnerable, in part because caries, previous restorations, access cavity preparation, canal instrumentation, and post-endodontic restorative

procedures may cumulatively reduce remaining dentin. Clinical studies also show that restorative history is relevant to endodontic risk; teeth with two or three previous restorations had approximately fourfold and sixfold higher odds, respectively, of requiring primary endodontic treatment after single-unit crown cementation compared with teeth with one previous restoration [1].

Cervical and pericervical dentin are particularly important because this region contributes to the biomechanical integrity of the tooth and is exposed to stress concentration during functional loading. Finite element evidence indicates that thinner cervical dentin produces greater stress concentration, while increasing residual dentin thickness reduces maximum and minimum stress values [2]. In vitro studies confirm that endodontic and restorative procedures substantially reduce tooth stiffness [3] and that teeth with thinner pericervical dentin exhibit reduced fracture resistance [4].

Root-to-crown ratio (RCR) is another clinically important morphological parameter, particularly in the context of prosthodontic and endodontic treatment planning. Teeth with unfavorable RCR may have reduced anchorage and increased risk of biomechanical failure. Several population studies have assessed RCR using panoramic radiography and cone-beam computed tomography (CBCT), reporting variation by tooth type, sex, and ethnicity [5, 6, 7, 9].

However, CDT and RCR data comparing endodontically treated teeth and healthy controls are scarce. Most existing studies have evaluated dentin thickness changes associated with specific procedures (instrumentation, post preparation) rather than comparing post-treatment anatomical dimensions with healthy references. Population-specific CBCT data, particularly for Turkish populations, are also limited.

Therefore, this study aimed to (1) compare CDT and RCR between endodontically treated teeth and healthy controls across 14 tooth types, (2) identify anatomical and demographic predictors of CDT, and (3) determine the proportion of endodontically treated teeth falling below the clinically relevant 1.0 mm CDT threshold.

The null hypothesis was that there is no statistically significant difference in CDT or RCR between endodontically treated teeth and healthy controls when compared across 14 tooth types in a Turkish population.

Methods

Study design and ethical approval

This retrospective observational CBCT study was conducted at the Department of Endodontics, Faculty of Dentistry, Ankara University, Ankara, Türkiye. The study protocol was approved by the Non-Clinical Research Ethics Committee of Ankara University Faculty of Dentistry (approval no: 19/14, dated 02 March 2026) and was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013). Because the study used anonymized retrospective radiographic data, the requirement for informed consent was waived by the ethics committee.

This manuscript was prepared in accordance with the Preferred Reporting Items for Studies in Endodontology (PROBE) recommendations [10] and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies [11].

Study population and sample selection

CBCT scans acquired between January 2020 and December 2025 were retrospectively reviewed from the institutional radiographic database. One tooth per patient was included in both the study and control groups to ensure statistical independence of observations.

The study group consisted of permanent teeth with completed root canal treatment, adequate root canal obturation visible on CBCT, fully formed root apices, and adequate image quality for measurement. The control group consisted of healthy permanent teeth with intact pulps, no endodontic treatment, no visible caries or restorations, no periapical pathology, fully formed root apices, and adequate image quality.

Teeth were excluded if they had incomplete root formation, root resorption, fractures, periapical lesions, severe crown destruction preventing accurate CEJ identification, poor-quality CBCT images, artifacts preventing accurate measurement, posts, or extensive coronal restorations obscuring cervical anatomy. Third molars were excluded due to high anatomical variability and frequent morphological irregularities that may compromise measurement reliability.

A total of 794 patients contributed one endodontically treated tooth each to the study group. The control group comprised 200 healthy teeth from 200 patients. Figure 1 presents the study flow diagram.

Sample size calculation

The statistical adequacy of the sample was evaluated using G*Power 3.1.9.7 software (Heinrich Heine University, Düsseldorf, Germany). For one-way ANOVA comparing measurements across 14 tooth types, assuming a medium effect size ($f = 0.25$), $\alpha = 0.05$, and power = 0.95, the minimum required sample size was 400. For the multiple linear regression model evaluating the combined effects of age, sex, and tooth type on CDT (15 predictors: age, sex, and 13 dummy-coded tooth types), assuming a small-to-medium effect size ($f^2 = 0.05$), $\alpha = 0.05$, and power = 0.95, the minimum required sample size was 395. The study group (n = 794) exceeded all calculated minimum sample sizes. For the control group (n = 200), the per-tooth-type ANOVA was underpowered relative to the calculated minimum of 400; however, the regression model and overall between-group comparison retained adequate power.

CBCT imaging protocol

All CBCT scans were acquired using a Planmeca ProMax 3D cone-beam computed tomography unit (Planmeca Oy, Helsinki, Finland). Images were obtained using manufacturer default settings optimized for dentoalveolar imaging. Typical scanning parameters included a field of view appropriate for the clinical indication and voxel size ≤ 0.2 mm; exposure parameters, including kVp and mA, were automatically

adjusted by the device according to patient anatomy to maintain diagnostic image quality while minimizing radiation dose according to ALARA principles.

Image reconstruction and analysis were performed using Synapse 7.1 software (Fujifilm, Tokyo, Japan), a certified PACS/DICOM viewer with calibrated linear measurement tools. Multiplanar reconstruction (MPR) was used to align measurement planes perpendicular to the long axis of each tooth. All measurements were performed on calibrated workstations under standardized viewing conditions, including ambient lighting, monitor brightness, and contrast settings. The software's built-in linear measurement tools operate on native DICOM coordinate data; measurement precision was nonetheless constrained by the spatial resolution of the acquired CBCT data.

CBCT was selected because it enables three-dimensional assessment of dental hard tissues and root morphology without the superimposition inherent to two-dimensional radiographs; professional position statements support its use in endodontics where three-dimensional information is required for diagnosis or management [12, 13]. Previous studies have validated CBCT-based measurements of residual dentin thickness and root canal wall dimensions [14, 15].

Measurement protocol

All measurements were performed by two calibrated examiners using Synapse 7.1 software. Examiners were blinded to patient demographic information and clinical history during image assessment.

CDT was defined as the shortest distance between the root canal wall and the external root surface at the cervical level. Measurements were performed on the axial slice corresponding to the cementoenamel junction. For each tooth, dentin thickness was measured in the mesial, distal, buccal, and lingual/palatal directions, and the smallest of these four values was recorded as the CDT for that tooth.

RCR was calculated as root length divided by crown length. Root length was measured from the root apex to the CEJ along the long axis of the tooth. Crown length was measured from the CEJ to the incisal edge in anterior teeth or the highest cusp tip in posterior teeth. For multi-rooted teeth, the longest root was used for RCR calculation.

The use of the CEJ as a reference landmark is consistent with anatomical RCR definitions, in which the root is measured from the apex to the CEJ and the crown from the CEJ to the incisal edge or cusp tip [5, 17].

Reliability assessment

To assess measurement reliability, 10% of the sample was randomly selected and measured independently by both examiners. Intra-observer reliability was assessed by repeated measurements after a two-week interval. Intraclass correlation coefficients (ICC) with 95% confidence intervals were calculated for continuous CDT and RCR measurements.

Inter-observer reliability for CDT measurements was excellent (ICC = 0.94; 95% CI: 0.91 to 0.96). Intra-observer reliability was excellent for both examiners (Examiner 1: ICC = 0.96; 95% CI: 0.94 to 0.97; Examiner

2: ICC = 0.95; 95% CI: 0.93 to 0.97). Inter-observer reliability for RCR measurements was excellent (ICC = 0.92; 95% CI: 0.89 to 0.95). Intra-observer reliability for RCR was excellent for both examiners (Examiner 1: ICC = 0.94; 95% CI: 0.92 to 0.96; Examiner 2: ICC = 0.93; 95% CI: 0.90 to 0.95).

Statistical analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated as means, standard deviations, medians, ranges, frequencies, and percentages. Normality was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots.

Between-group comparisons for CDT and RCR were performed using Mann-Whitney U tests when normality assumptions were not met. Comparisons across tooth types were performed using one-way ANOVA with Tukey HSD post hoc tests or Kruskal-Wallis tests with Dunn's post hoc tests, depending on distributional assumptions. Effect sizes were reported as eta-squared (η^2) for ANOVA and as rank-biserial r for Mann-Whitney U tests.

Multiple linear regression was used to identify predictors of CDT, with age and sex entered as covariates and tooth type dummy-coded using 13 indicator variables (reference category: maxillary central incisor). Model fit was assessed by R^2 and adjusted R^2, and individual predictor significance was evaluated at $\alpha = 0.05$. Because tooth type is a nominal variable with 14 categories, it was represented by 13 dummy variables rather than as a single numeric predictor; therefore, its overall contribution was assessed by the change in R^2 (ΔR^2) when the set of tooth-type indicators was added to the model, rather than by a single standardized coefficient.

Per-tooth-type comparisons between groups were considered exploratory. Both unadjusted p-values and Bonferroni-corrected p-values ($\alpha/14 = 0.0036$) are reported to account for multiple comparisons across 14 tooth types.

Results

Sample characteristics

The study group comprised 794 endodontically treated teeth from 794 patients. The mean age was 38.3 ± 13.8 years (range: 13–77), and 58.4% were female. The control group comprised 200 healthy teeth from 200 patients. The mean age was 37.4 ± 11.1 years (range: 19–72), and 56.5% were female.

Cervical dentin thickness in endodontically treated teeth

Mean CDT in the study group was 1.427 ± 0.522 mm (95% CI: 1.391–1.463; median: 1.364 mm; range: 0.007–3.572 mm). Overall, 20.0% (159/794) of endodontically treated teeth had CDT ≤ 1.0 mm.

Significant differences in CDT were observed across the 14 tooth types (one-way ANOVA: $F = 4.65$, $p < 0.001$, $\eta^2 = 0.072$). Mandibular central incisors and mandibular lateral incisors exhibited the thinnest CDT values (0.883 ± 0.613 mm and 0.881 ± 0.386 mm, respectively), with 85.7% and 77.8% having CDT ≤ 1.0 mm.

Maxillary first premolars also demonstrated a high prevalence of thin CDT, with 34.2% having CDT ≤ 1.0 mm. Data are presented in Table 1.

Table 1
Cervical dentin thickness and root-to-crown ratio by tooth type in the study and control groups

Tooth type	Study n	Study CDT (mm)	SD	CDT ≤ 1.0 mm (%)	Study RCR	SD	Control n	Control CDT (mm)	SD	CDT ≤ 1.0 mm (%)
Maxillary central incisor	31	1.706	0.509	3.2	1.087	0.393	11	1.405	0.225	0.0
Maxillary lateral incisor	40	1.300	0.573	30.0	1.247	0.283	6	1.273	0.410	33.3
Maxillary canine	41	1.603	0.460	4.9	1.718	0.746	7	1.637	0.230	0.0
Maxillary 1st premolar	73	1.288	0.507	34.2	1.314	0.431	22	1.393	0.263	0.0
Maxillary 2nd premolar	111	1.347	0.477	21.6	1.464	0.436	24	1.529	0.267	0.0
Maxillary 1st molar	123	1.489	0.441	13.8	1.338	0.419	22	2.194	0.343	0.0
Maxillary 2nd molar	55	1.513	0.472	18.2	1.290	0.458	23	2.236	0.298	0.0
Mandibular central incisor	14	0.883	0.613	85.7	1.073	0.324	6	1.091	0.221	50.0
Mandibular lateral incisor	9	0.881	0.386	77.8	1.082	0.407	8	1.102	0.211	37.5
Mandibular canine	18	1.378	0.499	22.2	1.090	0.449	5	1.404	0.266	0.0
Mandibular 1st premolar	34	1.325	0.516	17.6	1.539	0.423	17	1.517	0.168	0.0
Mandibular 2nd premolar	75	1.423	0.407	12.0	1.583	0.461	14	1.570	0.329	0.0
Mandibular 1st molar	112	1.500	0.588	18.8	1.515	0.424	20	2.510	0.287	0.0

CDT cervical dentin thickness, RCR root-to-crown ratio, SD standard deviation. Study group ANOVA for CDT: $F = 4.65$, $p < 0.001$, $\eta^2 = 0.072$; ANOVA for RCR: $F = 7.60$, $p < 0.001$, $\eta^2 = 0.112$. Control group ANOVA for CDT: $F = 37.14$, $p < 0.001$, $\eta^2 = 0.722$.

Tooth type	Study n	Study CDT (mm)	SD	CDT ≤ 1.0 mm (%)	Study RCR	SD	Control n	Control CDT (mm)	SD	CDT ≤ 1.0 mm (%)
Mandibular 2nd molar	58	1.512	0.631	15.5	1.484	0.373	15	2.287	0.381	0.0
Overall	**794**	**1.427**	**0.522**	**20.0**	**1.409**	**0.466**	**200**	**1.781**	**0.529**	**4.0**

CDT cervical dentin thickness, RCR root-to-crown ratio, SD standard deviation. Study group ANOVA for CDT: $F = 4.65$, $p < 0.001$, $\eta^2 = 0.072$; ANOVA for RCR: $F = 7.60$, $p < 0.001$, $\eta^2 = 0.112$. Control group ANOVA for CDT: $F = 37.14$, $p < 0.001$, $\eta^2 = 0.722$.

In multiple linear regression (Table 2), the set of 13 tooth-type dummy variables significantly improved model fit beyond age alone ($\Delta R^2 = 0.064$, $p < 0.001$). The full model (age + sex + tooth type) accounted for 9.1% of CDT variance ($R^2 = 0.091$, adjusted $R^2 = 0.075$, $F = 5.59$, $p < 0.001$). Age showed a weak but statistically significant negative association with CDT (B = − 0.006, $p < 0.001$), corresponding to an estimated reduction of approximately 0.06 mm per decade. Sex was not a significant predictor ($p = 0.284$).

Table 2
Multiple linear regression models for prediction of cervical dentin thickness

Predictor	B (study)	95% CI (study)	p (study)	B (control)	95% CI (control)	p (control)
Intercept	1.612	[1.378, 1.846]	< 0.001	2.485	[2.103, 2.867]	< 0.001
Age	−0.006	[− 0.008, − 0.003]	< 0.001	−0.004	[− 0.010, 0.003]	0.287
Sex (female)	0.038	[− 0.032, 0.108]	0.284	−0.201	[− 0.293, − 0.109]	< 0.001
Tooth type (13 dummies)	—	$\Delta R^2 = 0.064$	< 0.001	—	$\Delta R^2 = 0.720$	< 0.001
Model summary	**$R^2 = 0.091$**	**Adj $R^2 = 0.075$**	**F = 5.59**	**$R^2 = 0.790$**	**Adj $R^2 = 0.750$**	**F = 19.39**

CI confidence interval. Tooth type was dummy-coded with 13 indicator variables (reference: maxillary central incisor). The overall contribution of tooth type is reported as ΔR^2 (change in R^2 when the 13 dummy variables are added to the model containing age and sex). Individual dummy coefficients are available in Additional file 1 (Table S1). Study model: $F = 5.59$, $p < 0.001$; control model: $F = 19.39$, $p < 0.001$.

Root-to-crown ratio in endodontically treated teeth

Mean RCR in the study group was 1.409 ± 0.466 (95% CI: 1.377–1.441; median: 1.389; range: 0.315–4.102). Overall, 18.8% (149/794) of endodontically treated teeth had RCR < 1.0.

Significant differences in RCR were observed across tooth types (one-way ANOVA: $F = 7.60$, $p < 0.001$, $\eta^2 = 0.112$). Maxillary canines exhibited the highest mean RCR (1.718 ± 0.746), while mandibular central incisors showed the lowest mean RCR (1.073 ± 0.324). Data are presented in Table 1.

Cervical dentin thickness in healthy control teeth

Mean CDT in the control group was 1.781 ± 0.529 mm (95% CI: 1.707–1.855; median: 1.680 mm; range: 0.777–3.318 mm). Only 4.0% (8/200) of healthy control teeth had CDT ≤ 1.0 mm (Table 1).

Significant differences in CDT were observed across the 14 tooth types (one-way ANOVA: $F = 37.14$, $p < 0.001$, $\eta^2 = 0.722$). Molars exhibited the greatest CDT values (mandibular first molar: 2.510 ± 0.287 mm; maxillary second molar: 2.236 ± 0.298 mm), while mandibular incisors showed the thinnest CDT (mandibular central incisor: 1.091 ± 0.221 mm; mandibular lateral incisor: 1.102 ± 0.211 mm).

In multiple linear regression for the control group (Table 2), the full model (age + sex + tooth type) accounted for 79.0% of CDT variance ($R^2 = 0.790$, adjusted $R^2 = 0.750$, $F = 19.39$, $p < 0.001$). Tooth type was the dominant predictor ($\Delta R^2 = 0.720$, $p < 0.001$). Age was not a significant predictor ($p = 0.287$). Sex was a significant predictor in the control group ($B = -0.201$, 95% CI: −0.293 to − 0.109, $p < 0.001$), indicating that female patients had approximately 0.2 mm thinner CDT than males after controlling for age and tooth type.

Root-to-crown ratio in healthy control teeth

Mean RCR in the control group was 1.502 ± 0.382 (95% CI: 1.449–1.555; median: 1.460; range: 0.800–2.800). Data are presented in Table 1.

Comparison between endodontically treated and healthy teeth

Mean CDT was significantly lower in the study group than in the control group (1.427 ± 0.522 mm vs. 1.781 ± 0.529 mm; Mann-Whitney U test: $p < 0.001$; effect size $r = 0.26$; Cohen's $d = 0.68$). The mean difference was 0.354 mm (95% CI: 0.265–0.443). The null hypothesis of no difference in CDT was therefore rejected.

Per-tooth-type comparisons are presented in Table 3. After Bonferroni correction (adjusted $\alpha = 0.0036$), significant CDT reductions in endodontically treated teeth were limited to molar tooth types: mandibular first molars (ΔCDT = + 1.011 mm; $p < 0.001$), mandibular second molars (ΔCDT = + 0.775 mm; $p < 0.001$), maxillary second molars (ΔCDT = + 0.723 mm; $p < 0.001$), and maxillary first molars (ΔCDT = + 0.706 mm; $p < 0.001$). Several premolar and anterior tooth type comparisons reached nominal significance ($p < 0.05$) but did not survive Bonferroni correction (Table 3).

Table 3

Per-tooth-type comparison of cervical dentin thickness between groups with Bonferroni correction

Tooth type	Control mean ± SD (n)	Study mean ± SD (n)	ΔCDT (mm)	Mann-Whitney p	Bonferroni p	Significance
Maxillary central incisor	1.405 ± 0.225 (11)	1.706 ± 0.509 (31)	−0.301	0.067	0.940	ns
Maxillary lateral incisor	1.273 ± 0.410 (6)	1.300 ± 0.573 (40)	−0.028	0.962	1.000	ns
Maxillary canine	1.637 ± 0.230 (7)	1.603 ± 0.460 (41)	+ 0.034	0.422	1.000	ns
Maxillary 1st premolar	1.393 ± 0.263 (22)	1.288 ± 0.507 (73)	+ 0.105	0.025	0.346	ns†
Maxillary 2nd premolar	1.529 ± 0.267 (24)	1.347 ± 0.477 (111)	+ 0.181	0.011	0.154	ns†
Maxillary 1st molar	2.194 ± 0.343 (22)	1.489 ± 0.441 (123)	+ 0.706	< 0.001	< 0.001	***
Maxillary 2nd molar	2.236 ± 0.298 (23)	1.513 ± 0.472 (55)	+ 0.723	< 0.001	< 0.001	***
Mandibular central incisor	1.091 ± 0.221 (6)	0.883 ± 0.613 (14)	+ 0.208	0.033	0.458	ns†
Mandibular lateral incisor	1.102 ± 0.211 (8)	0.881 ± 0.386 (9)	+ 0.221	0.038	0.538	ns†
Mandibular canine	1.404 ± 0.266 (5)	1.378 ± 0.499 (18)	+ 0.026	0.857	1.000	ns
Mandibular 1st premolar	1.517 ± 0.168 (17)	1.325 ± 0.516 (34)	+ 0.192	0.023	0.318	ns†
Mandibular 2nd premolar	1.570 ± 0.329 (14)	1.423 ± 0.407 (75)	+ 0.147	0.086	1.000	ns
Mandibular 1st molar	2.510 ± 0.287 (20)	1.500 ± 0.588	+ 1.011	< 0.001	< 0.001	***

*CDT cervical dentin thickness, SD standard deviation, ns not significant. ΔCDT = control mean − study mean; positive values indicate thicker CDT in controls (reduced CDT in endodontically treated teeth). Bonferroni p = unadjusted p × 14. *** Significant after Bonferroni correction (p < 0.0036). † Nominally significant (p < 0.05) but not significant after Bonferroni correction.*

Tooth type	Control mean ± SD (n)	Study mean ± SD (n)	ΔCDT (mm)	Mann-Whitney p	Bonferroni p	Significance
		(112)				
Mandibular 2nd molar	2.287 ± 0.381 (15)	1.512 ± 0.631 (58)	+ 0.775	< 0.001	< 0.001	***

*CDT cervical dentin thickness, SD standard deviation, ns not significant. ΔCDT = control mean − study mean; positive values indicate thicker CDT in controls (reduced CDT in endodontically treated teeth). Bonferroni p = unadjusted p × 14. *** Significant after Bonferroni correction (p < 0.0036). † Nominally significant (p < 0.05) but not significant after Bonferroni correction.*

Maxillary anterior teeth (central incisors, lateral incisors, canines) showed no significant CDT differences between groups at any significance threshold (all $p > 0.05$).

Mean RCR did not differ significantly between the study group and control group (1.409 ± 0.466 vs. 1.502 ± 0.382; Mann-Whitney U test: $p = 0.082$). The null hypothesis of no difference in RCR was not rejected.

Discussion

Principal findings

This retrospective CBCT study demonstrated that endodontically treated teeth exhibit significantly lower cervical dentin thickness than healthy controls, with a mean difference of 0.354 mm and a medium effect size (Cohen's $d = 0.68$). After Bonferroni correction for 14 simultaneous comparisons, statistically significant CDT reductions were confined to molar tooth types, where absolute differences ranged from 0.706 mm (maxillary first molars) to 1.011 mm (mandibular first molars). In contrast, RCR did not differ significantly between groups. These findings partially reject the null hypothesis: CDT, but not RCR, differed significantly between endodontically treated and healthy teeth.

Cervical dentin thickness: comparison with the literature

The direction of the present findings is consistent with previous comparative cone-beam computed tomography evidence. Razumova et al. [18] compared intact and endodontically treated teeth and reported significantly lower dentinal thickness in treated teeth ($p < 0.05$), with dentine loss greatest in the coronal and middle thirds of the root and in molar teeth. Direct numerical comparison with the present data is limited, however, because that study expressed dentine loss as a percentage rather than in millimetres and measured at root-canal thirds rather than at the cementoenamel junction. The maxillary first premolar warrants particular comment. Katz et al. [19] reported that root canal and dowel space preparation in bifurcated maxillary premolars left residual dentin thickness below 1.0 mm on the palatal aspect of the buccal root. In the present study, teeth with posts were excluded, yet 34.2% of maxillary first premolars already had CDT ≤ 1.0 mm. This suggests that a substantial proportion of these teeth approach the critical threshold before any post space preparation is undertaken, and that the additional dentin removal required for a post may be poorly tolerated in this tooth type.

The finding that 20.0% of endodontically treated teeth had CDT ≤ 1.0 mm is clinically relevant, as reduced cervical dentin thickness, particularly in the region of 1 mm or less, has been associated with increased stress concentration and susceptibility to vertical root fracture [2, 20]. Vertical root fractures represent a significant complication in root-filled teeth, although reported prevalence varies widely—approximately 4% to 32%—depending on the diagnostic method and study population [31]. In one survey of root canal–treated teeth referred for extraction, vertical root fracture accounted for 10.9% of extractions [21]; such fractures occur predominantly in posterior teeth and typically present several years after treatment [22]. The high proportion of thin cervical dentin in certain tooth types—particularly mandibular incisors (77.8%–85.7%) and maxillary first premolars (34.2%)—suggests that these teeth may be inherently vulnerable to fracture regardless of the endodontic procedure performed.

Molar-specific CDT reduction

The observation that significant CDT differences were limited to molars after Bonferroni correction merits particular attention. Mandibular first molars showed the largest absolute difference between groups (ΔCDT = 1.011 mm), followed by mandibular second molars (0.775 mm) and maxillary second molars (0.723 mm). Several factors may explain this molar-specific pattern. First, molar teeth have larger canal dimensions and more complex root canal anatomy, potentially resulting in greater dentin removal during instrumentation [16, 23]. Second, molars are frequently subjected to more extensive instrumentation to achieve adequate debridement of their complex canal systems. Third, the biomechanical demands of the posterior region subject these teeth to greater functional loads, potentially contributing to progressive structural changes over time [3].

The clinical implication is that conservative access cavity preparation and minimal instrumentation strategies may be particularly important in molar teeth, where the margin between adequate canal debridement and structural compromise is narrowest. Preservation of pericervical dentin during access preparation has been associated with improved fracture resistance, although systematic-review evidence specifically for contracted endodontic access cavity designs remains mixed [24].

Anterior teeth: vulnerability regardless of endodontic status

Mandibular incisors consistently demonstrated CDT values below the 1.0 mm threshold in both groups. In the study group, 85.7% of mandibular central incisors and 77.8% of mandibular lateral incisors had CDT ≤ 1.0 mm. Notably, even healthy mandibular incisors showed relatively thin CDT (1.091 ± 0.221 mm and 1.102 ± 0.211 mm in central and lateral incisors, respectively), with 50.0% and 37.5% falling below the 1.0 mm threshold. This finding suggests that thin cervical dentin in mandibular incisors reflects inherent anatomical constraints rather than treatment-induced reduction. The between-group CDT differences for mandibular incisors (0.208 mm and 0.221 mm) were not statistically significant after Bonferroni correction, further supporting this interpretation.

Maxillary anterior teeth (central incisors, lateral incisors, canines) showed no significant CDT differences between groups at any threshold. Interestingly, maxillary central incisors in the study group exhibited numerically higher CDT than controls (1.706 vs. 1.405 mm; ΔCDT = − 0.301 mm), although this difference was not statistically significant (Bonferroni p = 0.940). This paradoxical direction may reflect selection bias:

endodontically treated maxillary central incisors that survived to be measured may represent structurally robust teeth, while more compromised teeth may have been extracted.

Sex as a predictor of CDT

An important finding of this study was the differential role of sex as a predictor of CDT between groups. In the control group, female sex was significantly associated with approximately 0.2 mm thinner CDT after controlling for age and tooth type ($B = -0.201$, $p < 0.001$). In contrast, sex was not a significant predictor in the study group ($B = 0.038$, $p = 0.284$). This differential effect may have two explanations. First, in healthy teeth, sexual dimorphism in tooth size and dentin dimensions is preserved, consistent with morphometric evidence of sexual dimorphism in mesiodistal dentin dimensions, with thinner dentin reported in female teeth [8]. Second, in endodontically treated teeth, iatrogenic dentin removal during access preparation and canal instrumentation may override the baseline anatomical sex differences, effectively masking the dimorphism that exists in untreated teeth.

This finding has clinical implications for risk stratification: female patients with healthy teeth may warrant closer monitoring of cervical dentin integrity when endodontic treatment is planned, particularly in molar regions where treatment-associated CDT reduction is greatest.

Root-to-crown ratio

Mean RCR did not differ significantly between endodontically treated teeth (1.409 ± 0.466) and healthy controls (1.502 ± 0.382; $p = 0.082$). This finding aligns with the expectation that root canal treatment does not directly alter crown or root length. The RCR values observed in the present study fall within the broad range reported for permanent teeth across populations, although mean values vary substantially with tooth-type composition and population. Sindi et al. [7] reported tooth-specific R/C ratios of approximately 1.6 to 2.0 in Saudi adults, and Ye et al. [9] characterized R/C ratios and short root anomaly in a Chinese population; direct numerical comparison across studies is limited by differences in imaging modality, measurement landmarks, and tooth-type distribution. Ethnic variation in RCR has been documented, with reported values varying by population and tooth type [25].

Maxillary canines exhibited the highest RCR (1.718 ± 0.746) in the study group, consistent with their characteristically long roots [7, 17]. Mandibular central incisors showed the lowest RCR (1.073 ± 0.324), indicating relatively short roots relative to crowns. Among endodontically treated teeth, 18.8% had RCR < 1.0, indicating that the crown was longer than the root. Although this proportion is notable, it did not differ meaningfully from healthy teeth. Short root anomaly, first described in maxillary central incisors with a mean root-to-crown ratio of approximately 1.1 compared with approximately 1.6 in unaffected individuals, has been associated with a predisposition to root resorption in the maxillary anterior region [26]; its clinical significance in endodontic prognosis, however, remains unclear.

Variance explained by tooth type

Tooth type explained markedly different proportions of CDT variance between groups: $\eta^2 = 0.072$ in the study group versus $\eta^2 = 0.722$ in the control group. In healthy teeth, anatomical tooth type is the dominant

determinant of cervical dentin dimensions, reflecting inherent morphological differences across the dentition. In endodontically treated teeth, however, the dramatically lower η^2 indicates that treatment-related factors—including canal instrumentation, access cavity design, and pre-existing caries—introduce variability that substantially attenuates the influence of tooth type. This finding reinforces the concept that post-treatment CDT is determined by a combination of original anatomy and procedure-related dentin removal, rather than by anatomy alone.

The multiple regression model for the control group accounted for 79.0% of CDT variance ($R^2 = 0.790$), with tooth type contributing the vast majority ($\Delta R^2 = 0.720$). In the study group, the full model explained only 9.1% of CDT variance. The large unexplained variance in the study group suggests that factors not captured in the model—such as extent of caries, number and type of prior restorations, instrumentation technique, and operator factors—are the principal determinants of remaining cervical dentin in endodontically treated teeth.

Clinical implications

The present findings support several clinical recommendations. First, the consistent CDT reduction in molars underscores the importance of conservative instrumentation protocols and minimal access cavity designs in posterior teeth. Preservation of pericervical dentin should be a primary objective during access preparation, as the mean CDT reduction in mandibular first molars (1.011 mm) approaches the total available dentin thickness in some cases. Second, mandibular incisors should be recognized as inherently thin-dentined teeth in which even conservative procedures may bring CDT below critical thresholds. Third, post-endodontic restorative planning should incorporate tooth type–specific risk assessment: molars may benefit from cuspal coverage, as survival of endodontically treated molars without crown coverage declines markedly over time and depends strongly on the amount of remaining tooth structure [27], whereas adhesive restorative approaches that distribute functional loads may be considered for anterior teeth [28].

The sex-dependent difference observed in healthy teeth further suggests that female patients with posterior teeth requiring endodontic treatment may represent a higher-risk subgroup for structural compromise, warranting particularly conservative preparation strategies.

Limitations

Several limitations should be considered when interpreting these findings. First, the retrospective cross-sectional design precludes causal inference. Pre-treatment CBCT scans were not available; therefore, the observed CDT differences between endodontically treated and healthy teeth cannot be attributed solely to the endodontic procedure. Caries excavation, previous restorations, and other pre-existing conditions may have contributed to dentin loss prior to root canal treatment. Second, information regarding specific instrumentation techniques, file sizes, access cavity dimensions, and clinician experience was not available, precluding analysis of procedure-specific variables. Third, the control group (n = 200) was smaller than the study group (n = 794) and did not meet the calculated minimum sample size of 400 for adequate power in per-tooth-type ANOVA. Although the overall between-group comparison and regression models retained adequate statistical power, the per-tooth-type control group analyses—particularly for tooth types with fewer than 10 specimens—should be interpreted with caution. Fourth, CDT was measured at a single cervical level

(CEJ), which may not capture variation along the root length. Fifth, CBCT measurements are subject to inherent limitations including voxel size constraints and potential blooming artifacts from radiopaque root canal filling materials [15, 29, 30]. Although the software's calibrated linear measurement tools minimize systematic error, sub-voxel measurement precision should not be overinterpreted.

Finally, the single-center design and Turkish population may limit generalizability to other ethnic groups, as root-to-crown ratios have been shown to vary with ethnicity [25].

Conclusions

Endodontically treated teeth exhibited significantly lower CDT than healthy controls, with a mean difference of 0.354 mm. After correction for multiple comparisons, statistically significant CDT reductions were confined to molar tooth types, where absolute differences exceeded 0.7 mm. Mandibular incisors demonstrated CDT values below the 1.0 mm clinical threshold regardless of endodontic status, suggesting inherent anatomical vulnerability. Sex was a significant predictor of CDT in healthy teeth but not in endodontically treated teeth, indicating that iatrogenic factors may override baseline sexual dimorphism. RCR did not differ significantly between groups. These findings support conservative access preparation, cautious instrumentation, and individualized restorative approaches—particularly in molars, mandibular incisors, and female patients—to preserve remaining cervical dentin integrity.

Abbreviations

CBCT
Cone-beam computed tomography
CDT
Cervical dentin thickness
RCR
Root-to-crown ratio
CEJ
Cementoenamel junction
ANOVA
Analysis of variance
ETT
Endodontically treated teeth
ICC
Intraclass correlation coefficient
MPR
Multiplanar reconstruction
PACS
Picture archiving and communication system
DICOM
Digital imaging and communications in medicine

VRF
Vertical root fracture
PROBE
Preferred Reporting Items for Studies in Endodontology
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
ALARA
As low as reasonably achievable

Declarations

Ethics approval and consent to participate

This study was approved by the Non-Clinical Research Ethics Committee of Ankara University Faculty of Dentistry (approval no: 19/14, dated 02 March 2026). The study was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013). Because the study used anonymized retrospective radiographic data, the requirement for informed consent was waived by the ethics committee.

Consent for publication

Not applicable. No individual patient data or identifiable images are presented.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

AB: conceptualization, methodology, data collection, statistical analysis, writing—original draft, writing—review and editing. CY: data collection, measurements, writing—review and editing. HO: data collection, measurements. IO: data collection, measurements. SNG: data collection. GH: data collection. MDÖ: supervision, writing—review and editing, project administration. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

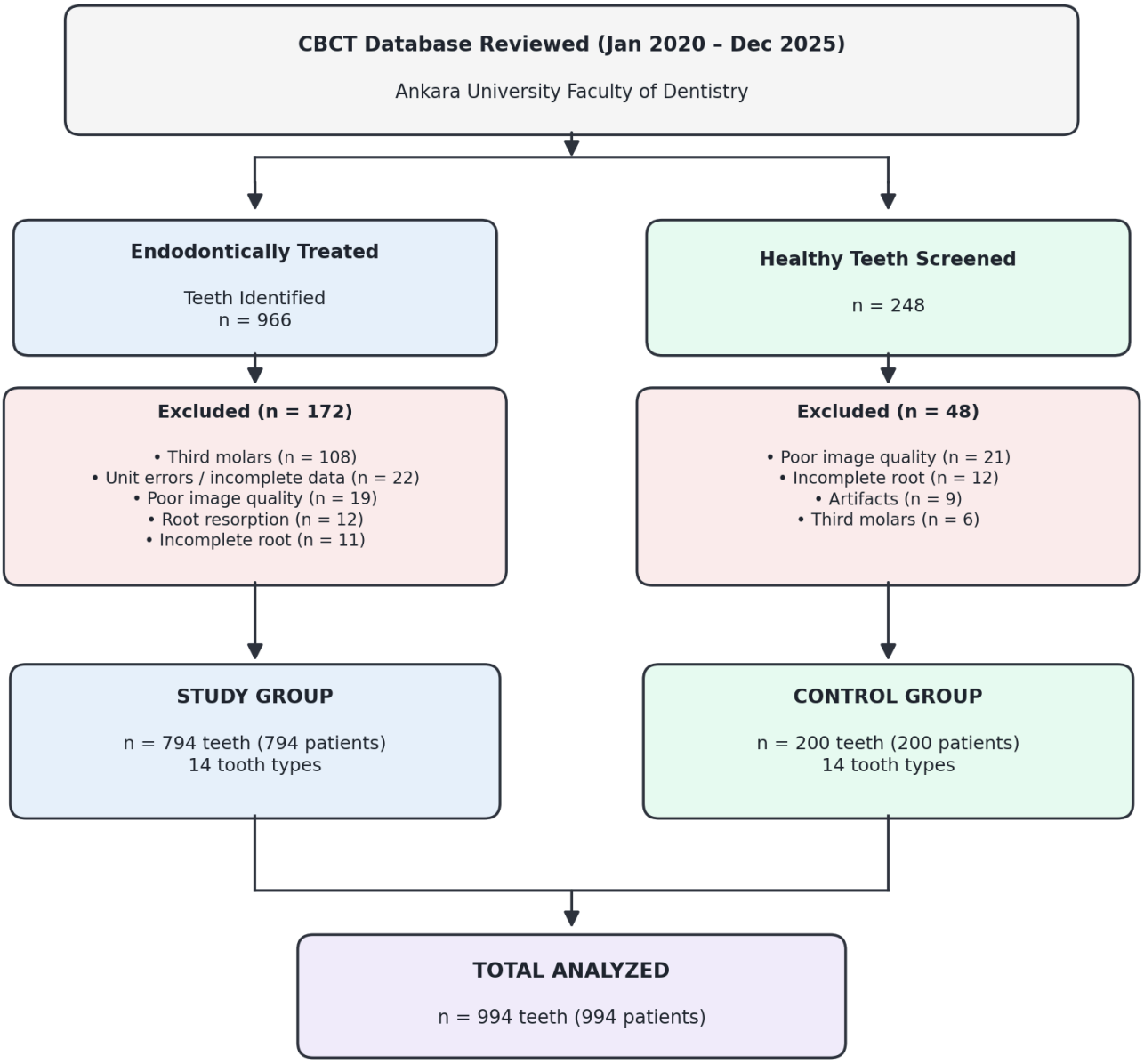


Figure 1

Study flow diagram showing patient/tooth selection, exclusion criteria, and final sample sizes. One tooth per patient was included in both groups.