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ORIGINAL RESEARCH

Prevalence and morphometric analysis of taurodontism in first permanent molars: a retrospective cone-beam computed tomography study

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Abstract

Background: Variations in pulp chamber morphology associated with taurodontism can complicate clinical procedures. Cone-beam computed tomography (CBCT) enables detailed three-dimensional assessment of dental morphology and may improve the detection of taurodont characteristics. This study aimed to determine the prevalence and morphometric characteristics of taurodontism in first permanent molars using CBCT. **Methods**: This retrospective study analyzed CBCT scans of 105 individuals aged 10–16 years. Maxillary and mandibular permanent first molars were evaluated in sagittal sections. Pulp chamber height (T_1) and the distance from the pulp chamber roof to the root apex (T_2) were measured. The taurodontism index was calculated as $T_1/T_2 \times 100$. According to the classification proposed by Shifman and Chanannel, teeth were categorized as normal, hypotaurodont, mesotaurodont, or hypertaurodont. Data distribution was evaluated, and group comparisons were performed using appropriate non-parametric and chi-square tests. A significant level of $p < 0.05$ was applied. **Results**: The mean T_1 was 3.60 ± 0.76 mm, and T_2 was 17.69 ± 2.10 mm, while the T_1/T_2 ratio was 20.86 ± 6.64. Taurodont morphology was identified in 21.4% of evaluated teeth, including 14.5% hypotaurodont, 6.0% mesotaurodont, and 1.0% hypertaurodont cases. However, pulp chamber height was significantly greater in maxillary molars compared with mandibular molars ($p = 0.010$). Additionally, the distribution of taurodontism differed significantly between the maxilla and mandible ($p = 0.047$). **Conclusions**: CBCT-based morphometric analysis demonstrated that taurodontism was present in a considerable proportion of first permanent molars in children and adolescents. Hypotaurodontism was the most frequently observed subtype. Within the applied inclusion criteria, no significant associations were observed with gender or tooth side. These findings provide CBCT-derived morphometric reference data for first permanent molars in a pediatric population. Furthermore, the results highlight the value of three-dimensional imaging in the accurate identification of taurodont morphology in clinical practice.

Keywords

Cone-beam computed tomography; Pediatric dentistry; Morphology; Permanent molars; Taurodontism

1. Introduction

Taurodontism is a developmental morphological anomaly that is characterized by vertical elongation of the pulp chamber, apical displacement of the furcation area, and absence of normal cervico-apical constriction in multirooted teeth [1, 2]. This condition is thought to result from altered timing in the horizontal invagination of Hertwig's epithelial root sheath during odontogenesis. As a result, affected teeth exhibit shortened roots and an enlarged pulp chamber [3]. These anatomical variations may complicate endodontic access and canal identification, thereby reducing treatment predictability. Additionally, reduced root length may adversely affect prosthetic stability and surgical planning [4, 5].

The reported prevalence of taurodontism varies considerably across studies. This variability has been attributed to multiple factors, including imaging modality, diagnostic criteria, sample size, and ethnic background of the studied population [6–8]. Ethnic and population-based differences in craniofacial development, tooth morphogenesis, and genetically regulated root formation patterns have been proposed as potential contributors to this variability. Therefore, prevalence data should be interpreted in the context of population-specific anatomical and genetic characteristics.

Conventional two-dimensional radiographic techniques, such as panoramic imaging, have limited diagnostic accuracy for detecting taurodontism. This limitation is primarily due to image distortion, magnification errors, and anatomical superimposition [9]. In contrast, cone-beam computed tomography (CBCT) provides high-resolution, three-dimensional, and distortion-free imaging, allowing precise visualization of pulp chamber morphology, furcation position, and root anatomy [10]. These advantages are particularly important for morphometric measurements such as pulp chamber height, root length, and roof–apex distance, which cannot be reliably assessed using two-dimensional methods [11]. With the increasing use of CBCT in dental diagnostics, a noticeable rise in reported taurodontism prevalence has been observed in the literature. This trend suggests that previously reported lower prevalence rates may have been underestimated due to limitations of conventional imaging techniques rather than reflecting true biological differences alone [12, 13]. Moreover, CBCT enables detailed assessment of jaw-specific (maxilla versus mandible) and tooth-specific distribution patterns. This capability enhances the understanding of taurodontism as a radiologically defined developmental morphology rather than merely a clinical variation [14, 15].

Despite the growing use of CBCT in dental diagnostics, epidemiological data on taurodontism in Turkey remain limited. Existing studies report inconsistent prevalence rates, largely due to differences in study design, age range, and imaging modality employed [16–18]. Furthermore, systematic CBCT-based investigations focusing on children and adolescents are scarce. This limitation is particularly evident for studies evaluating first permanent molars, which erupt early and play a critical role in occlusal development and long-term oral health. Given their early eruption and functional significance, the first permanent molars represent an ideal model for evaluating taurodont morphology. Accurate morphometric assessment in this age group requires imaging modalities with high spatial resolution to ensure reliable classification. Therefore, the present study aimed to evaluate the prevalence and morphometric characteristics of taurodontism in first permanent molars using CBCT in a pediatric and adolescent Turkish population. Additionally, the distribution of taurodontism was analyzed according to gender, jaw, side, and age groups.

2. Materials and methods

2.1 Study design and ethical approval

This study was designed as a retrospective descriptive investigation. Ethical approval was obtained from the local Non-Interventional Clinical Research Ethics Committee (Approval No: 2025/09-25). CBCT scans of 105 individuals aged between 10 and 16 years, recorded between 2020 and 2024, were retrospectively evaluated.

The inclusion criteria for this study were determined as follows: (i) belonging to individuals aged between 10 and 16 years, (ii) CBCT images were originally acquired for routine diagnostic purposes (orthodontic assessment and/or surgical planning), (iii) at least one maxillary (teeth no: 16, 26) or mandibular (teeth no: 36, 46) first permanent molar was fully visible in the image, (iv) the relevant teeth had completed root development, including the apical regions, and (v) image quality was sufficient and clear for morphometric measurements (pulp chamber roof, furcation area, and root apex).

The exclusion criteria were as follows: (i) presence of substance loss in the evaluated teeth due to caries, restorations, or trauma that would compromise the pulp chamber morphology, (ii) presence of root resorption, root canal treatment, or periapical lesions in the teeth, (iii) presence of any syndromic condition or craniofacial anomaly (such as cleft lip and palate) that could affect tooth development or morphology, (iv) presence of motion artifacts in the image or inability to clearly distinguish anatomical structures due to technical reasons.

All CBCT scans were originally acquired for routine clinical diagnostic purposes, including orthodontic assessment and/or surgical evaluation. The scans were not obtained specifically for research purposes; therefore, no additional radiation exposure was delivered to the participants. All imaging procedures complied with the ALARA (As Low As Reasonably Achievable) principle and were consistent with the Safety and Efficacy of a New and Emerging Dental X-ray Modality (SEDENTEXCT) guidelines for justification and optimization of CBCT examinations [19, 20].

2.2 Imaging and measurements

CBCT imaging was performed using a KaVo 3D eXam cone-beam computed tomography unit (Biberach, BW, Germany). All scans were acquired using standardized imaging parameters of 120 kVp, 5 mAs, a scan time of 7 seconds, a voxel size of 0.4 mm, and a field of view (FOV) of 13 $\times$ 4 cm.

The maxillary (teeth number 16 and 26) and mandibular (teeth number 36 and 46) first permanent molars of each subject were included for morphometric analysis. All CBCT images were exported in Digital Imaging and Communications in Medicine (DICOM) format. To ensure measurement standardization, only sagittal sections were analyzed. The sagittal plane was oriented parallel to the long axis of each tooth. The slice passing through the center of the pulp chamber and root canal system, where the pulp chamber roof, furcation area, and root apex were clearly visualized, was selected for analysis.

Measurements of pulp chamber height (T_1) and roof–apex distance (T_2) were performed on sagittal CBCT slices. This standardized approach enabled accurate identification of anatomical reference points and ensured consistent morphometric measurements across all examined teeth (Fig. 1, Ref. [3]).

- T_1: Height of the pulp chamber, defined as the distance between the pulp chamber roof and the furcation area (in mm).
- T_2: Distance from the pulp chamber roof to the root apex (mm).

The taurodontism index was calculated using the formula $T_1/T_2 \times 100$. Based on the resulting values, teeth were classified according to the Shifman and Chanannel classification as follows [3] (Fig. 2, Ref. [3]):

- Normal: <20;
- Hypotaurodont: 20–30;
- Mesotaurodont: 30–40;
- Hypertaurodont: >40.

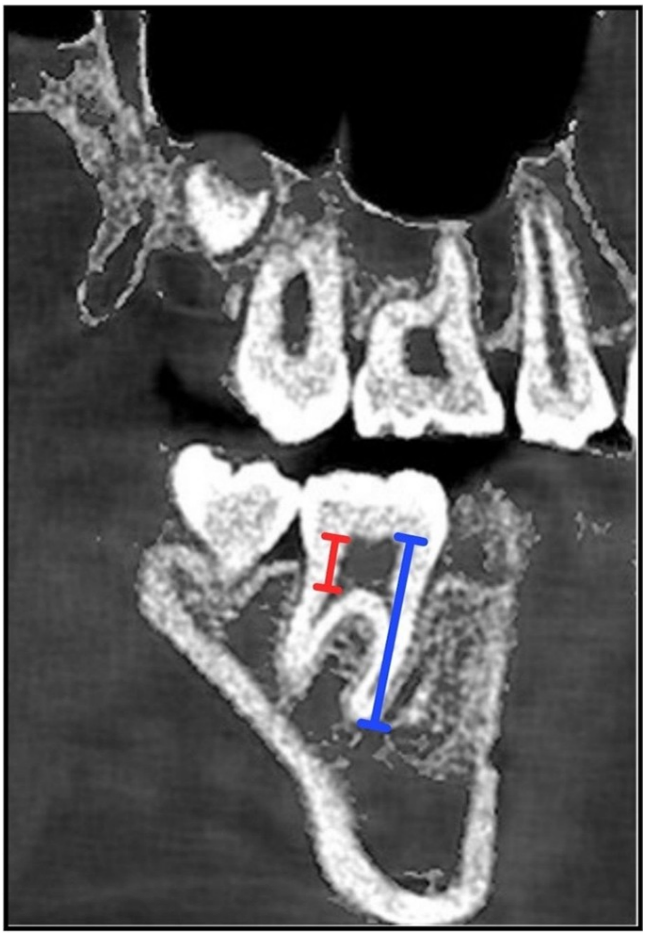

FIGURE 1. Sagittal CBCT section illustrating the morphometric measurement references on the mandibular right first molar (tooth 46). T_1, representing the pulp chamber height, was measured as the linear distance between the pulp chamber roof and the furcation area and is indicated by the red line. T_2, representing the distance from the pulp chamber roof to the root apex, is indicated by the blue line. All measurements were performed along the long axis of the tooth, and the taurodontism index was calculated as $T_1/T_2 \times 100$ according to the Shifman and Chanannel classification [3].

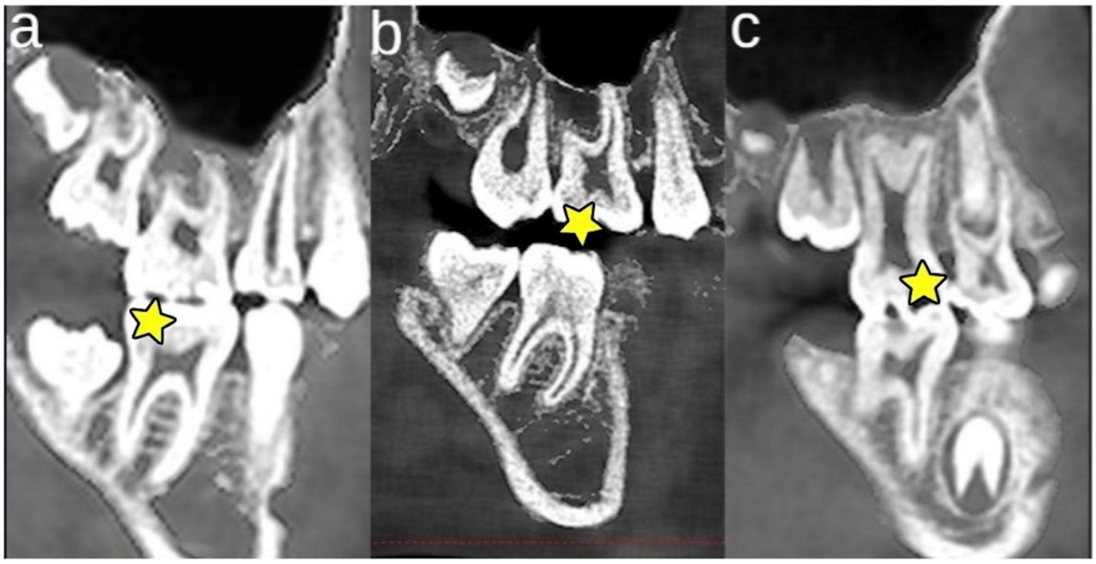

FIGURE 2. Representative sagittal CBCT sections illustrating different taurodontism morphologies in first permanent molars according to the Shifman and Chanannel classification [3]. (a) Hypotaurodont tooth showing mild apical displacement of the pulp chamber floor, (b) Mesotaurodont tooth showing moderate vertical enlargement of the pulp chamber, and (c) Hypertaurodont tooth characterized by marked apical elongation of the pulp chamber and shortened roots. The yellow star indicates the tooth evaluated for taurodontism classification in each image.

2.3 Sample size and power analysis

Sample size estimation was based on a preliminary pilot evaluation involving 30 patients (120 teeth). In this pilot analysis, the prevalence of taurodontism was approximately 22%. Based on this distribution, the corresponding effect size (Cohen's $w = 0.17$) was calculated and used to perform an a priori power analysis with (G*Power software, version 3.1.9.7, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, NRW, Germany) [21]. The analysis indicated that approximately 430 teeth would be required to achieve 85% statistical power at a significance level of 5% ($\alpha = 0.05$).

Due to ethical considerations and the limited availability of pediatric CBCT imaging in routine clinical practice, the final sample size was determined by the total number of eligible high-quality CBCT scans available during the study period. Accordingly, a total of 420 teeth scans obtained from 105 patients were included in the study.

A *post hoc* power analysis confirmed that the final sample size provided a statistical power of 84.2%. This level was considered sufficient for estimating the overall prevalence and morphometric distribution of taurodontism. However, the study was not specifically powered to detect differences in very low-frequency subtypes, such as hypertaurodontism. Therefore, findings related to these rare categories should be interpreted with caution.

2.4 Measurement reliability and reproducibility

To assess measurement reliability and reproducibility, 20% of the CBCT scans were randomly selected and re-measured after a two-week interval by the primary investigator to assess intra-observer reliability. Moreover, the same images were independently evaluated by an experienced oral and maxillofacial radiologist to assess inter-observer reliability. Measurement agreement was determined using the Intraclass Correlation Coefficient (ICC), which yielded a value of 0.85, indicating high measurement reliability. All statistical analyses were performed based on the initial measurements obtained by the primary investigator.

2.5 Statistical analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 21.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. As the primary morphometric variables (T_1, T_2, and the T_1/T_2 ratio) did not meet normality assumptions, non-parametric statistical tests were applied.

Associations between categorical variables were evaluated using the Chi-square test. For chi-square analyses, effect sizes were calculated using Cramér's V to quantify the strength of associations. To reduce the risk of Type I error associated with multiple *post hoc* comparisons, a Bonferroni correction was applied, and the adjusted significance threshold was set at p-adj (adjusted p-value) < 0.0167. Differences between paired morphometric measurements were analyzed using the Wilcoxon signed-rank test. A $p < 0.05$ was considered statistically significant unless otherwise specified.

3. Results

A total of 420 permanent first molars obtained from 105 patients aged between 10 and 16 years were evaluated. The mean age of the study population was 13.40 ± 1.96 years. All measurements were performed on CBCT images. The mean T_1 was 3.60 ± 0.76 mm, and T_2 was 17.69 ± 2.10 mm, while the mean T_1/T_2 ratio was 20.86 ± 6.64 (Table 1).

Regarding distribution characteristics, 55.2% of the evaluated teeth belonged to female patients, while 44.8% belong to male patients. Each permanent first molar (teeth number 16, 26, 36, and 46) was equally represented, accounting for 25% of the total sample. Maxillary and mandibular molars, as well as right- and left-sided teeth, were evenly distributed. Among taurodont teeth, hypotaurodontism was the most common subtype (14.5%), followed by mesotaurodontism (6.0%) and hypertaurodontism (1.0%) (Table 2).

According to the Shifman and Chanannel classification,

- 78.6% of the teeth were classified as normal,
- 14.5% as hypotaurodont,
- 6.0% as mesotaurodont, and
- 1.0% as hypertaurodont.

In the overall analysis, including all teeth, no statistically significant associations were observed between taurodontism classification and gender, jaw, or tooth side. To assess the potential influence of age on taurodontism classification, prevalence rates were evaluated across three age groups (10–12, 13–14, and 15–16 years). Taurodontism prevalence was 23.7% in the 10–12-year group, 25.0% in the 13–14-year group, and 17.7% in the 15–16-year group. No statistically significant differences were observed among the age groups. These findings indicate that age-related variation did not confound taurodontism classification within the study population (Table 3).

Morphometric analysis demonstrated that T_1 was significantly greater in maxillary first molars compared with mandibular first molars (Bonferroni-adjusted p-value, p-adj = 0.010). In contrast, no statistically significant difference was observed between the maxilla and mandible with respect to the T_2 (p-adj = 0.679). Paired comparisons between

TABLE 1. Descriptive statistics of the study population.

Variable	N	Min–Max	Mean ± SD
Age (yr)	105	10–16	13.40 ± 1.96
Pulp chamber height (mm)	420	3–10	3.60 ± 0.76
Distance from pulp chamber roof to apex (mm)	420	11.0–22.2	17.69 ± 2.10

N: Sample Size; Min: Minimum; Max: Maximum; SD: Standard Deviation.

TABLE 2. Frequency and percentage distribution of categorical variables.

Variable	Category	Frequency (N)	Percentage (%)
Gender			
	Female	232	55.2
	Male	188	44.8
Tooth number			
	#16	105	25.0
	#26	105	25.0
	#36	105	25.0
	#46	105	25.0
Jaw			
	Maxilla	210	50.0
	Mandible	210	50.0
Side			
	Right	210	50.0
	Left	210	50.0
Taurodontism classification			
	Normal	330	78.6
	Hypotaurodont	61	14.5
	Mesotaurodont	25	6.0
	Hypertaurodont	4	1.0

N: Sample Size. Percentages were calculated based on a total of 420 teeth.

TABLE 3. Prevalence of taurodontism according to age groups.

Age group (yr)	Total teeth (n)	Taurodont teeth n (%)	Normal teeth n (%)
10–12	156	37 (23.7%)	119 (76.3%)
13–14	100	25 (25.0%)	75 (75.0%)
15–16	164	29 (17.7%)	135 (82.3%)
Total	420	91 (21.4%)	329 (78.6%)

Chi-square test; p = 0.276. No statistically significant difference was observed in taurodontism prevalence among age groups.

homonymous right and left molars revealed no statistically significant differences for either T_1 or T_2, indicating bilateral symmetry of morphometric measurements (Table 4).

In the subgroup analysis limited to taurodont teeth, taurodontism subtype distribution did not differ according to tooth side. However, a statistically significant association was observed between jaw and taurodontism subtype distribution (p = 0.047), with hypertaurodont teeth occurring more frequently in the maxilla and hypotaurodont teeth more commonly detected in the mandible (Table 5).

4. Discussion

The evaluation of individuals aged 10–16 years provides important insight into taurodont morphology during the later stages of dental development. Previous studies by Shifman and Chanannel [3], followed by subsequent investigations, have suggested that ongoing root formation and delayed invagination of the epithelial diaphragm may influence pulp chamber dimensions and taurodontism classification [5]. To minimize this potential confounding factor, the present study included only first permanent molars with completed root development. Accordingly, the taurodont morphology identified in this cohort is more likely to represent a stable anatomical characteristic rather than a transient developmental variation.

The prevalence of taurodontism observed in the present CBCT-based study (21.4%) was higher than that reported in several earlier investigations. CBCT-based studies conducted in Iranian, Chinese, and Saudi populations by Jamshidi *et al.* [9], Li *et al.* [10, 11], and Jabali *et al.* [12] have reported prevalence rates ranging from 5% to 12%. In contrast, CBCT-based studies in Turkish Cypriot, Indian, and Pakistani populations have reported prevalence rates ranging from 20% to 24%, which are comparable to those observed in the present study [13–15]. This variation supports the growing consensus that three-dimensional imaging techniques provide

TABLE 4. Wilcoxon signed-rank test results for paired morphometric comparisons (T_1 and T_2).

Comparison	Z-value	p-value
T_1 (Pulp Chamber Height) teeth 36 to 16	–2.535	**0.011***
T_1 (Pulp Chamber Height) teeth 46 to 26	–1.781	0.075
T_1 (Maxilla *vs.* Mandible)	–2.593	**0.010***
T_2 (Maxilla *vs.* Mandible)	–0.414	0.679
T_2 (Roof–Apex Distance) teeth 26 to 16	–0.612	0.540
T_2 (Roof–Apex Distance) teeth 46 to 36	–0.344	0.731

The Wilcoxon signed-rank test was used for paired morphometric comparisons.
T_1: pulp chamber height, and T_2: the distance from the pulp chamber roof to the root apex.
Statistically significant differences are indicated by an asterisk and bold. (*) ($p < 0.05$).
Tooth-level comparisons (teeth 36–16 and 46–26) represent paired maxillary–mandibular first molars within the same individuals.

TABLE 5. Chi-square test results for the relationship between taurodontism classes and categorical variables.

Variable	Effect size	χ^2 (df)	p-value
Gender × Taurodontism class	Cramér's V = 0.134	7.565	0.056
Jaw × Taurodontism class	Cramér's V = 0.119	5.991	0.112
Side × Taurodontism class	Cramér's V = 0.090	3.370	0.338
Only taurodont teeth—Side × Class	η = 0.194	—	—
Only taurodont teeth—Jaw × Class	Cramér's V = 0.227	6.125	**0.047***

Bold values and an asterisk (*) indicate statistical significance ($p < 0.05$). Tests were conducted to examine associations between taurodontism classification (normal, hypo-, meso-, hyper-) and demographic or anatomical variables. Cramér's V and η represent effect sizes and were interpreted as weak when <0.3.*

greater sensitivity for detecting subtle variations in pulp chamber morphology compared with conventional two-dimensional radiographic methods, resulting in higher detection rates of taurodont morphology.

This interpretation is further supported by large-scale multinational evidence. In a recent multinational cross-sectional study and meta-analysis encompassing 20 countries, Pertek Hatipoğlu *et al.* [22] reported a pooled global prevalence of approximately 7% for taurodontism and highlighted substantial heterogeneity related to population characteristics, imaging modality, and diagnostic criteria. The discrepancy between this pooled estimate and the higher prevalence observed in the present study is most plausibly explained by methodological differences, particularly the exclusive use of CBCT imaging and the focus on first permanent molars in a pediatric population. These factors likely enhance diagnostic sensitivity rather than indicating a true overrepresentation of taurodontism.

Additional epidemiological evidence from diverse geographic regions further illustrates the influence of both population-specific factors and imaging methodology on reported prevalence rates. A conventional radiographic study conducted in a German population by Bürklein *et al.* [23] reported relatively lower prevalence rates of taurodont molars using two-dimensional imaging techniques. Similarly, a retrospective study from the United Arab Emirates reported lower prevalence values based on conventional radiographic techniques [24]. Studies from Bangladesh and Ghana reported taurodontism prevalence rates of approximately 8.7% and 17.1%, respectively, using two-dimensional radiographic assessment [25, 26]. Collectively, these findings indicate that taurodontism prevalence estimates should be interpreted in the context of imaging modality and study population rather than as absolute epidemiological values.

In the present study, no statistically significant differences were observed in taurodontism distribution according to jaw or side. However, the mean pulp chamber height was significantly greater in the maxilla. This finding may partially explain the tendency toward increased detection of taurodont-related morphological features in maxillary molars. Similar findings have been reported by Li *et al.* [10] and Pach *et al.* [15], who observed greater vertical expansion of the pulp chamber in maxillary molars using CBCT-based analyses. Conversely, studies from Iran and Saudi Arabia did not demonstrate significant jaw-related differences [8, 12], suggesting that jaw-related distribution patterns may vary across populations and imaging protocols.

With respect to gender, taurodontism was more frequently observed among females in the present study. However, this difference did not reach statistical significance. This observation is consistent with findings reported in Turkish, Northern Cypriot, and Indian populations [14, 17, 18]. Similarly, Einy *et al.* [16] reported a tendency toward a higher frequency of mild taurodontism among females in an Israeli population, while emphasizing that gender-related differences were not consistently significant across severity categories. Taken together, these results suggest that gender alone is not a primary determinant of taurodont morphology.

Regarding subtype distribution, hypotaurodontism was the most frequently identified form, followed by mesotaurodontism and hypertaurodontism. This pattern mirrors the classical distribution originally described by Shifman and Chanannel [3] and has been consistently reported in subsequent radiographic and CBCT-based investigations [10, 18]. A tendency toward increased hypertaurodont presentation in the maxilla was also observed in the present study. This finding is consistent with earlier CBCT-based reports demonstrating greater vertical pulp chamber enlargement of the pulp chamber in maxillary molars [10, 14].

Beyond prevalence estimation, recent CBCT-based investigations have emphasized associations between taurodontism and other complex dental morphologies. Studies by Akbarizadeh *et al*. [27] and Davvaz *et al*. [28] demonstrated a higher prevalence of taurodontism in patients with cleft lip and palate. They also reported significant associations between taurodont morphology and complex canal configurations, including C-shaped canals. These findings highlight the importance of three-dimensional imaging not only for accurate prevalence assessment but also for comprehensive evaluation of dental morphological complexity.

From a clinical perspective, the elongated pulp chamber and apically displaced furcation characteristic of taurodont teeth are well-recognized factors that may complicate endodontic and orthodontic procedures, as emphasized in both classical and contemporary reviews [5, 6]. Although the present study did not evaluate clinical treatment outcomes, a recent CBCT-based systematic review and meta-analysis by Martins *et al*. [29] demonstrated that three-dimensional evaluation of root canal morphology improves diagnostic accuracy. Such assessment may positively influence endodontic treatment planning and outcomes. Accordingly, the detailed morphometric data provided by the present study may support more informed clinical decision-making when interpreted alongside outcome-based evidence.

This study contributes to the literature as one of the few CBCT-based investigations focusing specifically on taurodontism in children and adolescents. Nevertheless, several limitations should be acknowledged. These includes the relatively small sample size and the inclusion of a single regional population. Additionally, the absence of multilevel statistical modeling to account for within-patient clustering may be considered a limitation. Future multicenter investigations employing larger and more heterogeneous samples, together with multilevel or mixed-effects modeling strategies, may provide a more robust analytical framework to account for within-patient clustering. In addition, the CBCT protocol used in the present study represents a methodological limitation. The voxel size of 0.4 mm, although consistent with ALARA principles and commonly applied in pediatric CBCT imaging, may have influenced the precision of linear morphometric measurements. Furthermore, measurements were performed exclusively on sagittal sections to ensure standardization; however, this approach may not fully capture the three-dimensional complexity of pulp chamber morphology. Future prospective studies incorporating larger, age-stratified, and multicenter datasets are warranted to further clarify the developmental mechanisms and clinical relevance of taurodontism.

5. Conclusions

This study evaluated the prevalence and morphometric characteristics of taurodontism in first permanent molars of children and adolescents using three-dimensional CBCT analysis. Taurodontism was identified in 21.4% of the examined teeth, with hypotaurodontism representing the most prevalent subtype. The use of CBCT enabled a detailed and reliable assessment of pulp chamber morphology, underscoring the impact of imaging modality on the detection and characterization of taurodont teeth. Within the applied inclusion criteria, no significant associations were observed between taurodontism prevalence and age, gender, jaw, or tooth side. These findings suggest that the observed taurodont morphology reflects a stable anatomical variation rather than a transient developmental feature. Although clinical treatment outcomes were not evaluated, the CBCT-derived morphometric data presented in this study may contribute to a more accurate anatomical understanding of taurodont teeth. These findings provide region-specific reference data for pediatric populations and may serve as a basis for future longitudinal and comparative studies investigating the developmental and clinical relevance of taurodontism.

AVAILABILITY OF DATA AND MATERIALS

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

AUTHOR CONTRIBUTIONS

AC and SK—jointly determined the study topic, selected the cases, and performed CBCT image analyses; wrote, revised, and finalized the manuscript together. Both authors collaboratively conducted the data evaluation, interpretation of results, and statistical analysis. Both authors reviewed and approved the final version of the article and share equal responsibility for the work.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study has been evaluated as a retrospective study by the Van Yüzüncü Yıl University Non-Interventional Clinical Research Ethics Committee, and it has been determined that obtaining informed consent is not required for retrospective studies in accordance with Law No. 5846 and the Fundamental Law on Health Services No. 3359. Since retrospective research involves the use of existing, anonymized radiographic records without any additional clinical intervention, informed consent—including parental or legal guardian consent for participants under 16 years of age was waived as per institutional and national regulations. During the research process, personal data protection and confidentiality principles were strictly followed.

This retrospective radiographic study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Van Yuzuncu Yil University Non-Interventional Clinical Research Ethics Committee under protocol number 2025/09-25.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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