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Original article

# QUANTITATIVE ASSESSMENT OF ENAMEL AND DENTIN VOLUMES IN PRIMARY TEETH USING MICRO-COMPUTED TOMOGRAPHY

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## SUMMARY

**Background**: Primary teeth's unique morphology, characterized by thinner enamel and dentin, contributes to rapid caries progression and challenges in pediatric dentistry.

**Purpose:** This study quantifies the volumetric and morphological characteristics of primary teeth using micro-computed tomography (micro-CT) to enhance clinical understanding and treatment planning.

**Materials and methods**: Exfoliated primary teeth (24 anterior, 24 posterior) from children aged 6–12 years were scanned using a SkyScan 1272 micro-CT (100 kV, 100 µA, 9 ìm pixel size). The samples were free of caries, restorations, or defects. Three-dimensional reconstructions measured enamel and dentin volumes. Descriptive statistics and independent t-tests compared volumes in enamel and dentin between anterior and posterior primary teeth.

**Results:** Morphometric measurements quantified enamel and dentin volumes, revealing significantly larger enamel (94.42 ± 28.77 mm³ vs. 29.85 ± 12.27 mm³, $p<0.001$) and dentin (147.11 ± 37.79 mm³ vs. 90.95 ± 29.95 mm³, $p<0.001$) volumes in posterior teeth compared to anterior teeth. The enamel-to-dentin ratio also differed significantly, reflecting molars' larger size and functional demands.

**Conclusion:** Micro-CT analysis identified notable morphological variations in primary teeth, specifically indicating thicker dentin with larger volumes in molars. These findings provide essential guidance for minimally invasive cavity preparation, addressing key challenges in pediatric dentistry. While the small sample size constrains the generalizability of the results, further studies with larger and more diverse populations are necessary to comprehensively evaluate caries susceptibility and restorative outcomes.

**Keywords:** primary teeth, micro-CT, tooth structures, tooth dimensions, enamel volume, dentin volume,

## INTRODUCTION

Despite the global progress in the prevention of dental caries and the various methods for the treatment of inflamed and/or infected pulp, a significant number of complications still arise from untreated or improperly treated primary teeth. The reasons for this are their particular morphology, the difficulties in managing the patient's behavior, and the isolation during the adhesive protocol [1]. The anatomy and morphology of primary teeth and their differences from permanent teeth have been studied in the specialized literature. Knowledge of the anatomy of primary teeth clearly explains the reasons for the rapid development of carious lesions, their rapid progression, and the frequent complications in primary dentition [2]. Their structural integrity, determined by the thickness of the enamel and dentin, affects their resistance to the development of carious lesions and wear. Unlike permanent teeth, primary teeth have thinner layers of enamel and dentin, which makes them more vulnerable to the development of carious lesions [3]. The enamel of primary teeth is thinner, and the coronal dentin's thickness is smaller than that of permanent teeth [3]. The tooth structures in the primary dentition have a lower degree of mineralization, a wide proximal contact zone, and a pronounced narrowing of the vestibular and lingual walls in the occlusal direction [3]. This predetermines a higher projection of the pulp to the external tooth surface and increases the risk of its involvement with the rapid progression of the carious lesion in the dentin.

For this reason, an appropriate treatment strategy should be selected that minimizes the possibility of creating pulp complications [4]. The characteristics of children as patients make it difficult to prepare cavities precisely for the operative treatment of primary teeth. Contrary to modern dental concepts and the minimally invasive approach, special care is required when performing minimally invasive dental procedures to limit unnecessary loss of hard dental structures [5].

Intraoral radiographs are the gold standard and essential for identifying carious lesions and determining the location and size of the pulp chamber [6]. However, they only provide a two-dimensional visualization of a three-dimensional structure and cannot provide detailed information about the morphology of primary teeth. New technologies and equipment introduced in dentistry in recent years allow for 3D analysis of primary teeth. Authors have used various methods and tools for three-dimensional analysis (spiral-CT, CBCT, morphometric analysis, magnetic resonance) [7], and most such studies have focused on permanent dentition [4, 8].

A three-dimensional reconstruction of a primary tooth accurately reflects its anatomical features, which can help the understanding of the reasons behind varying clinical outcomes and their operative treatment [9]. However, the anatomical details of primary teeth are still not well-studied due to their significant variability [9]. Understanding the volumetric properties of enamel and coronal dentin in primary teeth can provide valuable insights into tooth development, wear patterns, and the susceptibility to dental diseases such as caries.

Micro-computed tomography (micro-CT) is a non-destructive imaging technique that allows for high-resolution, three-dimensional visualization of dental tissues [10, 11]. Its precision in measuring enamel and dentin thickness makes it a valuable tool in dental research [12]. Despite its potential, there is limited literature on the use of micro-CT for analyzing primary molars, and no three-dimensional reconstruction of primary teeth has been conducted in Bulgaria.

## PURPOSE

This study **aims** to quantify the morphological features and volume of enamel and dentin of primary teeth using micro-CT, offering insights into their structural characteristics and clinical relevance.

## MATERIALS AND METHODS

Exfoliated primary teeth (incisors, canines, and molars) were collected from children aged 6–12 years during natural exfoliation. Informed parental consents were obtained. The Medical University of Sofia KENIMUS Ethics Committee approved the study procedures (Approval Number: No 1598/20.05.2022). The inclusion criteria for selecting the primary teeth were teeth with no evidence of carious lesions, restorations, sealants, or defects. These criteria were assessed under microscopic observation (Semorr 3000E, Semorr Medical Tech Co., Jiangsu, China). After extraction, the crowns were wiped with hydrogen peroxide gauze and stored in 10% formalin solution until the start of the study.

The distribution of the teeth included in the study is presented in Table 1.

**Table 1.** Primary teeth distribution by tooth groups

| Tooth | N | % |
|---|---|---|
| Anterior teeth | 24 | 50% |
| Posterior teeth | 24 | 50% |

Each tooth was placed in a transparent, sealed Eppendorf tube with distilled water-soaked cotton at the bottom to prevent drying out of the specimen and formation of cracks. The teeth were scanned using a SkyScan 1272 X-ray microtomograph (Bruker, Billerica, MA, USA) with an X-ray tube voltage of 100 kV, current of 100 μA, a 0.55-mm copper filter, a pixel size of 9 ìm, and a rotation step of 0.45°. The X-ray beam was conical in shape, and each voxel measured 12 μm. The crowns were projected at this resolution throughout their entire length into the detector field. The average scanning time for each sample was approximately 15 min.

To create a three-dimensional reconstruction of the enamel and dentin in the tooth crown, a series of two-dimensional images were superimposed after applying filters for radiation spectrum correction and circular interference (NRecon software, Bruker). A noise reduction filter and automatic segmentation were used to separate the crown from the pulp chamber. Morphometric measurements were conducted to determine the volumes of dentin and enamel in the tooth crown, as well as the volume ratios of enamel to dentin.

**Statistical analysis:** Data were analyzed using SPSS (v.26, IBM). Descriptive statistics (mean, standard deviation) were calculated for enamel and dentin volumes by tooth type. An independent samples T-test was used to compare the measurements across the tooth types. A p-value<0.05 was considered statistically significant.

## RESULTS

Figure 1 presents three-dimensional enamel and dentin reconstructions of scanned primary anterior and distal teeth.

**Fig. 1.** Three-dimensional reconstructions of enamel and dentin of anterior **a)** and posterior **b)** primary teeth.

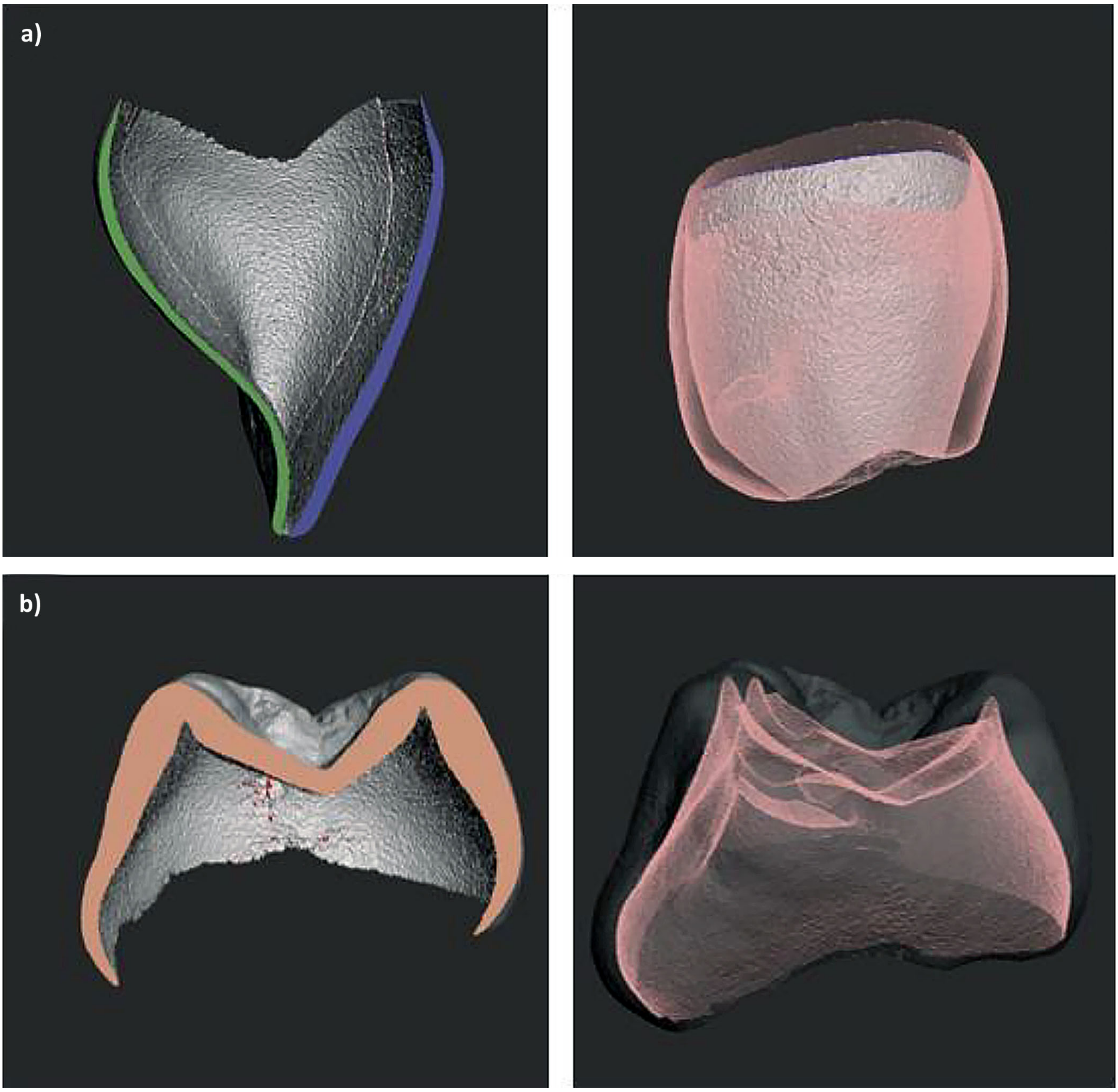
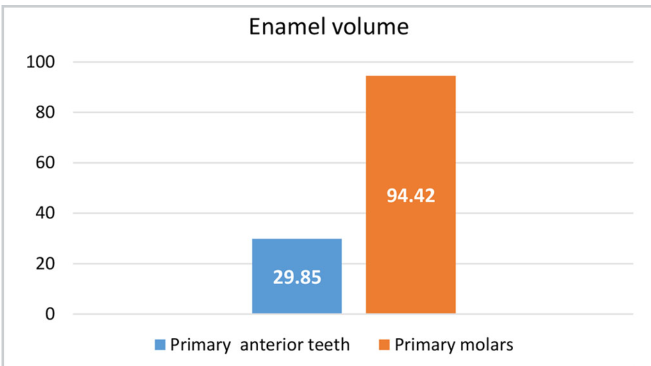



Diagram 1 shows the enamel volumes of anterior and primary teeth.

**Diagram 1.** Enamel volume in anterior and posterior primary teeth ($mm^3$)




Posterior teeth exhibited almost three times larger enamel volume than the anterior. This reflects the molars' larger size and complex morphology. The data are supported by statistically significant differences ($p<0.001$).

Diagram 2 shows the differences in the volumes of coronal dentin in anterior and posterior primary teeth.

The trend observed in diagram 1 is repeated for dentin volume. It is significantly larger in the distal areas than in the dentition's anterior area ($p<0.001$). Diagram 3 presents the ratio of enamel to dentin volumes in the tooth's crown in anterior and posterior teeth.

**Diagram 2.** Coronal dentin volume in anterior and posterior primary teeth (mm$^3$)

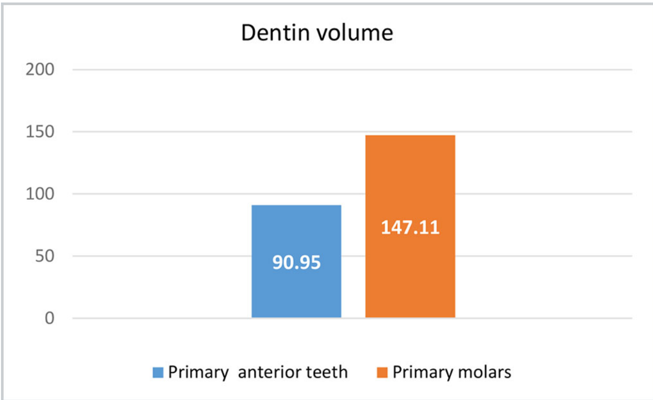
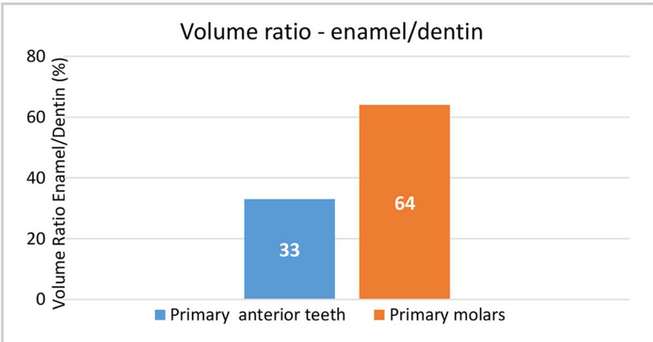



**Diagram 3.** Percentage ratio of enamel to coronal dentin in anterior and posterior teeth




The diagram shows that the ratio of enamel and dentin volumes in anterior and posterior teeth is statistically different ($p<0.001$). The difference in volumes in the distal areas of the dentition is twice as large.

## DISCUSSION

The present study aimed to describe the volume of the hard dental structures of primary teeth, which may impact clinical procedures and the cavity treatment of the teeth. Radiographs in different projections have been most commonly used to measure the thickness of enamel [13, 14]. These techniques only provide qualitative data that the enamel is thicker in permanent molars and thinner in primary molars, and definitive quantitative data cannot be obtained [16].

Furthermore, conventional radiographs superimpose the images, and the three-dimensional anatomy of the area is compressed into a two-dimensional image [17]. Therefore, estimates derived from radiographic images are unlikely to reflect enamel thickness accurately [16]. Enamel and dentin volumes of primary teeth have been estimated using various methods, each providing unique information about their structural and compositional characteristics. Scanning electron microscopy and energy dispersive spectroscopy have shown that the average enamel thickness of primary teeth is approximately 1.14 mm, while the average dentin thickness is 1.87 mm [18]. Computed microtomography provides three-dimensional reconstructions that accurately quantify enamel and dentin volumes. This method can non-destructively measure the thickness, distribution, and volume of dental hard tissues [19]. Dentin and enamel volumes of primary teeth estimated using high-resolution X-ray computed microtomography have been quantified in the literature. According to Ma et al., the average enamel volume in mandibular primary central incisors is 8.23 mm$^3$, while the average dentin volume is 31.65 mm$^3$ [18]. The average values we observed in our study differ significantly (~30 mm$^3$ for enamel and ~90 mm$^3$ for dentin) from those found in the mandibular primary central incisor, which is normal, considering that it is the smallest tooth in the primary dentition.

This study provides detailed insights into the structural characteristics of primary teeth using micro-CT. The thicker enamel and dentin in molars reflect their role in heavy mastication, while the thinner layers in incisors align with their cutting function. These findings are consistent with previous studies, which reported enamel thickness in primary molars ranging from 0.8 to 1.0 mm and dentin thickness from 1.5 to 2.0 mm [20].

The observed difference in mean enamel and dentin volumes in anterior and posterior teeth is consistent with anatomical expectations (Diagrams 1 and 2). Primary molars typically have larger crown and root structures to meet functional demands, including greater occlusal forces during mastication. This is reflected in their significantly higher mean dentin volume (147.11 mm$^3$) compared to anterior teeth (90.95 mm$^3$), which include incisors and canines and are primarily used for cutting and tearing food. The larger standard deviation in distal teeth compared to anterior teeth suggests greater variability in molar size, possibly due to differences in tooth type (e.g., first and second molars) or individual anatomical variations.

The results from the current study affect pediatric dentistry, especially in pulp therapy or restorative treatments, where tooth size, dentin, and enamel volume influence treatment planning. For example, larger posterior teeth may require more extensive restorative procedures or different approaches to caries management compared to smaller anterior teeth. The occlusal surfaces of the first primary molars have been shown to have thinner structures than those of the second primary molars [21]. The mesio-buccal cusp is thinner in maxillary second molars than the disto-buccal, disto-lingual, and mesio-lingual cusps [21]. The authors suggest this has characteristics that will reflect on cavity preparation. In the mesio-buccal cusp, clinicians should be cautious because of the increased risk of exposure to the pulp horn in this area [21]. The mesial, lingual, and distal walls of the lower first molars are thinner than the analogous walls of the second primary molars in the mandible [21]. In the maxilla, data have shown different results, namely that the medial and distal walls of the first molars are thinner than those of the second molars. When preparing cavities in these areas, the thinner tooth structures should be considered [18, 20].

## LIMITATIONS

This study has limitations due to its small sample size and the absence of age-specific analysis, as the thickness of enamel and dentin can vary with age-related tooth wear. Additionally, all the teeth analyzed were from children living in Bulgaria; therefore, a larger sample size from diverse geographical locations is necessary for a more comprehensive study.

## CONCLUSION

Micro-CT examination is an effective method for understanding tooth morphology, especially in areas that are not visible to the naked eye or through radiography. The findings from this study, along with a detailed examination of the morphological characteristics of enamel and dentin, aid in performing cavity preparation with minimal intervention. This approach allows for the creation of an appropriate cavity or endodontic access while preserving tooth structures. Micro-CT analysis indicated significant differences in enamel and dentin thickness across primary tooth types, with molars showing the thickest layers. Further studies are required to investigate the impact of these structural characteristics on caries susceptibility and restorative outcomes.

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