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ORIGINAL RESEARCH

A pilot study on developing quantitative indices for age-related changes in maxillary primary molar root canal morphology

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Abstract

Background: A thorough understanding of the root canal morphology of primary molars is highly important for pulp treatment of primary teeth. The purpose of this study was to elucidate age-related changes in the root canal morphology of primary molars and determine new indices to determine the root canal anatomy via cone-beam computed tomography (CBCT). **Methods**: CBCT data of primary molars from 58 children aged 3–8 years without systemic diseases that affect tooth development were collected. The following indices were defined and calculated using Mimics 17.0, 3-Matic 9.0, and ImageJ software: (i) the cross-sectional area of the root canal; (ii) $R_{.15}$: the proportion of the lateral canal wall with an inner diameter less than 0.15 mm; (iii) L_C/L_R: the ratio between the canal length and root length; and (iv) N_{dis}: the discontinuous canal count. Correlation analysis and binary logistic regression were performed to assess the variants and age-related changes in canal morphology. **Results**: On CBCT analysis, the cross-sectional areas of the mesiobuccal (MB) root, palatal (P) root and distobuccal (DB) root canals were negatively correlated with age ($p < 0.05$), with correlation coefficients of −0.41, −0.42 and −0.26, respectively. The $R_{.15}$ of MB roots was positively correlated with age ($p < 0.05$, $r_s = 0.39$). The L_C/L_R values for the MB, DB and P roots decreased with age, with correlation coefficients of −0.39, −0.42 and −0.29, respectively ($p < 0.05$). The risk of discontinuous canals for MB, DB and P roots increased with age ($p < 0.05$), with odds ratios of 1.61, 1.48 and 1.60, respectively. **Conclusions**: The new indices developed in the present study based on CBCT successfully demonstrated age-related changes in the root canals of primary molars.

Keywords

Quantitative indices; Cone-beam computed tomography; Primary molar; Root canal morphology; Age

1. Introduction

Primary root canal treatment (RCT) is a classic treatment method that can preserve pulp-infected teeth without pathological signs and is beneficial for maintaining the integrity of dentition and masticatory function [1]. A thorough knowledge of the root canal anatomy of primary teeth is critical for successful

RCT. According to previous studies on permanent teeth, canal morphology is genetically determined [2, 3] but also changes with age [4]. The continuous formation of secondary dentin can cause structural changes in the root canal system [5]. One study on permanent teeth revealed that younger patients had a greater prevalence of a single root canal configuration (Vertucci type I) than older patients did among the maxillary second premolars [6]. For mandibular second primary molars, the area of the root canal orifice of the mesial root decreases with age [7]. In addition, Amano *et al*. [8] reported that the volume ratio of pulp chambers to the crown in maxillary second deciduous molars in the mixed dentition stage was significantly lower than that in the primary dentition stage. Compared with the pulp chamber, the root canal system has more influence on RCTs, but unfortunately, for decades, studies on the changes in the canal anatomy of primary teeth with age have been underexplored. Hibbard *et al*. [9] reported more variations in the root canal anatomy of primary molars with root resorption than those without root resorption, but the ages of the children whose teeth were included in the study were unknown.

Various methods are applied in studies on canal anatomy. Canal staining and clearing are generally used to describe canal morphology [10], but this approach destroys tooth integrity. Microcomputed tomography (micro-CT) can be used to describe the three-dimensional (3D) shape of the root canal in detail with high resolution and is nondestructive [11]. In addition, methods such as filling the canals with vulcanized rubber/pigmented polyester resin followed by decalcification, stereomicroscopy, scanning electron microscopy, two-dimensional (2D) radiographic imaging, and cone-beam computed tomography (CBCT) can also be used to study canal morphology [12, 13]. However, except for CBCT and 2D radiographic imaging, the other methods mentioned above can be used only *in vitro* and are always used in the laboratory. The roots of primary teeth can be absorbed physically or pathologically, and it is difficult to obtain complete primary teeth for study *in vitro*. CBCT, which has a higher resolution, can better reflect the 3D shape of the root canal than 2D radiographic imaging [12] and has been used for research on permanent teeth *in vivo* [14, 15]. Many *in vivo* normal primary tooth samples can be obtained through CBCT.

Studies on age-related changes in the root canal morphology of primary molars are indispensable for understanding the physiological structure of deciduous teeth and providing a reference for related clinical work. To study age-related changes, observation indices should be determined first. In this study, we aimed to elucidate age-related changes in the root canal morphology of primary molars and determine new indices to evaluate these changes in root canal anatomy through CBCT.

2. Materials and methods

2.1 Data collection

CBCT scan data that were originally obtained from April 2018 to November 2019 for the diagnosis or treatment of supernumerary teeth, trauma, cysts, *etc.*, unrelated to this study were retrieved from the Department of Radiology at Peking University Hospital of Stomatology. Radiographic images of systemically healthy children aged 3–8 years were obtained. The maxillary first primary molars on these CBCT scans were evaluated as the study objects, and those meeting the following criteria were excluded:

- abnormal crown or root morphology;
- caries reaching the deep layer of dentin or abrasion reaching the dentin;
- pulpal infection caused by another disease;
- history of pulpotomy, pulpectomy or preformed metal crown restoration;
- root immaturity or internal or external root absorption;
- incomplete images or unsatisfactory image quality.

CBCT images were acquired using a 3D Accuitomo type F17 (Morita, Kyoto, Japan) at 80–90 kV and 5 mA, with a field of view of 6 cm × 6 cm. The voxel and slice thicknesses were both 0.125 mm. All CBCT scans were performed by a licensed radiologist strictly following the manufacturer's recommended protocol. The CBCT scans selected were divided into 6 groups according to age.

2.2 Index definition and measurement

The CBCT data were saved in Digital Imaging and Communications in Medicine (DICOM) format and transferred to Mimics 17.0 (Materialise Technologies, Leuven, Belgium). Through preliminary exploration and analysis, the following points and plane were defined to aid with the measurement of each root and canal (Fig. 1A).

Point A: the lowest point of the outer surface of the root furcation along the z-axis.

Point B: the anatomical root tip.

Point C: the point where the canal lumen disappeared toward the root tip for the first time.

L_R: the length of the root measured from point A to B along the z-axis.

L_C: the length of the canal measured from point A to C along the z-axis.

Plane D: the plane $1/3 \times L_R$ from point A toward the root tip along the z-axis; this plane is perpendicular to the z-axis.

If the root canal lumen reappeared after disappearing toward the root tip, it was recorded as a discontinuous canal, as shown in Fig. 1A. The L_C and L_R were calculated.

The canal segment with a thickness of 0.25 mm extending from plane D toward the root tip was taken as the region of interest for 3D reconstruction. First, an appropriate threshold for segmenting the canal and dentin was selected. The threshold was determined as follows. The threshold range of the lips on the CBCT scan at three different positions was measured, and the difference between the minimum and maximum thresholds of the three positions was calculated. The mean of the three differences was subsequently calculated and recorded as "d". The minimum threshold of the canal image was recorded as "c", and d plus c was defined as "p", which was recorded as the reference threshold of the canal. The reference threshold "p" was then slightly adjusted to improve the accuracy of segmentation according to the operator's judgment.

After determination of a proper canal threshold, a 3D model of the root canal segment of interest was reconstructed using

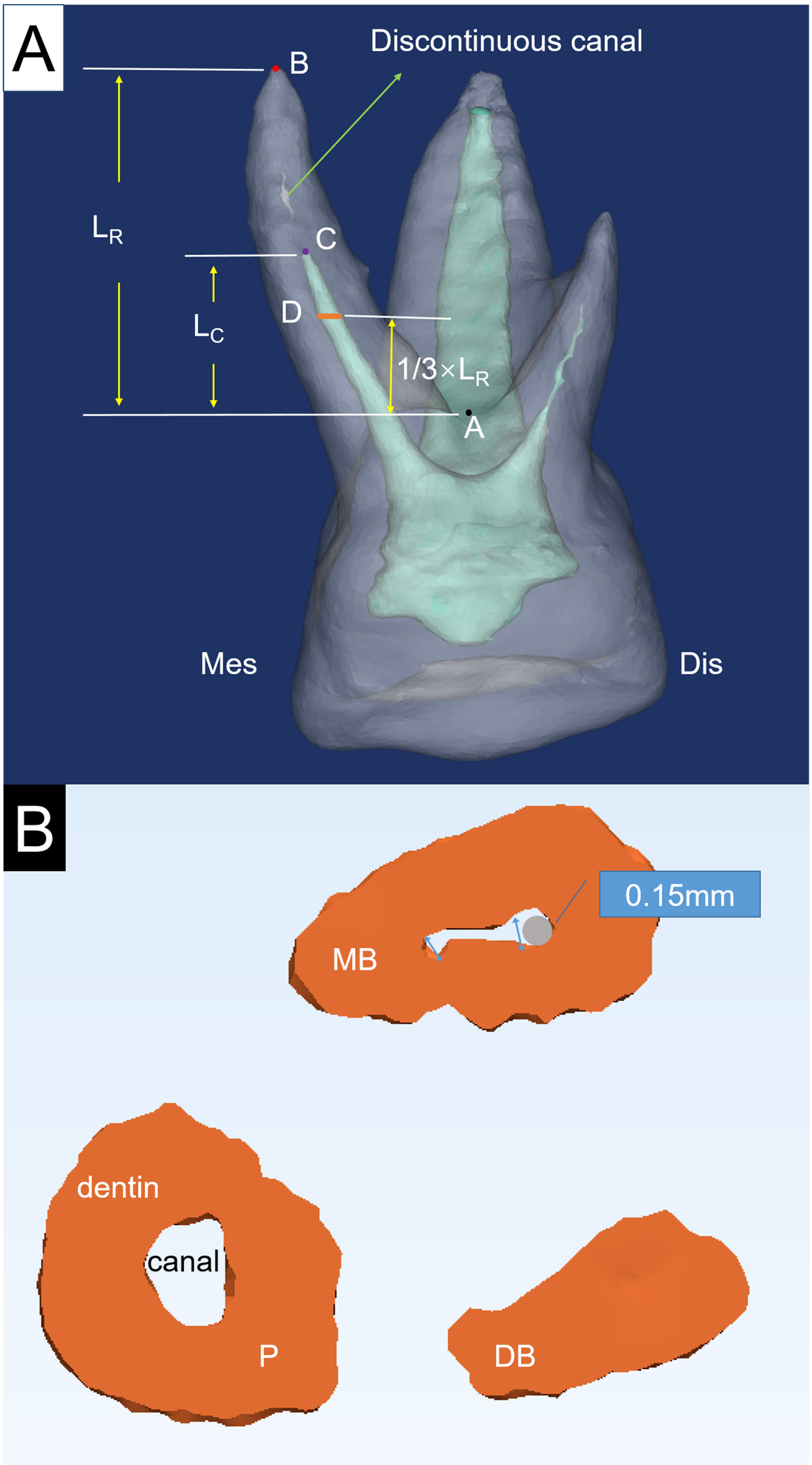

FIGURE 1. 3D reconstruction model of the root and canal for a maxillary first primary molar. (A) 3D reconstruction model of a maxillary first primary molar. Points A, B and C; plane D; and L_C and L_R are indicated. (B) Root canal segments with a thickness of 0.25 mm starting from plane D toward the root tip were taken as the region of interest and reconstructed with Mimics 17.0 software. The gray circle represents the tip of a #15 K-file, and the blue arrows represent the root canal diameter at different positions. A, the lowest point of the outer surface of the root furcation; B, the anatomical root tip; C, the point where the canal disappeared toward the root tip for the first time; DB, distobuccal root; Dis, distal surface; L_C, length of the canal measured from point A to C along the z-axis; L_R, length of the root measured from point A to B along the z-axis; MB, mesiobuccal root; Mes, mesial surface; P, palatal root; Plane D, the plane 1/3 × L_R from point A toward the root tip along the z-axis, which is perpendicular to the z-axis.

Mimics 17.0 software (Fig. 1B) and measured using 3-Matic 9.0 software (Materialise Technologies, Leuven, Belgium). The detailed procedure is shown in Fig. 2.

The following target variables were calculated and recorded:

- The cross-sectional area of the canal on plane D was measured using ImageJ (National Institutes of Health, Bethesda, USA).
- L_C/L_R: the ratio of canal length to root length.
- $R_{.15}$: the ratio of the inner lateral canal wall area with a root canal diameter less than 0.15 mm to the total inner lateral canal wall area of the segment of interest (Fig. 2).
- N_{dis}: the number of discontinuous root canals.

Before starting the study, 69 canal cross-sections not included in this study were used to assess the consistency of the image segmentation, with the mean intersection over union (MIoU) as an index. The MIoU was 0.81. The intragroup correlation coefficient (ICC) was used to test the consistency of the selection of the defined points in the image. The interexaminer and intraexaminer ICCs were 0.998 and 1, respectively.

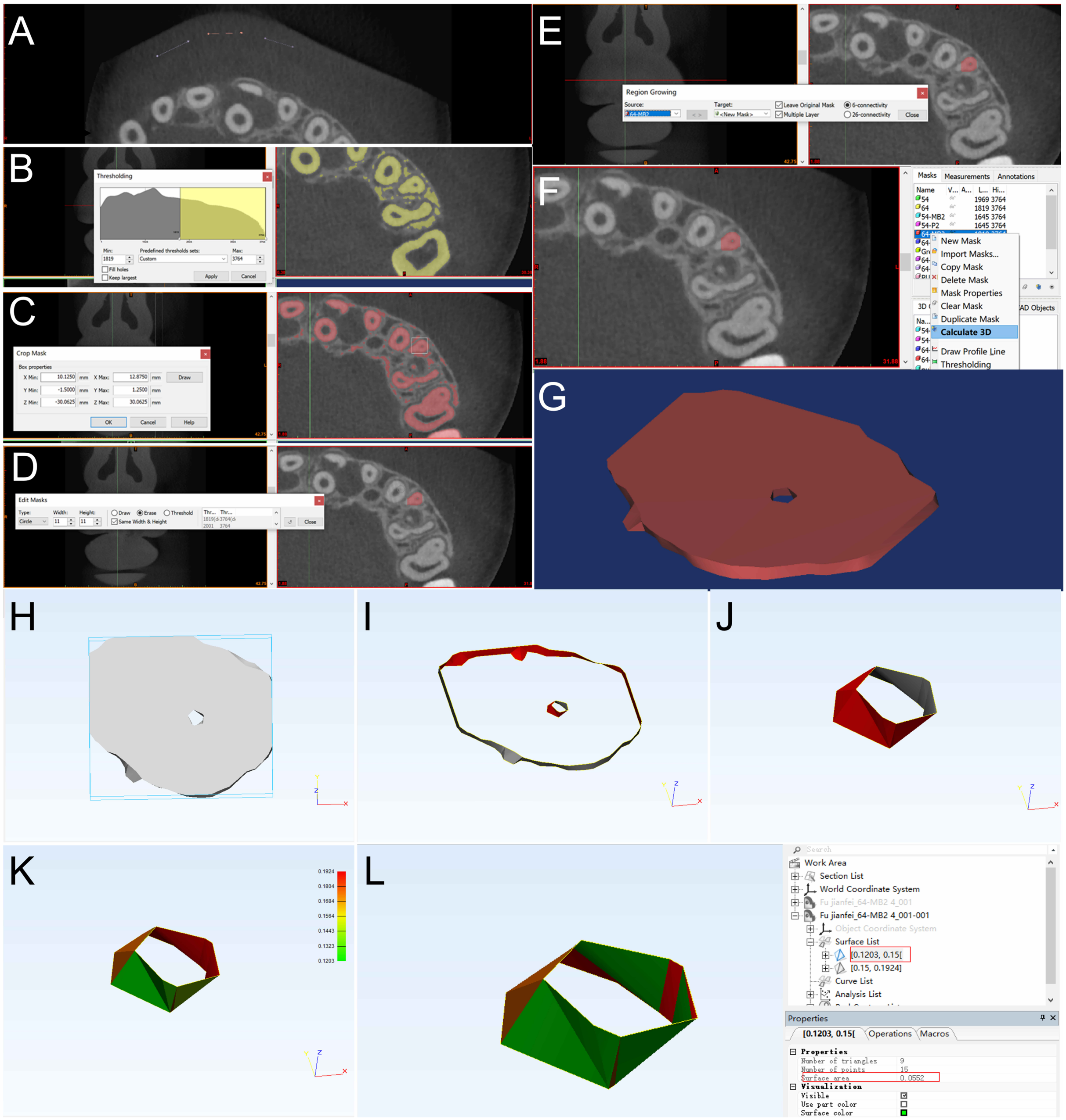

FIGURE 2. Software operation flowchart for 3D reconstruction and root canal diameter measurement in the region of interest. (A) Measurement of the threshold range of the lip in the CBCT scans at three different positions. (B) Selection of the proper threshold to segment the canal and dentin. (C–E) Selection of the region of interest from the CBCT image. (F,G) Reconstruction of the root canal of the target area to obtain a segmented 3D model of the root canal. (H–J) Extraction of the inner surface of the 3D root canal model. (K) Measurement of the diameter of the root canal. (L) Division of the extracted inner surface of the root canal into two parts according to whether the diameter was less than 0.15 mm, followed by determination of the area of each part (indicated by a red rectangle) and calculation of $R_{.15}$.

2.3 Statistical analysis

All the statistical analyses were conducted using SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA). The normality of the data obtained from the CBCT scans was tested using the Kolmogorov-Smirnov one-sample test. Area and length variables that did not exhibit a normal distribution were analyzed using a nonparametric test (Kruskal-Wallis test and Wilcoxon signed-rank test). The relationships of $R_{.15}$, L_C/L_R, and the canal cross-sectional area on plane D with age were analyzed using correlation analysis, and the linear regression coefficient between discontinuous canal occurrence and age was calculated by binary logistic regression. The significance level was set at $p < 0.05$.

3. Results

In total, 58 children (14 girls and 44 boys) were enrolled, including 107 maxillary first primary molars. The average age was 6.0 years, ranging from 3.0 to 8.7 years. All teeth were divided into six groups according to age, and the distribution of the teeth across these groups is shown in Table 1.

TABLE 1. Distribution of maxillary first primary molars across different age groups.

Age group (yr)	3~	4~	5~	6~	7~	8~
Teeth (N)	11	22	17	20	18	19

The cross-sectional area of each maxillary first primary molar root canal on plane D is shown in Table 2. The cross-sectional areas of the mesiobuccal (MB), distobuccal (DB) and palatal (P) root canals on plane D were negatively correlated with age, suggesting that the root canal cross-sectional area decreased with age. Axial CBCT images of teeth from children of different ages (Fig. 3) showed shrinkage of the lumen of all roots.

In addition, the cross-sectional area of P root canals was greater than that of DB and MB root canals ($p < 0.001$); the cross-sectional area of DB root canals was significantly smaller than that of MB root canals ($p = 0.031$). There were 49 patients whose right and left maxillary first primary molars were included in this study, and the Wilcoxon signed-rank test showed a significant difference in the root canal cross-sectional area between the left and right maxillary first primary molars ($p = 0.046$).

The root length and canal length were calculated and are shown in Table 3. The length of the P roots was greater than that of the DB roots and less than that of the MB roots ($p < 0.001$). The lengths of the MB, DB and P root canals were negatively correlated with age, with correlation coefficients of −0.55, −0.49 and −0.49, respectively ($p < 0.001$), suggesting a decrease in canal length with age. Moreover, the L_C/L_R of MB, DB and P was also negatively correlated with age (Table 4, Fig. 4).

A positive correlation was detected between the $R_{.15}$ of the MB roots and age ($r_s = 0.39$, $p < 0.001$), indicating that the canal diameter decreased with age (Table 4). No similar results were obtained for DB or P roots.

The number of discontinuous root canals (N_{dis}) in the different age groups was counted, and the percentage of discontinuous canals was calculated. The percentage of discontinuous MB, DB and P root canals increased with age (Fig. 5). Binary logistic regression analysis revealed that the risk of discontinuous canals for MB, P and DB roots significantly increased with age (Table 5).

4. Discussion

It is difficult to obtain complete primary teeth because of the physiological or pathological absorption of deciduous roots. CBCT provides a feasible method for studying the root canal morphology of deciduous teeth. In this study, we obtained complete 3D structural data of deciduous teeth through CBCT. In contrast to previous *in vitro* micro-CT or nano-CT studies [11, 16], the teeth included in this study were all normal teeth or teeth with caries not exceeding the superficial dentin and with normal pulp *in vivo*. Such samples can reflect the morphology of teeth under physiological conditions and are highly important for obtaining thorough knowledge of the normal anatomy of primary teeth.

The symmetrical distribution of both the root number and root canal morphology has been shown to be highly common in mandibular premolars [17]. However, studies of mandibular primary molars have shown that 28%~68% of the roots are symmetrical [18–20]. Maxillary primary molars have also been reported to have unilateral root variation [21]. Therefore, bilateral primary molars were included in this study, and the cross-sectional area of the root canal on plane D significantly differed between the right and left maxillary first primary molars.

Indices for root canal aging should not only reflect changes in root canal morphology on CBCT but also have clinical significance for serving as a reference for pulp treatment. The canal diameter is directly related to the file size [22]. Because of the irregular cross-sectional shape of the canal, measuring only the maximum and minimum diameter of the root canal cannot clarify the relationship between the inner diameter of the root canal and the file. In this study, the diameter of the canal segment of interest was measured at all positions, and the proportion of the root canal with a diameter less than 0.15 mm, *i.e.*, $R_{.15}$, was calculated. A cutoff value of 0.15 mm was chosen because the #15 K-file is commonly used as the initial manual file for preparing the root canals of deciduous molars. This observation variable can reflect the possibility of the file entering the canal and the proportion of the lateral wall area of the region of interest that can be touched by the #15 K-file on plane D for the near-circular canal and irregularly shaped canal. This measurement index can provide more information than the diameter of the root canal in a certain direction. The cross-sectional area of the canal can directly reflect changes in the canal regardless of the cross-sectional shape, which is a common index used in root canal measurements [16, 23].

In this study, the $R_{.15}$ of the MB roots increased with age, and the cross-sectional area of the MB root canals on plane D decreased with age, indicating a decrease in canal diameter. Similar results were found for the orifices of the mesial root canals of mandibular primary molars ($p < 0.01$) [7] and mandibular first molars [23]. These findings indicate

TABLE 2. Cross-sectional area on plane D of the mesiobuccal, distobuccal and palatal root canals.

Root canal	Age (yr)	Cross-sectional area of root canal (mm^2)				r_s	p
		Minimum	Maximum	Median	Mean		
MB							
	3	0.05	0.73	0.50	0.38		
	4	0.06	0.42	0.20	0.20		
	5	0	0.31	0.14	0.14	−0.41	<0.001
	6	0	0.58	0.16	0.18		
	7	0	0.30	0.02	0.08		
	8	0	0.47	0.11	0.12		
DB							
	3	0	0.61	0.14	0.24		
	4	0	0.30	0.13	0.11		
	5	0	0.36	0.06	0.09	−0.26	0.008
	6	0	0.34	0	0.08		
	7	0	0.30	0.03	0.10		
	8	0	0.20	0	0.06		
P							
	3	0.28	1.69	0.75	0.85		
	4	0.34	1.11	0.70	0.67		
	5	0.20	0.95	0.66	0.63	−0.42	<0.001
	6	0.22	1.38	0.59	0.58		
	7	0.06	0.73	0.44	0.42		
	8	0.06	1.16	0.42	0.47		

DB, distobuccal root; MB, mesiobuccal root; P, palatal root.

that as children age, the canal portion with an inner diameter less than 0.15 mm increases. This means that the #15 K-file becomes less likely to enter the root canal, or more likely to touch less of the canal although the file can enter the canal, especially when the canal presents an irregular shape. Furthermore, we observed that most MB canal cross-sections were oval or flattened on plane D (Fig. 3). The presence of an oval canal and a smaller canal diameter increase the difficulty of mechanical and chemical canal instrumentation, leaving larger areas untouched and more infected material remaining, such as bacteria and pulp debris [24, 25]. Failure of pulpectomy for primary molars has been reported to be correlated with age [26]. The age-related changes in root canal morphology observed in this study may explain this finding. Permanent tooth canal morphology also changes with age [27]. Solomonov *et al.* [28] reviewed papers about age-dependent changes in canal morphology, the structural characteristics of dentin and the relationship between RCT failure and age and suggested selecting appropriate instruments and methods based on the patient's age. This finding suggested that dentists may adopt different preparation instruments and methods for treating the deciduous teeth of children of different ages. However, the $R_{.15}$ of the DB and P canals was not correlated with age in this study. This is because most DB canal diameters were smaller than 0.15 mm on plane D at these young ages. In contrast to those of DB canals, for P canals, nearly all the diameters on plane D were greater than 0.15 mm at all ages. However, the area of the DB and P canals on plane D decreased significantly with age, reflecting age-related changes in the canals.

Changes in the anatomy of the lower half of the root canal were reflected by the variables L_C/L_R and N_{dis}. The results showed that L_C/L_R decreased and N_{dis} increased significantly with advancing age. Secondary dentin deposition causes root canal shrinkage, which can even block small-diameter canals, resulting in canal shortening. However, canal disappearance was usually observed to be incomplete on CBCT, and in some canals, the minor lumen could still be observed under the deposited dentin. This may be caused by differences in the rates of dentin deposition and small differences in the inner diameter of the root canal. Because of the lower resolution, these discontinuous canals may show no root lumen on two-dimensional clinical radiographs, which may affect the accuracy of root canal working length confirmation. This error can lead to incomplete root canal preparation and increase the risk of leaving residual infectious substances.

Because the lengths of the three roots of the maxillary first deciduous molars were significantly different, we divided the roots into three equal parts to observe the changes in the canals with age, as in previous studies [24]. During the experiment, for children older than 5 years, most of the DB root canal lumen and the majority of the MB root canal lumen could not be

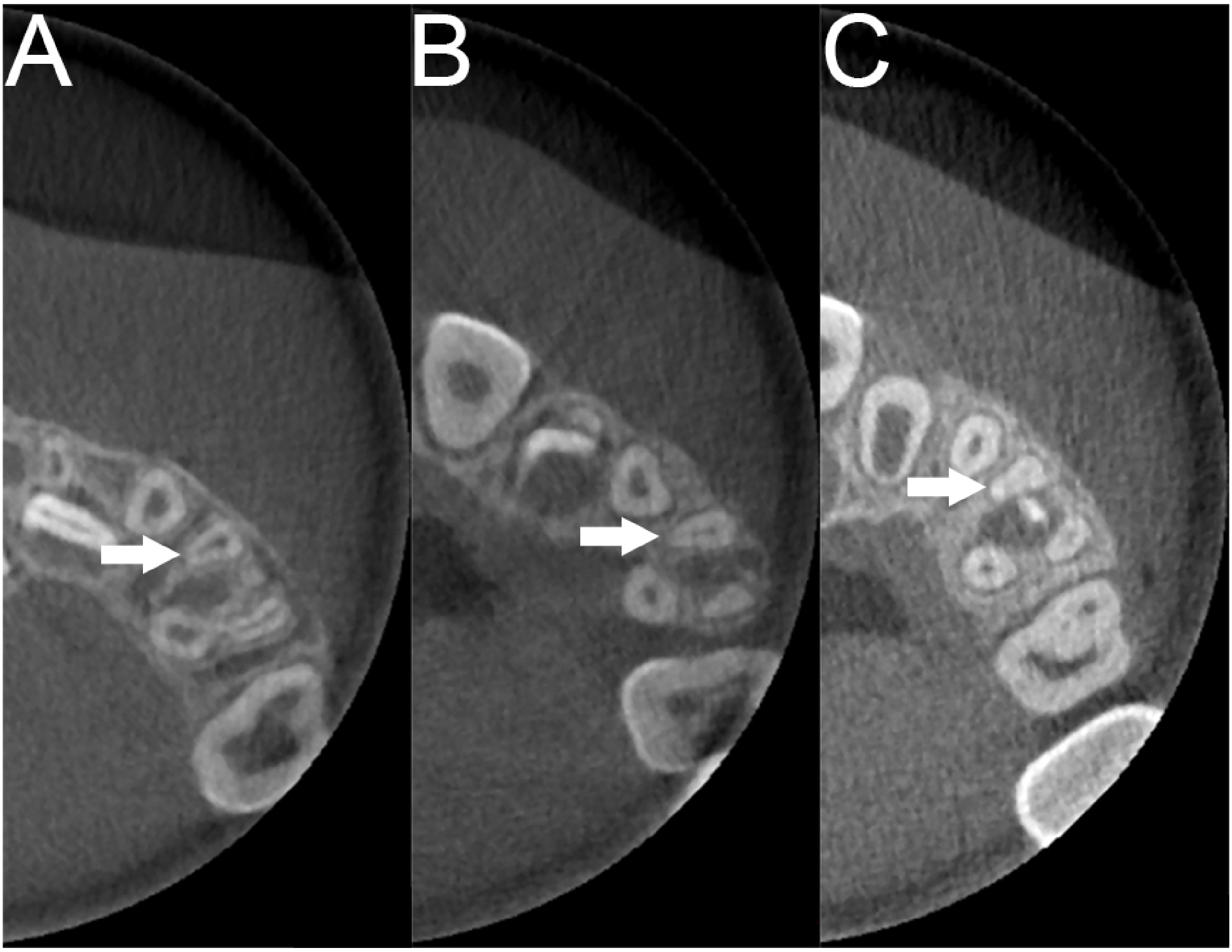

FIGURE 3. Decrease in the canal diameter of the maxillary first primary molar with age. (A) The MB canal of a 3-year-old child. (B) MB canal of a 6-year-old child. (C) MB canal of an 8-year-old child. From A to C, the lumen of the MB canal decreases.

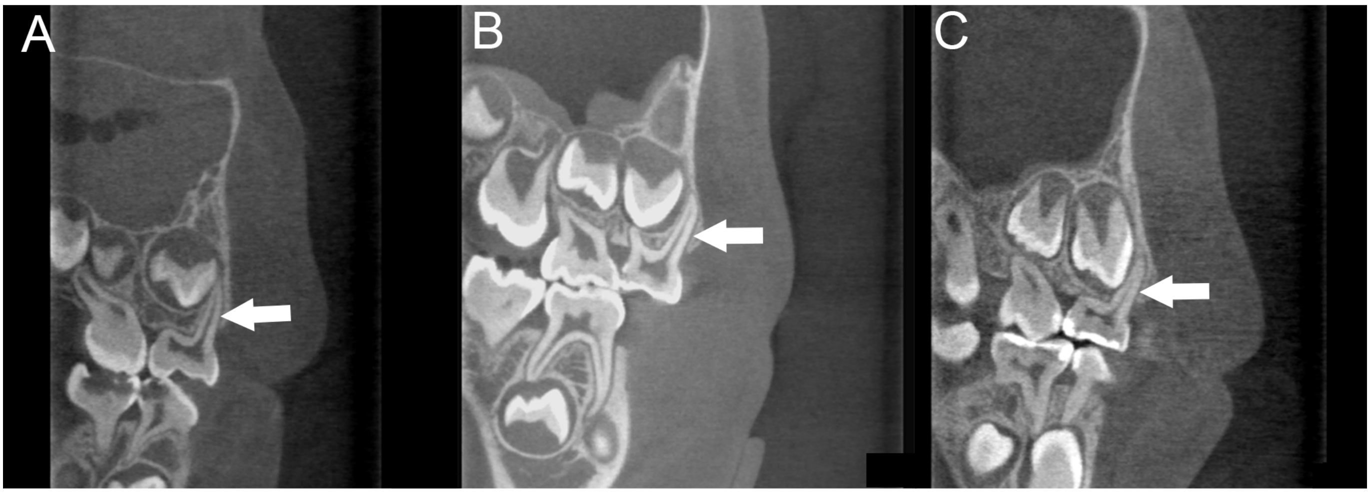

FIGURE 4. Decrease in the canal length of the maxillary first primary molar relative to the root length (L_C/L_R). (A) MB canal of a 4-year-old child. (B) MB canal of a 6-year-old child. (C) MB canal of an 8-year-old child.

observed on the plane positioned at the midpoint of the apical two-thirds of the root length. Therefore, the plane where the midpoint of the coronal two-thirds of the root length lies was chosen as the measurement plane and was named plane D.

In this study, four feasible observation indices were successfully developed for careful observation of the root canal

TABLE 3. Root length and canal length of mesiobuccal, distobuccal and palatal roots at different ages.

Root canal	Age (yr)	Root length				Canal length					
		Min	Max	Med	Mean	Min	Max	Med	Mean	r_s	p
MB											
	3	4.75	8.50	7.75	7.09	3.00	6.00	4.88	4.45	−0.55	<0.001
	4	5.63	8.25	7.00	6.94	3.25	5.38	4.31	4.35		
	5	4.25	9.38	6.75	6.84	0.88	4.37	3.38	3.24		
	6	4.13	7.88	6.37	6.14	1.25	4.63	3.38	3.21		
	7	3.38	9.50	7.12	6.50	0.25	5.50	2.88	2.88		
	8	3.87	8.00	6.25	5.93	0	5.25	2.38	2.31		
DB											
	3	4.00	6.00	4.88	4.88	1.75	4.50	2.75	3.01	−0.49	<0.001
	4	3.25	6.25	4.57	4.65	0.25	4.37	2.57	2.31		
	5	2.25	8.50	4.50	4.77	0	3.63	1.75	1.88		
	6	1.13	7.50	4.69	4.32	0	3.75	1.38	1.56		
	7	2.13	5.50	3.63	3.59	0	3.75	1.06	1.27		
	8	2.38	6.88	4.13	4.29	0	3.25	0.75	1.05		
P											
	3	4.12	8.50	6.38	6.24	3.75	6.87	4.75	5.02	−0.49	<0.001
	4	3.88	9.25	5.50	5.89	2.50	7.12	4.63	4.68		
	5	3.13	6.88	5.63	5.30	2.88	5.50	3.87	3.96		
	6	3.00	7.62	5.38	5.39	2.63	6.25	3.94	4.06		
	7	3.25	7.12	5.38	5.13	2.50	4.87	3.25	3.46		
	8	2.50	8.25	4.63	4.99	2.12	5.50	3.50	3.50		

DB, distobuccal root; MB, mesiobuccal root; Max, maximum; Med, median; Min, minimum; P, palatal root.

TABLE 4. Correlations of L_C/L_R and $R_{.15}$ with age for mesiobuccal, distobuccal and palatal roots.

	Age (yr)						r_s	p
	3	4	5	6	7	8		
L_C/L_R								
MB								
Median	0.65	0.64	0.48	0.56	0.46	0.40	−0.39	<0.001
Mean	0.62	0.62	0.48	0.53	0.46	0.39		
DB								
Median	0.56	0.50	0.36	0.33	0.30	0.18	−0.42	<0.001
Mean	0.62	0.48	0.40	0.33	0.36	0.24		
P								
Median	0.83	0.79	0.79	0.83	0.70	0.77	−0.29	0.002
Mean	0.81	0.80	0.76	0.77	0.69	0.72		
$R_{.15}$								
MB								
Median	0	0	0.18	0.29	1.00	0.57	0.39	<0.001
Mean	0.08	0.07	0.31	0.41	0.57	0.51		
DB								
Median	0.38	0.23	0.89	1.00	1.00	1.00	0.16	0.098
Mean	0.48	0.48	0.65	0.65	0.61	0.66		
P								
Median	0	0	0	0	0	0	0.09	0.349
Mean	0.01	0	0	0.02	0.07	0.02		

DB, distobuccal root; MB, mesiobuccal root; P, palatal root.

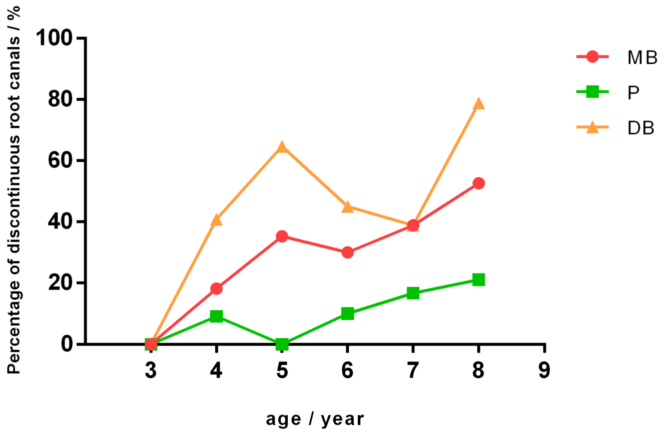

FIGURE 5. Percentages of discontinuous mesiobuccal, distobuccal and palatal root canals at different ages. DB, distobuccal root; MB, mesiobuccal root; P, palatal root.

TABLE 5. Binary logistic regression analysis for discontinuous canal and age in mesiobuccal, distobuccal and palatal roots.

Variable	B	*p* value	OR	95% CI for OR	
				Lower	Upper
Discontinuous canal					
MB	0.48	0.001	1.61	1.20	2.15
DB	0.39	0.003	1.48	1.14	1.91
P	0.47	0.043	1.60	1.02	2.51

B, unstandardized coefficient; CI, confidence interval; DB, distobuccal root; MB, mesiobuccal root; OR, odds ratio; P, palatal root.

morphology of deciduous teeth. It is hoped that more clinicians will participate in relevant work in the future to revise and improve these indices so that they can more accurately reflect the characteristics of the root canal morphology and improve our understanding of the root canal morphology of deciduous teeth.

This study has several limitations. First, for the study of age-related changes, obtaining CBCT scans of the same child at different ages is the best approach. However, because children are sensitive to radiation, CBCT cannot be performed only for scientific research. Therefore, it is more practical to choose scans from children of different age groups for comparison. Second, due to the strict indications for CBCT in young children, the number of CBCT images meeting the inclusion criteria was low, and the results of some indices may be affected by individual variation. However, the changes with age were still obvious. The final research results need to be verified by studies with larger sample sizes at multiple clinical centers. Third, due to the limitations of the resolution of CBCT, only the main root canal could be studied, and root canals smaller than the voxel size could not be identified.

5. Conclusions

New indices were successfully developed in this study to demonstrate age-related changes in the root canals of primary molars by CBCT. As age increases, the root canal of maxillary first primary molars becomes thinner, and the apical third experiences discontinuous calcification, posing a challenge for RCT.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available upon reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

BX, GLD and YJZ—designed the research study. GLD, ZPS and ZQC—performed the research. GLD—analyzed the data and wrote the manuscript. All the authors contributed to editorial changes in the manuscript. All the authors have read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted in accordance with the tenets of the Declaration of Helsinki for research involving human subjects and approved by the Ethics Committee of Peking University School and Hospital of Stomatology (approval number: PKUSSIRB-201949122). Informed consent to use the CBCT data was obtained from the patients' guardians.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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