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ORIGINAL ARTICLE

Evaluation of root canal morphology of human primary molars by using CBCT and comprehensive review of the literature

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ABSTRACT

Objective Knowledge of primary tooth morphology is essential for clinical dentistry, especially for root canal treatment and dental traumatology. However, this has not been well documented to date with a large sample. This study was carried out to investigate the variation in number and morphology of the root canals of the primary molars, to study the applicability of cone beam computerized tomography (CBCT) in assessing the same and to provide a comprehensive review of the literature. **Materials and methods** A total of 343 primary molars, without any root resorption, were divided into four main groups including the maxillary first molars, maxillary second molars, mandibular first molars and mandibular second molars. All of them were analysed in CBCT images in the axial, sagittal and coronal planes. Various parameters such as the number of roots, number of canals, the root canal type, diameter of root and root canal and root canal curvature were studied. **Results** Primary molars in all four groups showed variability in the number of roots and root canals. As far as length of the roots was concerned, the palatal root of the maxillary molar was found to be longest, while the distobuccal root was shortest. In mandibular molars, the mesial root was longer than the distal root. The length of distobuccal root canal of the maxillary molars and the distolingual canal of the mandibular molars was found to be shortest. The number of roots and root canals varied from two to four and three to four, respectively. The maxillary molars exhibited more one-canal than two-canal roots. **Conclusion** The present study provides comprehensive information to the existing literature concerning the variation in root canal morphology of the maxillary and mandibular primary molar teeth. These data may help clinicians in the root canal treatment of these teeth.

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Introduction

The primary dentition has numerous functions and is important in a child's development. Knowledge of the morphology and variation of the root canals of primary teeth is useful in visualizing endodontic therapy. However, the root and canal anatomy of primary teeth is rarely reported because of the scarcity of intact primary teeth without root resorption. Successful root canal therapy consists of thorough biomechanical instrumentation and chemical debridement, followed by hermetic obturation of the root canal system. However, the complexity of the root canal anatomy presents clinical challenges and difficulties that often jeopardize the primary goal of such therapy. Therefore, variations in the root canal systems and characteristic features in different races should be recognized before or during endodontic treatment.[1]

As primary teeth exhibit morphologic differences from the permanent teeth both in size and in general internal and external design, a comprehensive understanding of the root and the root canal morphology is of utmost importance.[2–7] Work by many researchers has resulted in a better understanding of the intricacies of the root canals.[2,8–10] To gather this knowledge, different techniques were used which either destroyed or altered the tooth structure, thus precluding further studies on the same teeth. Computed-based techniques have been popularly used for studying root canal morphology.[11] CBCT, one of these methods, potentially provides the clinician with the ability to observe an area in three different planes with a practical tool for non-invasive and 3-dimensional (3D) reconstruction imaging for use in endodontic applications and morphologic analyses. The combination of sagittal, coronal and axial CBCT images eliminates the superimposition of anatomic structures. Root morphology can be visualized in three dimensions, as can the number of root canals and their convergence or divergence from each other. As a result, CBCT has been suggested to assist in identifying root canal systems.[12]

To our knowledge, no previous study has investigated root and canal morphology using CBCT. Therefore, the present retrospective study was undertaken to assess the variation in

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number and morphology of the root canals of primary molars and to study the applicability of CBCT in assessing the root canal morphology of the primary molars.

Materials and methods

We designed a retrospective study composed of CBCT (Newtom 5G, QR, Verona, Italy) images of patients who presented to the Oral and Maxillofacial Radiology service at the Erciyes University Faculty of Dentistry between June 2011 and May 2015. The subjects were selected from the CBCT database and cases with systemic conditions or malformation not suitable for this study were excluded. The CBCT images had been taken because of the patients' previous dentomaxillofacial problems. Teeth were selected according to the following criteria: (i) primary molars with no periapical lesions; (ii) no root canals with open apices or resorption, (iii) no root resorption and (iv) CBCT images of good quality. Teeth with root canal fillings, restorations or crowns were excluded from study. The final sample group comprised 75 children (33 boys, 42 girls; mean age = 57.95 ± 7.32 months, age range = 39–78 months). Thus, 343 primary molars were analysed and divided into four groups:

- Group I—Maxillary first molars ($n = 81$).
- Group II—Maxillary second molars ($n = 100$).
- Group III—Mandibular first molars ($n = 72$).
- Group IV—Mandibular second molars ($n = 90$).

The CBCT images were analysed with the inbuilt software (NNT) in a Dell Precision T5400 workstation (Dell, Round Rock, TX), with a 32-inch Dell LCD screen with a resolution of 1280 × 1024 pixels in a darkroom. The contrast and brightness of the images were adjusted using the image processing tool in the software to ensure optimal visualization. Two dentomaxillofacial radiologists evaluated concurrently all the images to reach a consensus in the interpretation of the radiographic findings. The teeth were evaluated using the NNT toolbar by carefully rolling downward through the images from the floor of the pulp chamber to the apex to determine the number of roots, the number of root canals and the canal configuration in the axial tomographic slices. Selecting and moving the cursor on one image to change the centre of view altered the reconstructed slices in three orthogonal planes. Tomography sections of 0.150 mm in the axial, coronal and sagittal planes were created. Axial and cross-sectional images (coronal and sagittal images) were transmitted to a personal computer in the digital imaging and communications in medicine (DICOM) format and reconstructed into multi-planar reconstruction images using the DICOM viewer: ExaVision SX Ver.1.13 (Ziosoft, Inc, Tokyo, Japan). These views were used to examine the root canal system.

The teeth involved were investigated radiographically by CBCT and the following observations were evaluated:

- number of roots and their morphology; to understand root morphology, axial views above the cervical area were analysed,
- number of canals per root,
- root canal type (according to Vertucci's classification),
- root canal curvature,
- the eight different variants in the root canal morphology of the primary molars were as follows (Figure 1):
  - shapes of the root canals from the tomographic images were examined at various root levels; cervical (a), middle (b) and apical (c) levels of the roots.
  - diameter of root: the perpendicular distance from the cervical line to the apex.
  - diameter of root canal: measurement was made at the greatest diameter from the cross-section of the roots, irrespective of the various aspects of the canal.

To check for the diagnostic reproducibility of the inter-reliability of the investigators, 10% of the radiographs assigned by them were randomly examined each day for 2 consecutive weeks. Examination of results using the Wilcoxon matched pairs signed-rank test showed no statistically significant difference.

Statistically significant differences were evaluated using descriptive statistics to determine the frequency, mean, standard deviation and range for all four groups with SPSS 16.0 for Windows (SPSS, Chicago, IL). *P*-value of < 0.05 was considered statistically significant. The total number of roots and root canals, the root canal configuration, bilateral and unilateral appearance, the incidence and the correlations between left- and right-side occurrences, cross-sectional root canal outlines and consistency of the root canal morphology from the cervix to the apex of the respective primary molars and between genders were analysed. The three-dimensional parameter results and the average length of roots and root canals were statistically compared using the paired-sample *t*-test within group and independent sample *t*-test between groups, respectively. A chi-squared test was used to analyse the differences in the prevalence of cross-sectional root canal outlines at various root levels and differences in the degree of root canal outline consistency between the maxillary and mandibular primary molars.

Results

The observations made during the course of the study are shown in Tables 1–4. Examples of roots and root canals and the shapes of the roots and canal systems are also shown on the CBCT images in different directions and different root levels as well, Figures 2 and 3 present exemplary cross-sectional CBCT images corresponding to different types of roots and root canals.

Table 1 shows the number of roots and root canals of each primary molar in all the four groups. In the mandibular molars, most of the samples had two roots; in the maxillary molars, in most of the samples both the distobuccal and palatal roots were fused. The frequency distribution of the number of roots and root canals did not differ between genders ($p > 0.05$).

Table 2 presents the number, curvature and type of root canals in all the groups. In the mandibular molars, out of 162 samples 11 samples had one canal in the mesial root and the others had two canals. In the maxillary primary first molars, one canal was seen in the mesiobuccal root in most of the samples. All the distobuccal and palatal roots of the maxillary molars were single-canal roots. The number of root canals in

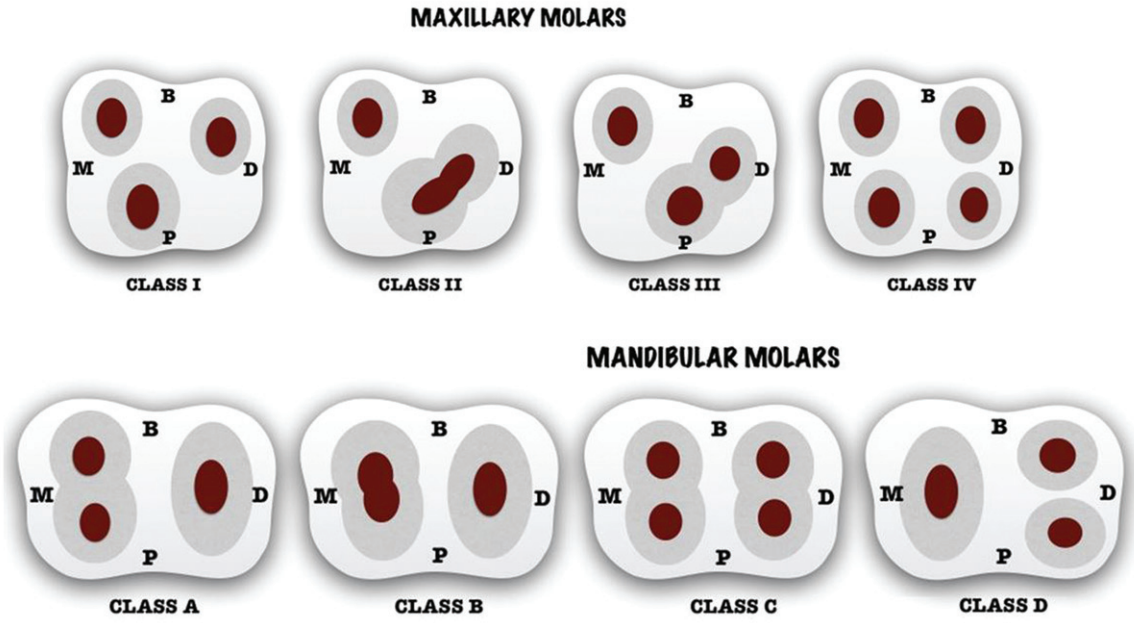

Figure 1. Different variants in root canal morphology of primary molars.

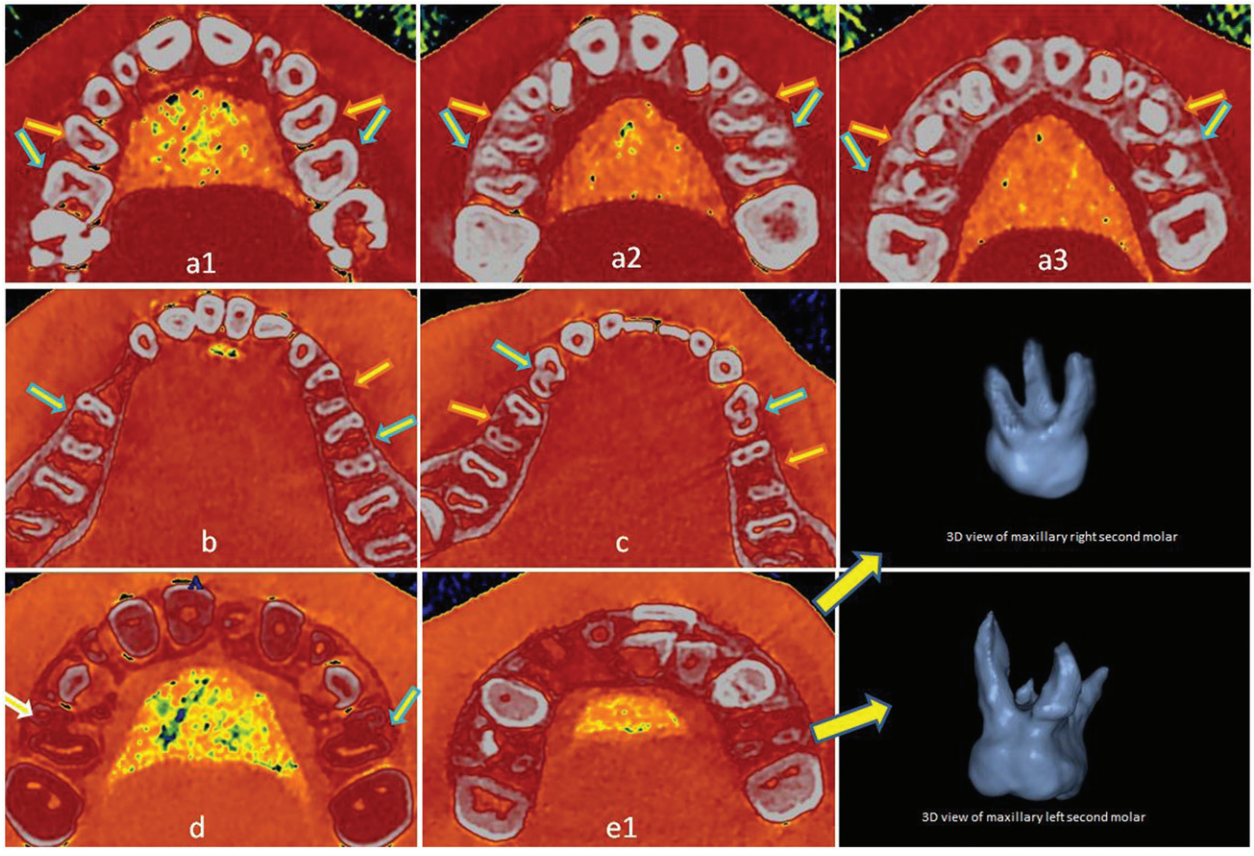

Figure 2. (A1–3) Cross-sectional CBCT images corresponding to horizontal lines at the apical (A1), middle (A2) and cervical (A3) levels of the roots of maxillary primary molars. (B) Mandibular primary molars with two roots and two canals in each root. (C) Mandibular primary first molars with two roots and one canal in each root (blue lined arrow); mandibular primary left second molar with two roots and two canals in each root (red lined arrow); mandibular primary right second molar with two roots: mesial canal with one root canal and distal root with two root canals. (D) Maxillary primary second molars with two roots: mesial root with two canals and distal root with one canal. (E1) Maxillary right primary second molar with three roots and one canal in each root: maxillary left primary second molar with four roots and one canal in each root and its 3-D view (E2).

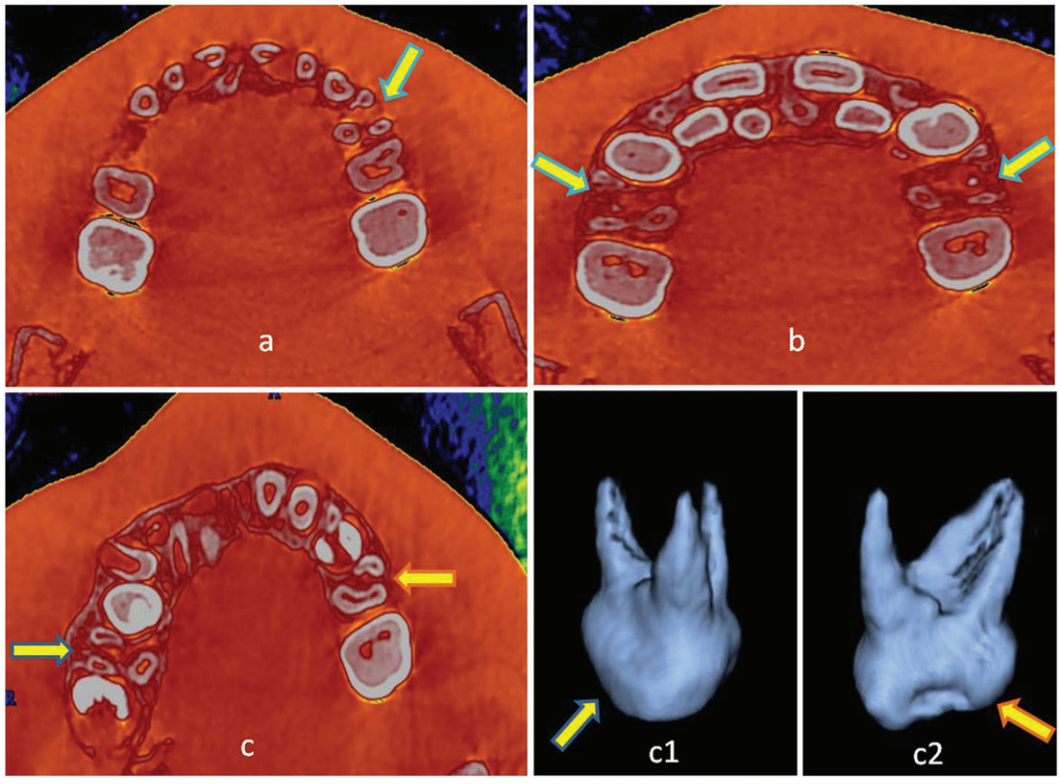

Figure 3. (A) Cross-sectional CBCT images of maxillary left primary first molar with three roots and three canals in each root. (B) Three rooted maxillary primary second molars that have three canals in each tooth. (C and C1) The cross-sectional and 3D images of the maxillary right primary second molar that has three roots and three canals (blue lined arrows). (C and C2) Maxillary left primary second molar that has fused distal and palatinal roots and canals and separated mesial root and canal (red lined arrows).

Table 1. Number of roots and root canals in primary molars.

Number of roots/canals	Maxillary first molar ($n = 81$)	Maxillary second molar ($n = 100$)	Mandibular first molar ($n = 72$)	Mandibular second molar ($n = 90$)
Two-root	7	9	*68*	82
3-canal	6	5	52	58
4-canal	1	4	16	24
Three-root	74	87	4	8
3-canal	48	50	3	6
4-canal	25	37	1	2
Four-root	0	4	0	0
4-canal	0	4	0	0

the respective roots of the maxillary second primary molars was similar to that in the maxillary first primary molars.

The specimens investigated in this study included type I, where roots have one canal, and type IV, where the roots have two canals; therefore, if there were two root canals in one root, these two canals were completely separated. In the mandibular primary molars, Vertucci types IV and I canal configurations were the most prevalent in the mesial and distal roots, respectively.

Table 3 shows the axial tomographic images of roots and root canals at various root levels, i.e., cervical (a), middle (b) and apical (c) levels of the roots. Regardless of the shape of the root canals at the cervical and/or middle levels, most root canal outlines tended to be ovoid at the apex. Differences in the prevalence of cross-sectional root canal outlines between the mandibular and maxillary molars at various levels of the root were statistically significant ($p < 0.05$).

Table 4 presents the consistency of the root canal morphology throughout the entire root and root canal length in all the four groups. In the mandibular first primary molars, the distolingual root was showed the shortest measurement. Table 5 presents different variants in the root canal morphology of the primary molars. In the mandibular molars, the most frequently observed variant was class III and in the maxillary molars it was class A. Overall, in both groups of teeth no statistical differences were found between the root canals of the first and second molars with respect to length ($p > 0.05$). The mesial and palatal canals of the mandibular and maxillary molars, respectively, presented a significantly higher length than the other canals in the same group of teeth ($p < 0.05$).

Discussion

The present study provides a detailed report on the root canal morphology of the mandibular and maxillary primary first and second molars. According to the present study, the sum of roots and root canals can be visualized clearly in axial sections. Multi-planar CBCT scans obtained from axial sections could be a useful tool for the study of the anatomy of root canals without surgical intervention.

To successfully perform a root canal treatment on a primary tooth, a detailed knowledge of the internal and external morphology of each of the primary teeth is required.[2] A thorough knowledge of dental anatomy of the primary dentition is essential for all treatment aspects. The major cause of failure of pulpectomy is an inability to recognize and,

Table 2. Distribution of the number of root canals in individual roots of each primary molar.

		Number of root canals					
				Curvature of canals			
Tooth	Root	1-canal	2-canal	Straight	Curved	S-shaped	No of samples
Maxillary first molar	MB	54	27**	12	67	2	81
	DB	14	0	3	7	4	
	P	14	0	8	4	2	
	DB + P	0	77	48	26	7	
Maxillary second molar	MB	83	17**	17	78	5	100
	MP	4	0	4	0	0	
	DB	17	0	10	4	3	
	P	17	0	5	8	4	
	DB + P	0	83	56	39	5	
Mandibular first molar	M	7	65**	16	50	6	72
	D	61	11**	43	18	7	
	DL	4	0	3	1	0	
Mandibular second molar	M	4	86**	23	55	12	90
	D	79	11**	54	23	13	
	DB	8	0	4	3	1	
	DL	8	0	3	3	2	

+: fused; B: buccal; D: distal; L: lingual; M: mesial; P: palatal.
**type IV; other canals: type I.

Table 3. Cross-sectional outlines of different root canals at different root levels.

		Root canal outlines at root different root levels*								
		Cervix			Middle			Apex		
Tooth	Name of root	O	F-O	R	O	F-O	R	O	F-O	R
Maxillary first molar	MB	15	59	6	22	243	8	39	8	33
	DB	12	54	7	42	9	15	33	15	25
	P	28	10	35	39	11	23	38	14	21
	DB + P	0	4	3	1	3	3	2	2	3
Maxillary second molar	MB	11	80	9	25	57	18	44	20	36
	MP	1	0	3	2	0	2	3	0	1
	DB	7	67	17	29	47	14	25	23	43
	P	13	24	54	15	18	58	31	7	53
	DB + P	4	5	0	6	2	1	6	0	2
Total		91	303	134	181	390	141	221	89	217
Mandibular first molar	M	4	61	7	47	11	14	39	7	26
	D	9	48	11	31	8	29	27	4	37
	DL	1	2	0	1	0	2	0	0	3
Mandibular second molar	M	8	70	12	51	8	31	53	6	31
	D	12	54	16	28	16	38	47	11	24
	DB	3	4	1	5	1	2	6	1	1
	DL root	2	3	3	3	2	3	3	0	5
Total		39	242	50	166	46	119	175	29	127

*Significant difference existed in the prevalence of root canal shapes between maxillary and mandibular primary molars at different root levels ($p < 0.05$).
+: fused; B: buccal; D: distal; L: lingual; M: mesial; P: palatal; O: Oval; R: Round; F-O: Flat-oval.

therefore, adequately treat all of the canals of the root canal system.[13–18]

Reported studies related to the root and root canal morphology of human primary molars are presented in Tables 6 and 7. In the primary mandibular molars, two canals in the mesial root and one canal in the distal root comprised the most commonly observed anatomical configuration.[2,4–6] The internal and external morphology of the primary mandibular first molar closely resembles that of the primary mandibular second molar.[3,7] In Gaurav et al.'s[19] study, the mesial root of all the samples had two canals, i.e., the mesiobuccal, mesiolingual and the distal roots showed the presence of two canals in 20% of the samples and the presence of one canal in the remaining 80% of samples. The findings are in accordance with the findings of Aminabadi et al.,[5] Zoremchhingi et al. [4] and Hibbard and Ireland [2] who found more than one canal in 25%, 40% and 20% of distal roots, respectively. In the present study, the majority of primary mandibular molars had two canals and similar results were observed.

The maxillary primary first and second molars have been described as having three divergent and separated roots.[2,3,6] This agrees with a report by Zoremchhingi et al.[4] and a study examining a method of root canal accessibility.[5] In the present study, a maxillary second molar tooth with four separate roots was observed, which has not been reported before.

The prevalence of fused distobuccal and palatal roots in the maxillary primary molars varies among studies. In the present study, five of 14 (17.2%) maxillary primary molars showed fusion between the distobuccal and palatal roots, which is lower than in Wang et al.'s [11] study (27.7%). In their study, most maxillary primary molars had one canal for each root, with two canals in distobuccally-palatally fused roots.

Table 4. Mean (± SD) of the morphometric 3D data in each root of primary maxillary and mandibular molars.

	Root canal	Root length (mm)		Canal length (mm)	
		Min–max (mm)	Mean ± SD	Min–max (mm)	Mean ± SD
Mandibular first molar	M	5.9–11.7	7.1 ± 1.3	5.7–11.4	5.9 ± 1.3
	D	5.4–11.3	6.4 ± 1.5	5.1–11.2	5.1 ± 1.8
	DL	5.2–11.8	5.9 ± 1.0	4.9–11.5	5.4 ± 1.7
Mandibular second molar	M	6.4–12.7	8.2 ± 1.3	6.1–12.5	6.9 ± 1.3
	D	5.8–12.0	8.6 ± 1.7	5.6–11.8	6.6 ± 1.8
	DL	5.3–11.6	7.7 ± 1.4	5.0–11.1	6.4 ± 1.4
Maxillary first molar	MB	6.1–12.0	6.9 ± 1.8	4.8–11.9	5.4 ± 1.8
	DB	5.5–11.5	6.1 ± 1.6	4.4–11.0	4.8 ± 1.7
	P	6.7–11.9	7.7 ± 0.9	6.0–11.8	6.3 ± 2.1
	DB + P	6.3–11.8	7.4 ± 1.2	5.3–11.3	6.1 ± 1.9
Maxillary second molar	MB	6.3–12.1	7.2 ± 1.1	5.2–11.8	6.1 ± 1.6
	MP	3.7–5.1	4.1 ± 1.3	3.1–4.8	3.7 ± 1.1
	DB	5.8–11.9	6.9 ± 1.5	5.0–11.6	5.9 ± 1.5
	P	6.8–12.4	8.3 ± 1.7	5.8–12.3	6.5 ± 2.1
	DB + P	6.5–12.1	7.9 ± 1.4	5.5–12.0	6.1 ± 1.8

M: mesial; D: distal; MB: mesio-buccal; DB: disto-buccal; P: palatal; SD: standard deviation.

Table 5. Distributions and percentages of the eight categories of variants in the root canal anatomy of primary molars.

Variant	Maxillary first molar		Maxillary second molar		Variant	Mandibular first molar		Mandibular second molar	
	sample	%	sample	%	sample	sample	%	sample	%
class I	26	32.1	29	29.0	class A	53	73.6	65	722
class II	12	14.8	13	13.0	class B	7	9.7	4	44
class III	43	53.1	54	54.0	class C	12	16.7	13	144
class IV	0	0	4	4.0	class D	0	0	8	49

This result was also comparable to the report by Zoremchhingi et al.[4] Mesbahi et al. [20] reported that 37.5% of the maxillary first primary molars had similar root canal communication. In the present study, 23 of 181 maxillary molars had one canal for each root, with two canals in distobuccally-palatally fused roots. In Wang et al.' s [11] study, three of 18 (17%) maxillary primary molars demonstrated communication between the mesiobuccal and distobuccal root canals.

In the maxillary first molars, the incidence of a double canal system in the MB root was reported in 6.7%,[4] 7.4% [6] and 35% [2] of samples and, in the DB root, in 3.7% of the specimens.[6] In the present study, a double canal system was observed in the MB root of 44 maxillary first molars (24.3%).

A study reported by Goodacre [3] found that the mean lengths of the MB, DB and palatal roots of the maxillary second molars were 10.8, 9.7 and 10.8 mm, respectively, and in the maxillary first molars they were 8.8, 8.2 and 7.8 mm, respectively, which is higher than the results of the present study. In the Fumes et al. [17] study, the mean lengths of the MB, DB and palatal roots of the maxillary second molars were 8.5, 6.5 and 7.4 mm, respectively, and in the maxillary first molars they were 7.9, 6.7 and 5.9 mm, respectively.

In the primary mandibular molars, the morphology of the double ribbon-shaped canal system has been reported to range from 24–100% in the mesial root and from 22.2–60% in the distal root.[4,6] In this study, the cross-sections of the root canal outlines were divided into oval, flat-oval and ribbon shapes. The present study showed that oval root canal outlines were mostly observed at the apical level. In Wang et al.'s[11] study, the palatal roots of the maxillary second primary molars and ribbon-shaped root canals were observed, but there were only a few. In their study, it was noted that the number of ovoid and ribbon-shaped root canals occurred equally at the cervical level in the molars. In the mandibular molars, the flat-oval shape occurred more frequently than the oval shape at the middle level. In the present study, the shapes of root canals from the cervical to the apical level and the number of oval root canal outlines were increased.

Conclusion

This study showed the complexity of the root canal system in the primary molars. CBCT provides effective and accurate clues and knowledge of variations in the root canal diameter and root canal morphology, which could help clinicians to obtain a thorough understanding of the variations in the root canal morphology of primary molars, thus allowing them to overcome problems.

Why is this study important to dentists?

- The present findings may help clinicians to obtain a thorough understanding of the morphological variations of the root and root canals in the primary molars to overcome problems and, thus, allow appropriate management strategies for root canal treatment.
- CBCT is a relatively new and effective technology, which provides an auxiliary imaging modality to supplement conventional radiography for assessing the variation in root canal morphology of primary teeth.
- The number of samples in the present study was large enough to gain an understanding of the primary molars' morphology and its distribution.

Table 6. The review of primary molars' root canal system.

Teeth	Number of canals and apices	Reference	Year	Number of teeth (canal studies)	One canal	%	Two canals	%	Three canals	%	Other variations*	%
Maxillary First Molar	Mesiobuccal root	Bagherian et al. [6]	2010	27	25	92.6	2	7.4	—	—	—	—
		Aminabadi et al. [5]	2008	40	40	100	—		—	—	—	—
		Zoremchhingi et al. [4]	2005	15	14	93.3	1	6.7	—	—	—	—
		Wang et al. [11]	2013	8	7		1		—	—	—	—
		Sarkar and Rao [16]	2002	8	4	50	4	50	—	—	—	—
		Fumes et al. [17]	2014	10	1	100			—	—	—	—
		Hibbard and Ireland [2]	1957	17	8	47	6	35	—	—	3 (18%)	18
	Distobuccal root	Bagherian et al. [6]	2010	27	26	96.3	1	3.7	—	—	—	—
		Aminabadi et al. [5]	2008	40	40	100	—	—	—	—	—	—
		Zoremchhingi et al. [4]	2005	7	7	100	—	—	—	—	—	—
		Wang et al. [11]	2013	4	4	100	—	—	—	—	—	—
		Sarkar and Rao [16]	2002	8	8	100	—	—	—	—	—	—
		Fumes et al. [17]	2014	10	1	100	—	—	—	—	—	—
		Hibbard and Ireland [2]	1957	12	10	83	—	—		—	2 (17%)	17
	Palatal	Bagherian et al. [6]	2010	27	27	100	—	—	—	—	—	—
		Aminabadi et al. [5]	2008	40	40	100	—	—	—	—	—	—
		Zoremchhingi et al. [4]	2005	7	7	100	—	—	—	—	—	—
		Wang et al. [11]	2013	4	4	100	—	—	—	—	—	—
		Sarkar and Rao [16]	2002	6	6	100	2	25	—	—	—	—
		Fumes et al. [17]	2014	10	1	100	—	—	—	—	—	—
		Hibbard and Ireland [2]	1957	12	12	100	—	—	—	—	—	
	Fused distobuccal and palatal roots	Zoremchhingi et al. [14]	2005	8	—		8	100	—	—	—	—
		Wang et al. [11]	2013	4			4		—	—	—	—
		Sarkar and Rao [16]	2002	2			2	100	2	25		
		Hibbard and Ireland [2]	1957	5	1	20	4	80	—	—	—	—
Maxillary Second Molar	Mesiobuccal root	Bagherian et al. [6]	2010	14	14	100	—	—	—	—	—	—
		Aminabadi et al. [5]	2008	36	36	100	—	—	—	—	—	—
		Zoremchhingi et al. [4]	2005	15	7	46.6	8	53.3	—	—	—	—
		Wang et al. [11]	2013	10	6		4			—		
		Sarkar and Rao [16]	2002	9	2	22.2	7	77.7		—		
		Fumes et al. [17]	2014	10	1	100	—			—		
		Hibbard and Ireland [2]	1957	23	11	48	4	17	1	4	7	30
	Distobuccal root	Bagherian et al. [6]	2010	14	14	100	—	—	—	—	—	—
		Aminabadi et al. [5]	2008	36	26	72.2	10	29.1	—	—	—	—
		Zoremchhingi et al. [4]	2005	15	11	73.3	4	26.6	—	—	—	—
		Wang et al. [11]	2013	9	9	100	—	—	—	—	—	—
		Sarkar and Rao [16]	2002	9	7	77.7	2	22.2	—	—	—	—
		Fumes et al. [17]	2014	10	1	100	—	—	—	—	—	—
		Hibbard and Ireland [2]	1957	15	15	100	—	—	—	—	—	—
	Palatal	Bagherian et al. [6]	2010	14	14	100	—	—	—	—	—	—
		Aminabadi et al. [5]	2008	36	36	100	—	—	—	—	—	—
		Zoremchhingi et al. [4]	2005	15	9	60	6	40	—	—	—	—
		Wang et al. [11]	2013	9	9	100	—	—	—	—	—	—
		Sarkar and Rao [16]	2002	8	8	100	—	—	—	—	—	—
		Fumes et al. [17]	2014	10	1	100	—	—	—	—	—	—
		Hibbard and Ireland [2]	1957	15	15	100	—	—	—	—	—	—
	Fused distobuccal and palatal roots	Wang et al. [11]	2013	1			—	—	1	100		
		Sarkar and Rao [16]	2002	1	1	100	—	—	—	—	—	—
		Hibbard and Ireland [2]	1957	8	38	5	62	—	—	—	—	
Mandibular First Molar	Mesial root	Bagherian et al. [6]	2010	27	5	18.5	22	81.5	—	—	—	—
		Aminabadi et al. [5]	2008	46	—	—	46	100	—	—	—	—
		Zoremchhingi et al. [4]	2005	15	1	6.7	14	93.3	—	—	—	—
		Wang et al. [11]	2013	2	—	—	2	100	—	—	—	—

(continued)

Table 6. Continued

Teeth	Number of canals and apices	Reference	Year	Number of teeth (canal studies)	One canal	%	Two canals	%	Three canals	%	Other variations*	%
		Sarkar and Rao [16]	2002	10	3	30	—	—	7	70	—	—
		Hibbard and Ireland [2]	1957	25	5	20	6	24			14	56
	Distal root	Bagherian et al. [6]	2010	27	21	77.8	6	22.2	—	—	—	—
		Aminabadi et al. [5]	2008	46	37	80.4	9	19.6	—	—	—	—
		Zoremchhingi et al. [4]	2005	15	6	40	9	60	—	—	—	—
		Wang et al. [11]	2013	2	1	50	1	50	—	—	—	—
		Sarkar and Rao [16]	2002	10	8	80	2	20	—	—	—	—
		Hibbard and Ireland [2]	1957	25	17	68	—	—			8	32
Mandibular Second Molar	Mesial root	Bagherian et al. [6]	2010	22	—	—	22	100	—	—	—	—
		Aminabadi et al. [5]	2008	38	—	—	38	100	—	—	—	—
		Zoremchhingi et al. [4]	2005	15	—	—	15	100	—	—	—	—
		Wang et al. [11]	2013	9	—	—	9	100	—	—	—	—
		Sarkar and Rao [16]	2002	14	2	14.3	12	85.7	—	—	—	—
		Hibbard and Ireland [2]	1957	22	5	23	7	32	2	9	8	36
	Distal root	Bagherian et al. [6]	2010	22	14	63.6	8	36.4	—	—	—	—
		Aminabadi et al. [5]	2008	38	—		38	100	—	—	—	—
		Zoremchhingi et al. [4]	2005	15	6	40	8	53.3	1	6.7	—	—
		Wang et al. [11]	2013	5	4	80	1	20	—	—	—	—
		Sarkar and Rao [16]	2002	14	11	78.6	3	21.4	—	—	—	—
		Hibbard and Ireland [2]	1957	22	18	82	3	14	—		1	5
	Distobuccal root	Wang et al. [11]	2013	4	4	100	—	—	—	—	—	—
Distolingual root	Wang et al. [11]	2013	4	4	100	—	—	—	—	—	—	

Table 7. The review of primary molars' root numbers.

Teeth	Reference	Year	Number of teeth	Two roots (fused distobuccal and palatal roots)	%	Three roots	%
Maxillary first molar	Bagherian et al. [6]	2010	27	21	77.7	6	22.3
	Zoremchhingi et al. [4]	2005	15	8	53.3	7	46.7
	Wang et al. [11]	2013	8	4	50	4	50
	Sarkar et al. [16]	2002	8	2	25	6	75
	Hibbard and Ireland [2]	1957	17	5	29	12	71
Maxillary second molar	Bagherian et al. [6]	2010	14	4	28.6	10	71.4
	Zoremchhingi et al. [4]	2005	15	—		15	100
	Wang et al. [11]	2013	10	1	10	9	90
	Sarkar et al. [16]	2002	9	8	88.8	1	11.1
	Hibbard and Ireland [2]	1957	23	8	35	15	65
				Two roots (mesial and distal)			
Mandibular first molar	Bagherian et al. [6]	2010	27	27	100	—	—
	Zoremchhingi et al. [4]	2005	15	15	100	—	—
	Wang et al. [1]	2013	2	2	100	—	—
	Sarkar et al. [16]	2002	10	10	100	—	—
	Fumes et al. [17]	2014	10	10	100	—	—
	Hibbard and Ireland [2]	1957	25	25	100	—	—
Mandibular second molar	Liu and Chen [18]	2010	370	347	93.8	23 (extra distal root)	6.2
	Bagherian et al. [6]	2010	22	21	95.5	1 (extra mesial root)	4.5
	Zoremchhingi et al. [4]	2005	15	13	86.7	2 (extra mesial root)	13.3
	Wang et al. [11]	2013	9	4	44.4	5	55.5
	Sarkar et al. [16]	2002	14	14	100	—	—
	Fumes et al. [17]	2014	10	10	100	—	—
	Hibbard and Ireland [2]	1957	22	22	100	—	—

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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