Original Article

Evaluation of Root Canal Morphology of Human Primary Mandibular Second Molars by Using Cone Beam Computed Tomography

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Abstract

Objectives: The aim of the present study was to investigate the root canal configurations of primary mandibular second molars (PMSMs) using Vertucci classification. **Materials and Methods:** The root canal types of 228 PMSMs (228 mesial and 228 distal roots) were evaluated. In addition, the relationship between external root morphology and Vertucci classification was investigated. The Chi-square test or Fisher Exact Chi-square test was used for the evaluations, and $P < 0.05$ was considered statistically significant for all tests. **Results:** The most commonly observed root canal type, which was observed in 228 roots (50%), was Type 4 followed by Type 8 (15.79%), Type 5 (14.47%), Type 1 (9.21%), and Type 3 (6.57%). In 150 mesial roots, the root canal Type 4 was observed whereas the same type was observed in 78 distal roots, and the difference was significant ($P < 0.001$). In flat roots (82.9%), the most frequently observed root canal type was Type 4 (50.8%) ($P < 0.001$). **Conclusion:** Various root canal types were observed in both mesial and distal roots although Type 4 was the most commonly observed. Root canal types showed a consistent relationship with separated and conical root shapes whereas the flat roots showed different root canal types.

Keywords: *Primary teeth, root canal, Vertucci classification*

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Introduction

In childhood, primary teeth (PT) have crucial roles such as chewing, speaking, and maintaining spaces for permanent teeth; thus, the early loss of PT may negatively affect these functions. Therefore, maintaining PT in the dental arch is the first aim of a pediatric dentist when the pulp tissue is irreversibly inflamed or nonvital, and the common necessary procedure is the root canal treatment.[1,2]

Removal of the infected or necrosed pulp tissue, preparation and irrigation, and finally three-dimensional (3-D) obturation of root canals are the stages of the root canal treatment of PT.[2] During these stages, it is critical that each process should be carefully carried out to achieve success. Therefore, detailed knowledge of root canal morphology and comprehensive understanding of different root canal configurations are needed to avoid any failures or retreatments.[2,3]

In the literature, different studies[2-7] which evaluated the root canals and root canal morphologies of PT in different populations using several techniques such as clearing method,[4,6] computed tomography,[5] and cone beam computed tomography (CBCT)[3,7] were reported. Moreover, in recent years, CBCT has become popular in clinical dental practice for diagnosis in the oral and maxillofacial region, and this technique enables more detailed evaluation by reconstruction of 3-D images.[8,9]

To clarify the variations of root canal morphology of PT, the properties such as the number of the roots, angulation of roots, number of root canals, root canal length, and root canal curvatures were investigated.[2,7] However, no study was found in the literature which evaluated

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the root canal configurations of PT using Vertucci classification[10] [Figure 1]. The aim of the present study was to investigate the root canal configurations of primary mandibular second molars (PMSMs) using the classification of Vertucci. In addition, the relationship between external root morphology and Vertucci classification was evaluated.

Materials and Methods

At the beginning of the study, 623 extracted PMSMs of 448 patients (186 females and 262 males), aged 4–6 years, who applied to Bulent Ecevit University, Faculty of Dentistry, Department of Pediatric Dentistry between January 2016 and June 2016, were examined for the inclusion criteria. All extractions of PMSMs were due to extensive caries that made the tooth crown unrestorable, There was no extraction process which was performed for the present study, and the ethical approval was given by the Ethics Committee of Bulent Ecevit University (protocol number 2015-145-30/12). Each tooth was stored in 0.1% thymol solution until the experiment. The average period between the extraction and experiment for each tooth was approximately 3 or 4 weeks. Before the examination for inclusion criteria, each tooth was immersed in 5.25% NaOCl for 15 min to remove organic residues from root surface, and calculus or stains were cleared with scalers and curettes. The roots of all teeth were examined with radiographs and magnifying glasses to identify a fracture, pathological or physiological resorption, perforation, or obliteration. The teeth which had a root or roots with undesirable conditions stated above were excluded from the study. After the selection process, 228 teeth were included into the current study and numbered from 1 to 228. A total number of 456 roots (228 mesial and 228 distal roots) were investigated.

Carious lesion in every tooth was removed by tungsten carbide burs in low speed, and access cavities were prepared with water-cooled diamond burs in high speed. The root canals were irrigated with 10 mL 5.25% NaOCl[11] to remove nonvital pulp tissue or its remnants. Then, all root canals were irrigated with 10 mL saline solution and dried with sterile paper points. After these processes, all root canals were filled with Iohexol solution (Omnipaque; Novaplus, Cork, Ireland) to clarify the view of the root canals during CBCT imaging. Each and every root apex was covered with a soft modeling wax to prevent any microleakage of solution, and all teeth were placed in a silicone-based impression material (Zetaplus, Zhermack, Rovigo, Italy) to immobilize them during the CBCT imaging.

Cone beam computed tomography scanning and image evaluation

Each tooth was imaged in Bulent Ecevit University Faculty of Dentistry, Department of Dentomaxillofacial Radiology using CBCT; Veraviewepocs 3D R100/F40 (J Morita Mfg. Corp., Kyoto, Japan) and a flat panel detector with six fields of view. All scans were conducted with a 4 cm field of view, at 0.125 mm voxel resolution with 90 kVp and tube current of 3 mA with imaging time of 17 s. All of the images were produced in high-resolution mode. Axial scans and multiplanar reconstructions were obtained, and volumetric data were displayed using the system software to provide serial coronal and sagittal sections along each tooth plane. All images were displayed on a 23-inch flat panel screen (EIZO RadiForce MS 230 W 23-inch Class Color LCD monitor, Eizo Nanao Corporation, Ishikawa, Japan).

CBCT images were evaluated by two pediatric dentists and one dentomaxillofacial radiologist in a dark room to reach a consensus for the interpretation of the findings. All root canal configurations were investigated and compared with the classification of Vertucci.[10] In addition, external root morphology in each mesial or distal roots of the tooth was classified as two roots/separated, one root/flat, or one root/conical [Figure 2], and the relationship between the classification of Vertucci[10] and external root morphology was also evaluated.

Statistical analyses

All data were recorded on a personal computer using software (Excel, Office 2013, Microsoft, Redmond, WA, USA), and descriptive statistics were used to identify the frequency of classification types. Likewise, the relationship between configurations types and external root morphology was also statistically evaluated. In these evaluations, the Chi-square test or Fisher exact Chi-square test was used, and $P < 0.05$ was considered statistically significant for all tests.

Results

The results of the evaluation of the root canal configurations in PMSMs, and the descriptive analyses are shown in Table 1. The most commonly observed root canal type was Type 4, seen in 228 roots (50%), followed by Type 8 (15.79%), Type 5 (14.47%), Type 1 (9.21%), and Type 3 (6.57%) [Figure 3]. In 150 mesial roots, the root canal Type 4 was observed whereas the same type was observed in 78 distal roots, and the difference was statistically significant ($P < 0.001$). In 42 distal roots, the root canal Type 5 was observed whereas the same type was observed in 24 mesial roots, and the difference was significant ($P = 0.017$). On the other hand, in 30 distal roots, the root canal Type 1 was observed whereas the

Table 1: The results of the descriptive analysis of root canal types

Type	Mesial root, *n* (%)	Distal root, *n* (%)	Total, *n* (%)	*P*
Type 1	12 (5.26)	30 (13.16)	42 (9.21)	0.006*
Type 2	0	6 (2.63)	6 (1.32)	0.030*
Type 3	6 (2.63)	24 (10.53)	30 (6.57)	0.001*
Type 4	150 (65.79)	78 (34.21)	228 (50.00)	<0.001*
Type 5	24 (10.53)	42 (18.42)	66 (14.47)	0.017*
Type 6	0	6 (2.63)	6 (1.32)	0.030*
Type 7	6 (2.63)	0	6 (1.32)	0.030*
Type 8	30 (13.16)	42 (18.42)	72 (15.79)	0.123

**P* value means the significant result

Table 2: The results of the descriptive analysis of external root morphology

Root shape	Mesial root, *n* (%)	Distal root, *n* (%)	Total, *n* (%)
Separated	43 (18.85)	1 (0.44)	44 (12.9)
Flat	180 (78.95)	198 (86.84)	378 (82.9)
Conical	5 (2.2)	29 (12.72)	34 (4.2)
Total	228 (100)	228 (100)	456 (100)

Table 3: Distribution of root canal types in root canal shapes

Root canal type	Root canal shapes			Total, *n* (%)
	Separated, *n* (%)	Flat, *n* (%)	Conical, *n* (%)	
Type 1	0	26 (6.9)	16 (47.0)	42 (9.6)
Type 2	0	6 (1.6)	0	6 (1.3)
Type 3	0	30 (7.9)	0	30 (6.6)
Type 4	18 (40.9)	192* (50.8)	18 (53.0)	228 (50.0)
Type 5	14 (31.8)	52 (13.8)	0	66 (14.0)
Type 6	0	6 (1.6)	0	6 (1.3)
Type 7	0	6 (1.6)	0	6 (1.3)
Type 8	12 (27.3)	60 (15.9)	0	72 (15.8)
Total	44 (100)	378 (100)	34 (100)	456 (100)

*Means the significant result ($P<0.001$)

same type was observed in 12 mesial roots, and the difference was also significant ($P = 0.006$).

The descriptive analysis of external root morphology is shown in Table 2. The most frequently observed

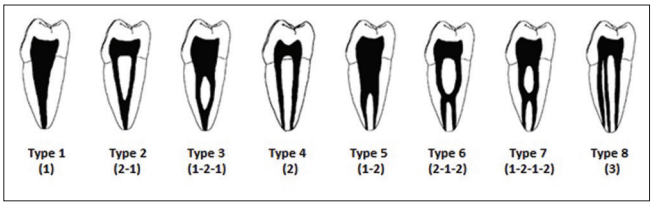

Figure 1: Classification of Vertucci

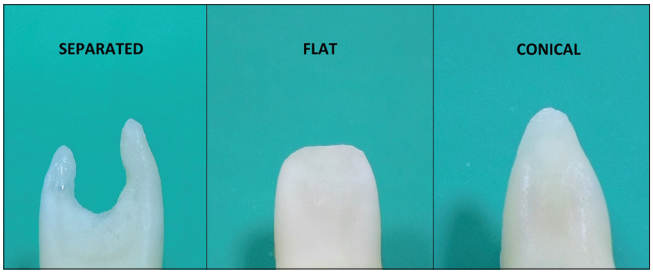

Figure 2: The view of evaluated root shapes

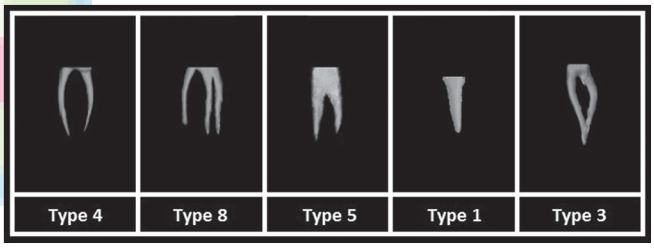

Figure 3: Examples of the reconstructed cone beam computed tomography images of the most observed root canal types (the types were put in order from left to right according to the most observed to least)

Table 4: Root canal numbers of primary mandibular second molars in different studies

Study	Number of teeth	Mesial roots		Distal roots	
		n (%)	Number of canals	*n* (%)	Number of canals
Zoremchhingi *et al*. 2005[5]	15	0	1	6 (40)	1
		15 (100)	2	8 (53.3)	2
		0	3	1 (6.7)	3
		0	Other variations	0	Other Variations
Yang *et al*. 2013[3]	487	11 (2.26)	1	120 (24.64)	1
		476 (97.44)	2	364 (74.75)	2
		0	3	3 (0.62)	3
		0	Other variations	0	Other variations
Bagherian *et al*. 2010[6]	22	0	1	14 (63.6)	1
		22 (100)	2	8 (36.4)	2
		0	3	0	3
		0	Other variations	0	Other variations
Aminabadi *et al*. 2008[18]	38	0	1	0	1
		38 (100)	2	38 (100)	2
		0	3	0	3
		0	Other variations	0	Other variations

shape was flat (82.9%), followed by separated (9.6%), and conical (7.5%). Furthermore, the most commonly observed root shape was flat in both mesial (78.95%) and distal roots (86.84%). When the relationship between the external root morphology and the root canal type was evaluated, it was found out that Type 4 was the most frequently observed root canal type in all three root shapes. The rate of observing Type 4 in flat shape was found statistically significant ($P < 0.001$). Distribution of root canal types in three root canal shapes is shown in Table 3.

Discussion

Inability to recognize the root canals is generally accepted as the major cause of failure of root canal treatment.[7] In the study performed by Yang *et al*.,[3] it is concluded that detailed knowledge of roots and root canal morphology is crucial to improve the success in the endodontic treatments of PT. The classification of root canal morphology of permanent teeth was classified by Vertucci,[10] and this classification was used in different studies[12-15] to evaluate the root canal configurations of permanent teeth in different populations. However, after a detailed search in the literature, no reported results obtained by using the classification of Vertucci were found for PMSMs.

Using the conventional radiography techniques to evaluate the configurations of PT root canals has limitations since the images of the roots and root canals always overlap each other.[3,5] Hence, it is difficult to obtain detailed and clear data. On the other hand, even though the clearing method was the most commonly used technique for these studies, it was also accepted that the technique provides limited information.[5] In recent years, it has been possible to obtain 3-D images of the oral and maxillofacial structures by CBCT on a high resolution, and this resolution provides clearer and understandable images.[8,9] Since having this advantage, CBCT has been suggested[16,17] as a good option for the studies which evaluate root and canal morphology of teeth. Therefore, using CBCT imaging technique was preferred in the present study.

Many studies[3,5,6,18] have reported differences in the number of root canals in the mesial and distal roots of evaluated PMSMs [Table 4]. Zoremchhingi *et al*.[5] reported that 100% of the mesial roots and 53.3% of the distal roots had two canals, and 40% of the distal roots had one canal. In the study conducted by Aminabadi *et al*.,[18] 100% of the mesial roots and 100% of the distal roots had two canals. In the study by Bagherian *et al*.,[6] 100% of the mesial roots and 36.4% of the distal roots had two canals, and 63.6% of the mesial roots had one canal. Yang *et al*.[3] reported that 97.44% of the mesial roots and 74.75% of the distal roots had two canals. Although the number of canals varied in these studies, the most commonly reported root canal configurations in PMSMs were two canals[3,5,6,18] in the mesial root and two canals[3,5,18] in the distal root. In the studies conducted by Zoremchhingi *et al*.[5] and Yang *et al*.,[3] 6.7% and 0.62%, respectively, of the distal roots of the PMSMs had three root canals. In contrast, in the present study, different root canal configurations were found for both the mesial and distal roots of PMSMs; the differences between this study's results and the findings reported by other studies may primarily be due to the fact that no study has yet focused on the classification of PT root canals using any specific classification method. The size of the evaluated sample may be another reason for variations in the findings. In the study by Zoremchhingi *et al*.,[5] only 15 PMSMs were evaluated. A similar sample size ($n = 22$) was also evaluated in the study by Bagherian *et al*.[6] In the study by Aminabadi *et al*.,[18] the sample size was larger than the samples in other studies, but the number of teeth was still limited to 38. In the present study, the sample size was much larger than the sample sizes in the previously mentioned studies[5,6,18] ($n = 228$). This difference may increase the possibility of finding different root canal configurations in PMSMs.

Zoremchhingi *et al*.,[5] Aminabadi *et al*.,[18] and Bagherian *et al*.[6] reported that all investigated PMSMs had two canals in the mesial roots. Although the rate of two canals in mesial roots was not 100% in the study of Yang *et al*.,[3] authors reported a very close rate (97.44%) with previous studies. However, in the present study, more than 2 root canals were found in mesial roots of 30 teeth (13.16%) and the root canal type was Type 8 (three root canals). Besides, in 12 teeth (5.26%), Type 1 (one root canal) was observed in the mesial roots. Consistent with this result, Yang *et al*.[3] reported that they found 11 teeth (2.3%) which had a single root canal in the mesial roots. On the other hand, the most detected root canal type (65.79%) in the mesial roots was Type 4, and 2 root canals could be clearly observed in this type. Hence, this result supports the common results of previous studies.[3,5,6,18] The interesting point is that the root canal Type 5 has also two root canals as Type 4 although the root canal is bifurcated into two canals in the middle or the apical third of the root canal system. Hence, this observation may increase the rate of mesial roots which have 2 root canals. However, the rate of Type 5 in mesial roots was found as 10.53% in the present study. Now that the knowledge on the variations of root canal anatomy is considered as a critical factor to have success on root canal treatment, this rate may be considered as an important result for the mesial roots.[7]

Similar to the observation in the mesial roots, various root canal types were observed in the distal roots of the evaluated PMSMs. Most of the previous studies[3,5,18] reported that distal roots of PMSMs had mostly two canals. However, in the present study, 18.42% (n = 42) of the teeth had distal roots with Type 8 canal configuration. Zoremchhingi *et al*.[5] reported that three root canals were observed in one sample even though they evaluated only 15 teeth, and this finding supports the results of the present study. In addition, Yang *et al*.[3] noted that they observed 3 root canals in distal roots, and this result is also consistent with our findings. In 30 teeth (13.16%), only 1 root canal was observed in the distal roots, and the root canal type was Type 1, whereas the distal roots of 78 teeth (34.21%) showed Type 4. These results are compatible with the common explanations.[2,3,5-7,18,19] On the other hand, the prevalence (18.42%) of Type 5 in the distal roots was more that (10.53%) in mesial roots. Besides, other different root canal types such as Type 2, Type 3, and Type 6 were also detected in the distal roots, and the distribution of all root canal types was not so different from each other, apart from Type 4. In the present study, the prevalence of Type 4 was significantly higher in mesial roots than the distal roots, and this type had the highest portion. However, the rates of Type 1, Type 2, Type 3, Type 5, and Type 6 were significantly higher in distal roots than mesial roots. Hence, it was well understood that the possibility of observing different and complex root canal types may be higher in distal roots than the mesial roots, which should be taken into account.

This present study also investigated the shape of the root. Separated roots showed root canal types consistent with their external morphology, and 72.7% of all the separated roots had two root canals. In the separated roots, the Type 4 root canal configuration was observed most often (40.9%). However, the Type 5 root canal configuration had two separated root canals, and it was observed in 31.8% of the root canals, which is close to the Type 4 rate. Therefore, the difference between these two rates was not statistically significant ($P > 0.05$). Bagherian *et al*.[6] reported that only one (4.5%) of evaluated samples had two separated roots in the mesial root (mesiobuccal and mesiolingual), and each root had one canal. Zoremchhingi *et al*.[5] reported the same root and root canal morphology in 2 (13.3%) of the 15 PMSMs. In the study by Yang *et al*.,[5] the same morphology was observed in 132 (27.08%) of the 487 samples. The differences in these results may be explained by differences in the method used to evaluate the sample size. However, it is important to note that both the occurrence of 3 root canals (Type 8) in this root shape and the root canal rate (27.3%) were considerably high, and in previous studies,[3,5,6,18] only Yang *et al*.[3] reported the same root and root canal morphology with 0.62% rate.

In conical roots, only Type 4 (53%) and Type 1 (47%) root canal system configurations were observed, and there was no significant difference between these two types ($P > 0.05$). In flat roots, all root canal types were observed in this study, and Type 4 was the most common root canal configuration (50.8%) ($P < 0.001$). Based on this result, 50% of all flat roots could have a Type 4 root canal system configuration. In previous studies,[3,5,6,18] regardless of whether the shape of the root was flat or conical, the most common result was one root having one or two root canals; the findings from those studies are compatible with the results of our study. However, only one[5] of these studies reported a root canal configuration as 1 root with 3 root canals in one sample of 15 PMSMs. Still, the present study's findings indicate that various types of root canals can be observed in flat roots without any consistency with the shape. In addition, the results of previous studies only investigated the number of roots and root canals; they did not explain the relationship between the external root morphology and the type of root canal. Therefore, it is not possible to fully compare and discuss our study's results with the results from previous studies.

Conclusion

The knowledge of the possible number of root canals alone may not be enough to reach success in root canal treatment of PT. Hence, being aware of different root canal configurations in PT supports that knowledge and increases the chance of dentists for being successful. Thus, different from the common findings of previous studies, the results of the present study showed various root canal types in both mesial and distal roots of PMSMs.

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Conflicts of interest

There are no conflicts of interest.

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