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Research Article

Comparison of Two Different Root Canal Classification Systems in Primary Molars - A Micro-Computed Tomography Study

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Received: February 12, 2024; **Published:** March 01, 2024

Abstract

Purpose: For successful root canal treatments in pediatric dentistry, it is critical increasing knowledge of the root canal morphology of primary teeth using an accurate and simple classification technique. The present study aimed to: (i) Characterize the root canal anatomy in primary molars in the Turkish population (ii) Compare the accuracy of two classification systems to describe the complexity of the canal system.

Methods: A total of 59 human primary mandibular second molar (PMSM) teeth were included in this study. Root canal systems were analyzed using 3D reconstructed images obtained from Micro-CT. Two classification systems were used (Vertucci and Ahmed., *et al*.). The analyzes results of root morphology with axial slices at the different root levels in addition to 3D images, were used as the gold standard for both systems and the differences were calculated with Spearman's Rho.

Results: The root canal morphology in primary molars is highly complex. The Vertucci classification was not able to characterize 37 (62.7%) and 19 (32.2%) of the mesial and distal roots, respectively; however, all canal types were classified using the Ahmed classification. According to the gold standard, only 10 (16.94%) of the mesial roots had two canals starting at the orifice and ending at the apex. For the distal root, 15 (25%) of the teeth had one canal starting at the orifice and ending with one canal at the apex. The most common types were Type IV and Type I for mesial and distal roots, respectively, according to Vertucci. Micro-CT results allowed detailed and accurate characterization of the root canal morphology in the primary molar teeth and revealed that the primary teeth had a more complicated canal morphology compared to previous reports.

Conclusion: Although reports were classified using the Vertucci classification, it was found to be deficient in classifying many of the canal types in primary molars. The use of the new system developed by Ahmed was more accurate and provide more detailed information compared to Vertucci.

Keywords: *Micro-CT; Primary Molars; Root Canal Classification*

Introduction

Avoiding the premature loss of primary teeth is a crucial concept in pediatric dentistry to lead the sequence and chronology of the proper eruption of permanent teeth [1]. To accomplish this goal, root canal treatment is often performed to maintain the function of the teeth and dental arch development [2]. Successful endodontic procedures lie in the comprehensive understanding of the morphology and anatomy of root canal systems [3].

A variety of studies have assessed anatomical and morphological characteristics of permanent teeth in order to contribute to treatment strategies [4-6]. On the other hand, a literature review has revealed only a few studies on primary root canal morphology including radiography, dye perfusion, scanning electron microscopy, cross-sectioning, and clearing techniques [7-10]. These traditional procedures are invasive and provide two-dimensional (2D) information [11]. With advanced imaging techniques such as cone beam computed tomography (CBCT) and micro-computed tomography (Micro-CT), achieving three-dimensional (3D) images that exhibit more accurate morphology of root canals is possible [12]. However, a study by Acar., *et al*. [13] showed that although CBCT is useful in clinical settings, it cannot effectively analyze the internal morphology of primary teeth. They reported that Micro-CT provides a more detailed and accurate visualization of the morphology and anatomy of teeth and root canal systems.

Primary second molar teeth are one of the last exfoliated primary teeth. Therefore, root canal treatment requirements due to deep caries may be higher for these teeth. Having a detailed knowledge of the root canal system increases the chance of success in this treatment. The literature review has revealed only three studies with Micro-CT on the root canal morphology of primary second molars. In a study by Fumes., *et al*. [8] a limited number of primary second molar teeth (10 teeth) were evaluated for diameters, roundness and length of canals as well as thickness of dentin but not detailed canal configuration knowledge was reported. Similarly, in other studies by El Hachem., *et al*. [14] and by Wang., *et al*. [15], very few teeth (10 and 9 teeth, respectively) were evaluated.

With the development of new imaging techniques, there is a need for new classification systems to describe the root canal system in detail due to the increasing amount of information about root canal morphology. Wein and Vertucci classifications have been the most commonly used methods and have proven to be useful [16]. Although these systems were not intended for the primary dentition, most of the micro- CT studies on deciduous teeth mentioned above have used those classifications [14,15,17]. However, different research reported that all the specimens did not fit into the classification of these traditional systems [7,18,19]. Recently, a new classification technique for root canal morphology of permanent and primary teeth was introduced for the research and clinical purposes by Ahmed., *et al*. [19]. They claimed that their system allowed root canal configurations to be defined in a simple, accurate and reliable manner. However, there is no study using and evaluating this system in defining primary root canal configuration and comparing it with the Vertucci system. Even though each procedure for classifying root canal morphology has its own unique benefits, each system also has a number of drawbacks [20]. Many previously unreported anatomical complexities are being identified with the increasing range of imaging methods which also demonstrates that any classification system realistically may not be able to classify the complex root canal morphology in great detail [21]. Although these complex classification systems are relevant only for scientific investigation rather than clinically, dental practitioners must be aware that each tooth may display several types of root canal configuration [22].

In view of the above, the present study aimed to: (i) Characterize the root canal anatomy in primary second mandibular molars (PSMM) in the Turkish population, and (ii) Compare the accuracy of two classification systems to describe the complexity of the canal system.

Materials and Methods

Collection of the study sample

Approval for this study was obtained from the institutional ethical committee 151/9.3.22. 59 primary mandibular second molars were chosen randomly from the teeth extracted due to various orthodontic reasons, pulpal abscesses, and chronic infections and these molars were kept in distilled water at 4°C. The selection criteria were to ensure that the teeth removed were intact, with fully developed root apices and no macroscopic root resorption.

Micro-CT scanning

Prior to scanning, for exact repositioning in the Micro-CT scanning system (SkyScan 1172 Micro-CT, Bruker, Belgium), each tooth was mounted in an acrylic block. The scanning was conducted using the parameters: aluminum and copper filter, 95 kW X-ray voltage, 104 mA X-ray current, 3600 rotation, 170 ms duration, 19.7 µm image pixel size, 0.700 rotation step deg, frame Averaging = on, random Movement = on.

A total of 514 raw images were obtained for each root sample and saved in TIF format. Reconstruction was performed by using the NRecon software (SkyScan NRecon version1.6.6, Bruker Micro-CT, Kontich, Belgium) and saved as BMP files. On the axial plane, 614 cross-sections were obtained for each root sample. The images were interpreted using the Image J software (version 1.51n; National Institutes of Health, USA). The BMP files were imported to the software as image sequences. The volume was converted to 8-bit and the threshold was adjusted using the stack-histogram to segment the root canal. Then the volume was binarized and viewed using the Volume Viewer plugin (v.2.01). The Volume Viewer application allowed us to evaluate the 3-D volumetric data. We could view the data as a maximum intensity projection or an isosurface to define the root number of teeth. Additionally, by using the rendering editor component we could manipulate opacity to see the structures in the volume that we want to observe, while marking the structures that we do not want to see as transparent. This has allowed a detailed evaluation of the canal morphology.

Classification systems used

In order to define the root canal morphology precisely and accurately, 3D images were evaluated simultaneously with the evaluation of axial slice images by two researchers together, one experienced radiologist, and the other experienced pediatric dentists by consensus. The different results were discussed together and the specialists came to an agreement on each inconsistency. The root and canal numbers were recorded with two different systems (Vertucci 1974 and new classification system by Ahmed 2013) [23] to create the master list as the gold standard. Then, only 3D images were evaluated twice with a two-week interval without using axial sections by a single observer who was a pediatric dentist with 17-years of experience, who also did not participate in the creation of the master list, twice with a two-week interval. In the "first" and "second observation", the root and canal morphology was recorded with two different systems as in the master list. While defining the root canal morphology according to the Vertucci classification, which consists of a set of eight variants of root configurations varying from type I to type VIII, each root was evaluated and variant type was recorded separately for each other (Figure 1). The specimens that did not fit into the classification of this system were called and recorded as 'undefined'. Since the Vertucci system does not allow defining the root number, it was recorded separately in a different list. On the other hand, the new classification system by Ahmed includes codes for three separate components: the tooth number, the number of the roots and the root canal configuration (Figure 2). As the system allows that the tooth number to be written using any numbering system and since only mandibular second molar teeth were used in our study, for left and right teeth '75 and 85' were used, respectively. The number of roots is added as a superscript before the tooth number. Any root division, whether in the coronal, middle, or apical third, was classified as having two or more roots. A superscript number was used to identify the type of root canal configuration in each root. The continuous path of the root canal system was identified, beginning at the orifice and continuing via the canal and foremen. The data are presented as descriptive statistics (Table 1).

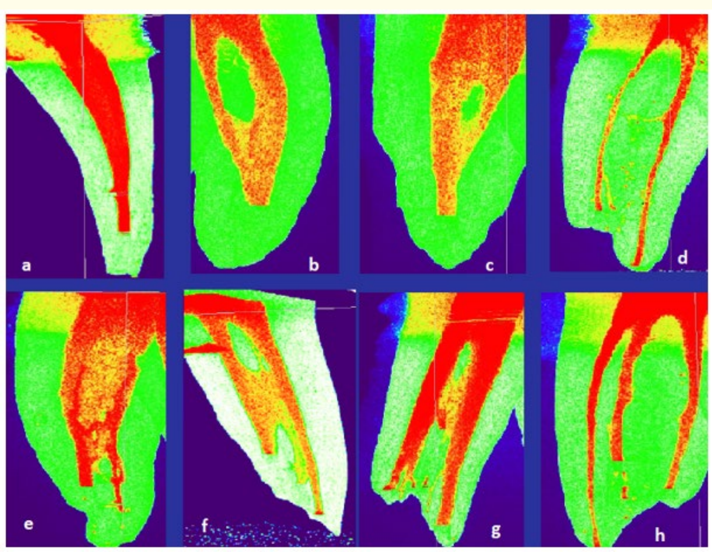

Figure 1: *Examples of 3D reconstructions of root canal configurations:*

1. According to Vertucci's classification; a. Type I, b. Type II, c. Type III, d. Type IV, e.Type V, f. Type VI, g. Type VII, h. Type 8.

*2. According to Ahmed's classification; a.75M*D1 b.75M2-1-2D* c.85M*D1-2-1 d.75M2D* e.85M*D1-2 f.85M2-1-2D* g.75M1-2-1-2D* h.75M3D*.*

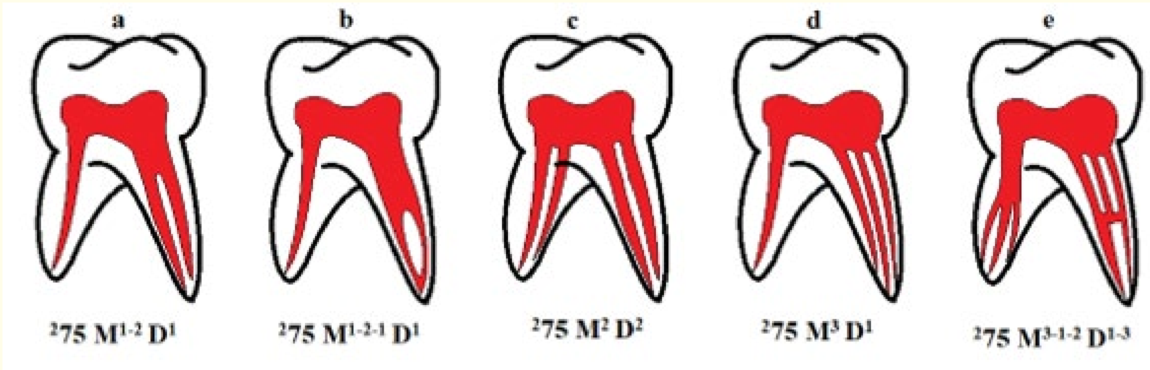

Figure 2: *Illustrations of different root canal configurations in mandibular primary molars according to Ahmed., et al.*

Figure 3A and 3B shows the reconstructed 3D images and axial slice images of the root canal system of primary second mandibular molars. Additionally, figure 4 shows the classification of Vertucci and Ahmed on 3D images.

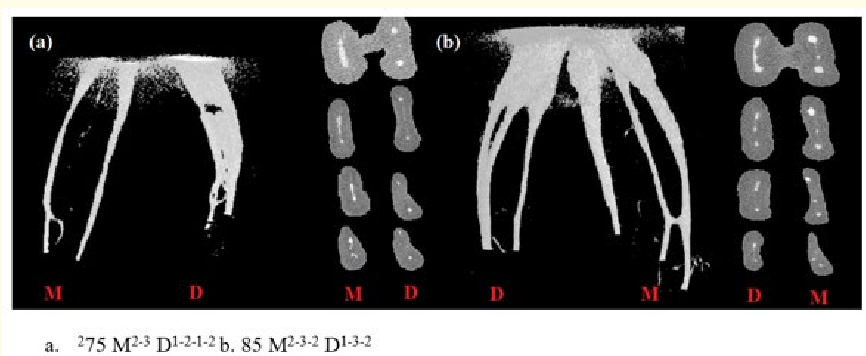

Figure 3: *3D reconstructed images and axial slices of primary mandibular molars using the new classification system.*

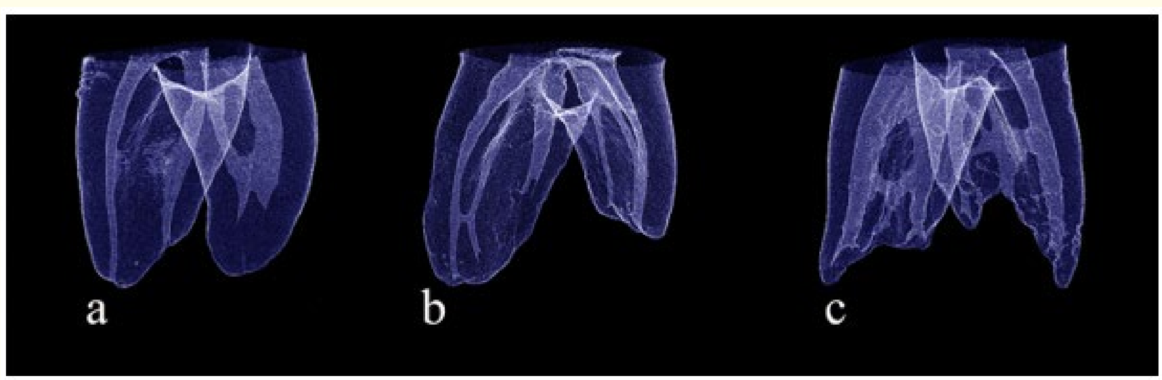

Figure 4: *Examples of 3D reconstructions of root canal systems of primary mandibular molars.*

Statistical analysis

Statistical analysis was performed using commercially available software program (SPSS 20.00; SPSS, Chicago, IL, USA). The weighted kappa coefficients for the data for each classification were calculated to assess intra-observer reliability based on the following criteria: < 0.10, no agreement; 0.10 - 0.40, poor agreement; 0.41 - 0.60, significant agreement; 0.61 - 0.80, strong agreement; 0.81 - 1.00, excellent agreement. The differences between the gold standard and observations as well as the differences between the two classification systems were evaluated using Spearman's Rho correlation coefficient test and Chi-Square test, respectively. P values < 0.05 were considered to indicate significance.

Results

Table 1 shows Spearman's correlation coefficient values that reflects the levels of agreement between the gold standard (3D + axial slices) and observations obtained from 3D images. A statistically significant correlation was found between the observations with a correlation coefficient ranging from 0.664 to 0.998. Additionally, the level of intra-observer agreement calculated for each root according to the classification type was shown in table 1. The Kappa values were 0.938 and 0.957 for the Ahmed's system and they were 0.836 and 0.935 for the Vertucci System.

GS-SO	

Table 1

Table 2 shows the distribution of the root canal morphology in the gold standard list according to the classification of Vertucci and Ahmed. For the mesial roots, most of the teeth had 2 orifices at the coronal level of the canal (37 roots). In addition, the maximum number of root canals for the mesial root was 4 at the coronal level and it was seen in only 1 tooth. The root canal numbers at the apical level were varied between 1-4 and half of them had 2 canals. For distal roots, most of the teeth had 1 orifice at the coronal level of the canal. The maximum number of root canal at the coronal level for the distal root was 3. At the apical level, the maximum number of root canals for the distal root was 5 and it was seen in only 1 tooth. In addition, most of the distal roots had 1 or 2 canals at the apical level.

n(%)

Table 2

37 (62.7%) of 59 mesial roots and 19 (32.2%) of 59 distal roots were not defined according to the Vertucci system and thus were marked as 'undefined' (Table 2). No unidentified canal type was found for either the mesial or distal root according to the Ahmed's system. A significant difference was observed between the two classification systems for defining the primary molar canals. Also, there was a significant difference between the mesial and distal root results for classification with Vertucci ($p < 0.05$).

For the mesial roots, the most common canal types were $^{2}85M^{2}D^{*}$ (16.9%), $85M^{1-2}D^{*}$ (10.2%) and $^{2}85M^{2-1-2}D^{*}$ (8.5%), respectively according to Ahmed (Table 1). Of the 22 mesial roots that could be classified according to Vertucci, the most common type was Type IV (10), followed by Type V (6) and Type VI (5), respectively (Table 2).

For the distal roots, the most common types were $^{2}85M^{*}D^{1}$ (25.4%), $^{2}85M^{*}D^{1-2}$(%18.6) and $^{2}85M^{*}D^{1-2-1}$ (11.86%), according to Ahmed (Table 1). Of the 40 distal roots that could be classified according to Vertucci, the most common types were Type I (15), Type V (11) and Type III (7), respectively. Additionally, while 5 teeth were classified as Type VII, 1 tooth was classified as Type VI and one was classified as Type VIII.

Discussion

Micro-CT has been considered as the latest non-invasive technique for the investigation of root canal anatomy to overcome the shortcomings of earlier morphologic methods [24]. Although Micro-CT reveals more detailed information about root canal morphology, one of the major drawbacks is that it is not suitable for clinical practice [25]. Acar., *et al*. [13] compared Micro-CT and CBCT in the evaluation of primary molars and reported that Micro-CT enabled more comprehensive information about minor anatomic structures than CBCT. In order to avoid the limitations of these traditional procedures and evaluate the root canal systems of primary second mandibular molars quantitatively, Micro-CT was used in the present study.

Several studies found only one or two canals in the mesial and distal roots of primary mandibular molars [7,25,26]. The most common root canal configuration of primary mandibular molars has been stated as two canals in the mesial root and one canal in the distal root [24,25,27]. Three canals in the mesial root [28] and three canals in the distal root [26] have also been reported in the literature. Wang., *et al*. [2013] used Micro-CT to evaluate the morphology of primary molars and reported that all primary mandibular molars had two canals in the mesial roots while distal roots had either one or two canals. In the study of Fumes., *et al*. [8], two canals in the mesial root and one canal in the distal root configuration were observed in 40% of the primary mandibular second molars by using Micro-CT. In the present study, most of the mesial roots had 2 canals at the coronal level (37 roots) and the number of root canals varied from 1 to 4. The mesial root canal numbers at the apical level varied 1-4 and half of them had 2 canals. For distal roots, most of the teeth had 1 canal at the coronal level of the root and the maximum number of root canals was 3. At the apical level, the maximum number of root canals for the distal root was 5 and it was seen in only 1 tooth. Also, most of the distal roots had 1 or 2 canals at the apical level. The present Micro-CT study revealed that primary molar root canal configurations were more complicated than previously reported studies [14,15,24,25]. These results will contribute to the general concept of primary molar teeth morphology.

Since the tooth anatomy is really complex, several classification systems are available for classifying the variations. Each of the classification methods noted so far has its own benefits and drawbacks [2-4,15]. Different configuration-type classifications have been suggested in the literature [18,29]. The classification system proposed by Vertucci., *et al*. [23] together with additional configuration types (V-VIII) has been the most often utilized. Although primary teeth have different and complex canal morphology compared to permanent teeth, there is no special classification system for them. The Vertucci system was used in several studies; however, it was not intended for the primary dentition. Moreover, the recent imaging devices providing more detailed information, Vertucci has become a system that has deficiencies not only in the classification of primary teeth, but also in the classification of permanent teeth. According to the recent reports utilizing superior 3D imaging technology, several canal configurations have been classified as "non-classifiable" using the Vertucci method [26-28,30]. One study reported that as many as 13% of specimens did not fit into the classification of Vertucci, while up to 37 root canal configuration types were identified [31].

A recent classification system, which was introduced for the research and clinic practice in both dentition (primary/permanent) by Ahmed., *et al*. [18] promises to define the root canal configurations in a simple, precise and efficient manner. In the present study, the morphology of the PSMM was classified by both the traditional (Vertucci) and the recent system by Ahmed., *et al*. The results showed that 62.7% of mesial roots and 32.2% of distal roots were not defined according to the Vertucci system and were termed as 'undefined'. The Vertucci classification system cannot fully meet the root canal configurations of PSMMs. On the other hand, no unidentified canal type was found for both mesial and distal roots according to the Ahmed's system. The new system by Ahmed., *et al*. [18] allows a simple and detailed description of the root canal configuration of PSMMs. To the best of our knowledge, no clinical investigation has made this comparison in primary molars; hence, assessing the current study's findings by considering previous studies is challenging.

Bagherian., *et al*. [24] evaluated PSMM teeth with clearing technique using the Vertucci system and reported that all the mesial root canals were type IV and that all the distal root canals imitated the external root morphology (%63 type IV and %37 as type I). In contrast, in the present study, the most common type in mesial roots was type IV (10 teeth) but, this ratio corresponded to only one-fifth of the total number of teeth. Similarly, the most common types were Type I (15 teeth) for distal roots, but this ratio corresponded to only one-fourth of the number of teeth. In this study, evaluation of the root canals was conducted from coronal to apical and the differences between the regions were observed. The differences between our results and the findings of previous studies [8,15] may be due to a number of reasons. First, using Micro-CT allowed us to obtain detailed data. Second, the classification system by Ahmed., *et al*. provided a simpler and more detailed presentation of the obtained data. Finally, the size of the evaluated sample, which had only one group of primary molars with a vast number of samples allowed us to obtain more comprehensive information about the root canal morphology. These findings concerning the root canal morphology may lead to pediatric dentists becoming more careful at the apical and coronal levels of root during root canal treatment in primary molars.

Although having a higher number of samples (59) compared to the other 3 PSMM studies [8,14,15], one of the limitations of this research was including only one ethnic group. In addition, using large sample of every single type of primary molars may contribute to obtain more detailed knowledge for the root canal morphology. Although we obtained high resolution images of PSMMs with Micro-CT, clinical studies are more useful when investigating the real prevalence of the anatomy.

Conclusion

- Using Micro-CT to investigate the root canal morphology of primary teeth provides more accurate information.
- Although it is obvious that both the complex structure of primary molars and the cooperation problems of pediatric patients directly affect the success rate of clinical endodontic treatment, detailed knowledge of root canal morphology may be helpful for pediatric dentists in this issue.
- Each of the classification system noted so far has its own benefits and drawbacks. Finding a sound root canal classification system may be essential to facilitate communication among dental practitioners.

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