Received date: 16 July 2024 / **Accept date:** 05 August 2024
DOI: 10.61139/ijdor.1517056

Evaluation of Root Canal Morphology Molar Teeth and Distance Between Additional Canals Using CBCT

Esra Balkanlıoğlu[1*], Zeynelabidin Şimşekyılmaz[2]

1. Department of Endodontics, Kahramanmaras Sutcu Imam University, Kahramanmaras,Türkiye
2. Endodontist, Vefadent, Istanbul,Türkiye

***Corresponding author**: Balkanlıoğlu E., Msc. PhD. Ass. Prof., Department of Endodontics, Kahramanmaras Sutcu Imam University, Kahramanmaras, Türkiye.
E-mail: dt.esrabalkanlioglu@gmail.com.

Abstract

Background: This study was conducted to analyze the morphological variations of maxillary and mandibular molars in the Turkish population, to evaluate the distances between the additional canals vertically and horizontally, to guide clinicians by determining the distance between the canals.
Materials and Methods: The maxillary and mandibular first and second molars (a total of 50 teeth per group) were using in the study. The teeth were embedded in an arch-shaped silicone impression material. Cone beam computed tomography *(*CBCT) images of the teeth were recorded. Two examiners scrutinized the root canal systems and sought out any additional canals.
Results: Upper first molars; 16% had three canals, 64% had four canals and 20% had five canals. The average distance between mesiobuccal 1(mb1)-mesiobuccal 2(mb2), mesiobuccal 1(mb1)-mesiobuccal 3(mb3), and distobuccal 1(db1)-distobuccal 2(db2) was 2.35, 2.52 and 1.91 millimeters, respectively. Upper second molars; 32% had three canals, 52% had four canals and 16% had five canals. The distance between mb1-mb2 and db1-db2 canals was 2.14 and 2.01 mm, respectively. In 16%, the mb2 canal was observed at an average depth of 0.72 mm from mb1. No significant difference was found between the number of canals and additional canals in the upper first molars and upper second molars teeth (p=0,275).Lower first molars; Two canals were detected in 8%, three canals in 20%, four canals in 28% and five canals in 44%. While 60% of the midmesial canals merged with the mesiolingual canal, 20% merged with the mesiobuccal, and 20% terminated in separate apices. Mesiobuccal(mb)-midmesial and mesiolingual(ml)-midmesial distances were 1.81 and 1.76 mm, respectively.Lower second molars; 4% had one canal, 8% had two canals, 60% had three canals, 28% had four canals. No midmesial canal was observed in the lower second molars. There was a significant difference between the number of teeth with three canals in the lower first molars and lower second molars teeth (p=0,00).
Conclusions: During root canal treatment, all canal access must be accurately identified. Using adequate light sources, checking the pulp floor with canal probes, strengthening the theoretical knowledge about the points where additional canals can be found can reduce the risk of missed canals.
Strengthening the theoretical knowledge of where additional canals can be found can reduce the risk of missing canals.

Research Article (HRU Int J Dent Oral Res 2024; 4(2): 30-37)

Keywords: Additional canal; root morphology; CBCT, second mesiobuccal canal, midmesial canal.

Introduction

In human dentition, it has been widely documented that root canal morphology exhibits significant anatomical variations across different tooth types. Specifically, root canal systems display a diverse array of configurations in terms of the number and arrangement of their components (1). Over the years, extensive research and clinical studies have been conducted on the diversity of root and canal morphologies. Variations in this aspect exist not only between different populations but also within populations, and can even be observed within the same individual (1). Clinicians should be aware of different root canal configurations and the presence of accessory canals, as these factors are essential for complete instrumentation and disinfection of the root canal system. Successful execution of root canal therapy depends on thorough disinfection of the root canal system. The complexity of root canal anatomy and presence of morphological variations present substantial challenges for practitioners in this field. Inadequate knowledge of the anatomical features of the root and canal systems of treated teeth can potentially lead to complications (2, 3). Specifically, the inclusion of additional canal systems is widely regarded as a substantial factor leading to treatment failure (4). The morphology of the maxillary and mandibular molar root canals is affected by various factors, including ethnicity, age, and sex (5, 6).

Several techniques have been employed throughout the years to evaluate root canal morphology and variations. Traditional radiographic imaging offers essential insights into the dental anatomical variations that are valuable for clinical applications (7). Periapical radiographic images are commonly used in clinical practice to provide a wealth of information. However, their interpretation can sometimes be difficult because of the presence of numerous regional anatomical landmarks and overlapping hard tissues of the adjacent teeth and other structures within the orofacial region. These factors can make it challenging to accurately interpret periapical radiographs. Numerous three-dimensional anatomical anomalies may remain concealed because of the possibility of two-dimensional representation and the accompanying distortion of the geometric image (8, 9).

In recent years, clinical research has evaluated the frequency of additional canals using loupes or microscopes that allow for magnification (7). Additionally, computerized systems have been using to analyze the morphology of root canals (10). CBCT offers the advantage of producing three-dimensional (3D) images while using relatively low levels of radiation exposure in contrast to other medical imaging techniques. Several studies have reported the usefulness of a diagnostic tool to assess root canal anatomy (11-15).

There has been much research on variation and configuration, but few studies have evaluated the distances between the additional canals. This research endeavors to provide clinicians with a direction to pinpoint the location of additional canals by assessing the spatial distances and to enhance treatment success by minimizing the number of overlooked canals. Moreover, this study aimed to examine the morphological differences in maxillary and mandibular molars among the Turkish population and to evaluate the vertical and horizontal distances between the additional canals. Ultimately, this study seeks to guide clinicians in identifying additional canals when they cannot be easily detected.

Materials and Methods

Ethical Dimension of the Research

This study was approved by the local ethics committee of Kahramanmaras Sutcu Imam University (2024/06). The research adhered to the recommendations outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for cross-sectional investigations.

Population and Sample of the Study

Sample size calculation was measured G-Power method: When the power of the test was 0.80, type I error was 0.05, and effect size was 0.25, the sample size was calculated as 180 using F test. Considering the data losses, it was set as 200.

Type of Research

This study included 200 maxillary and mandibular teeth that were removed as part of the examination, diagnosis, and treatment plan for individuals who had previously been admitted to the surgical clinic. Since extracted teeth are not images taken from patients, it was used when there are areas that are not clearly visible in the CBCT images, so that the patient does not need to receive an extra dose of radiation if the CBCT needs to be taken again. The following criteria were applied for tooth inclusion in our study:

1) completely closed apexes and complete root development;
2) absence of prior root canal treatment; and
3) absence of fractures or cracks.

The criteria that were applied to exclude teeth from our study were as follows:

1) any teeth that had metallic restorations,
2) teeth that exhibited canal calcification,
3) teeth that had undergone periapical surgery, and
4) teeth that had developmental anomalies.

The calculi and soft tissue debris on the tooth were removed using a curette. Prior to use, the teeth were stored in a solution containing 0.1% thymol. The samples were divided into four distinct categories, each comprising 50 teeth. The categories included 50 mandibular first molars, 50 mandibular second molars, 50 maxillary first molars, and 50 maxillary second molars.

Data Collection Tools

The silicone impression material was prepared in the form of an arch, and the teeth were embedded in each group. Formal tone rephrasing: The axial, coronal, and sagittal planes were used to acquire CBCT images of the

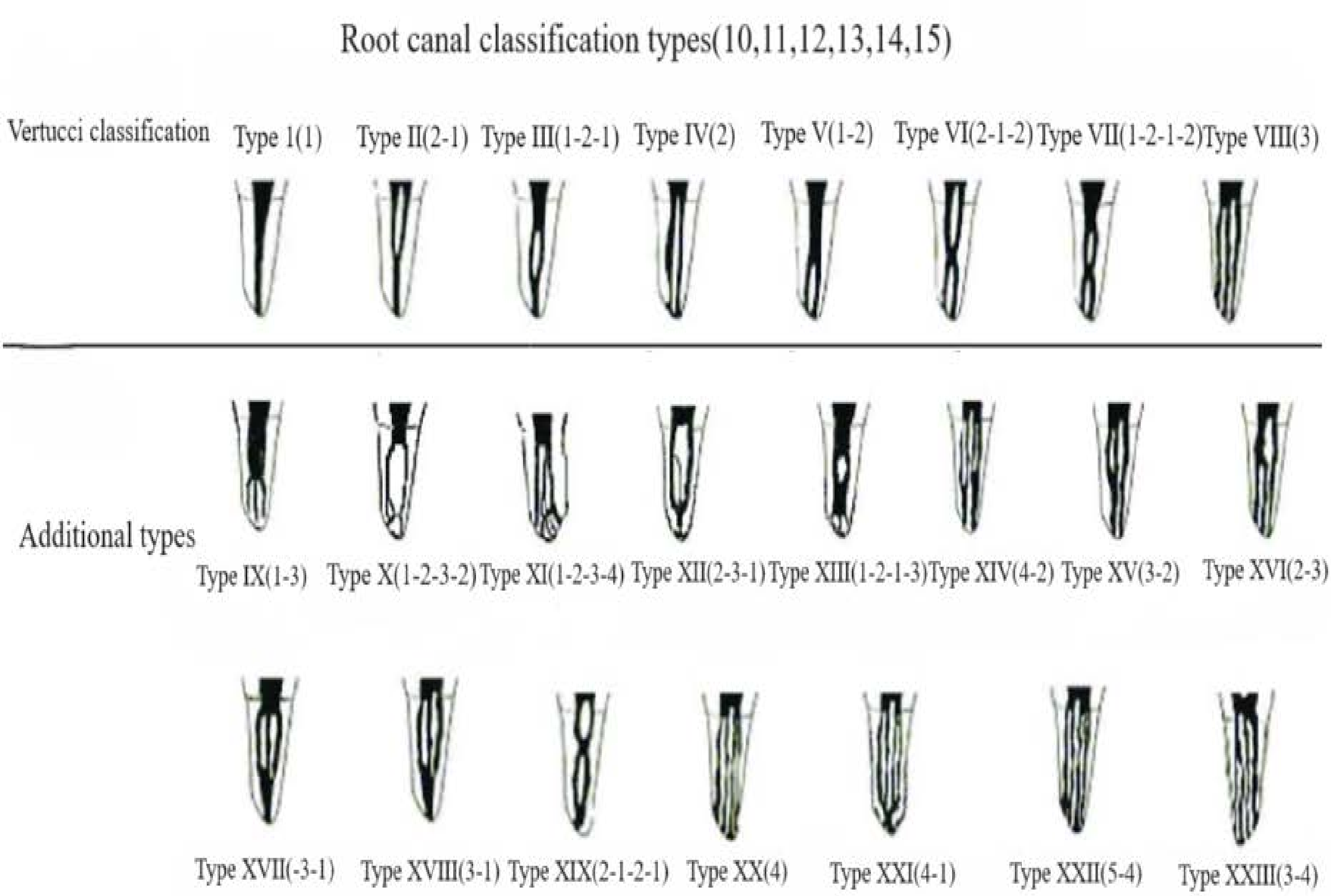
Received date: 16 July 2024 / **Accept date:** 05 August 2024
DOI: 10.61139/ijdor.1517056

teeth. All CBCT images were acquired high-resolution mode (voxel size=0.4 mm), FOV=16x5 cm) with exposure settings of 90 kVp, 12 mA, 12 s, and 0.2 mm resolution Planmeca (Planmeca, Helsinki, Finland). Images were analyzed in 0.2 mm sections along the entire root canal system (from canal access to the apices). CBCT images of the teeth were analyzed using Planmeca romexis software (Planmeca OY, Helsinki, Finland). The image-processing tool of the software was employed to optimize the visualization of the images by adjusting their contrast and brightness. The following text was rephrased to use a formal tone while preserving the original content and structure: analysis and recording of root canal system
changes, including the number of canals, their position, and the distances between the additional canals and canal configurations, were performed for each tooth. The analysis was performed by two observers (BE, ŞZ) who have been working as endodontists for seven years, and interrater agreement was assessed using the Kappa test.

The Vertucci classification system was employed as a foundation for categorizing the root canal morphology of teeth (16). Additional root canal types not included in this classification (Figure 1) were also considered, and images of the specimens were taken (17).

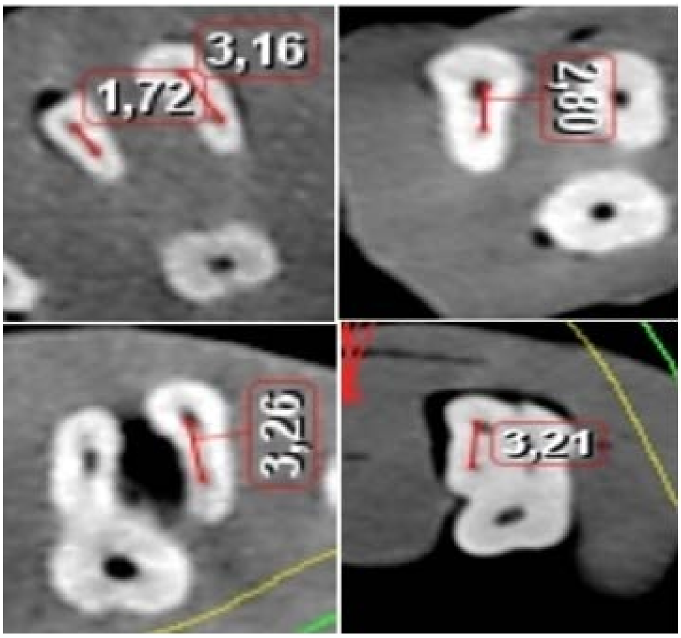
After additional canals were identified, the central points of each canal were marked. The distance between the main and additional canals was determined by drawing a straight line between these points. The distances between the points of the lines were measured in millimeters (mm), as illustrated in Figure 2.

Figure 1: Root canal classification types (10,11,12,13,14,15)- Vertucci classification - Additional types (17)



Received date: 16 July 2024 / **Accept date:** 05 August 2024
DOI: 10.61139/ijdor.1517056

Figure 2: Distances between additional canals and main canals were measured in millimeters



Data Analysis

Test for Conformity to Normal Distribution and/or Homogeneity of Variance Test: Categorical variables will be written as number, percentage, mean standard deviation and non-categorical variables as median (min-max). Compliance with normal distribution will be determined by Kolmogrov Smirnov test.

Comparison Groups and Analytical Statistics Methods: Chi square test and fisher exact test will be applied in the evaluation of qualitative data. The comparison groups are Upper first molars, Lower first molars, Upper second molars and Lower second molars.

Results

Interrater agreement was evaluated by Kappa test and the agreement between two observers was found to be 0.890.

Upper First Molars

Analysis of the upper first molars revealed that 16% had three canals, 64% had four canals and 20% had five canals (Table 1). The second mesiobuccal canal (mb2) was found in 24% of the teeth. In 40% of the cases, mb2 and the first mesiobuccal canal (mb1) are merged (Figure 3). In 10% of the teeth with five canals, mb2 and the third mesiobuccal canal (mb3) were observed (Figure 4), whereas mb2 and db2 canals were observed in 10% of

cases (Figure 4). The mesial canal configurations were type II (8 %), type III (12 %), type IV (8 %), and type V (4 %) (Table 3). The mean distance between mb1-mb2, mb1-mb3 and db1-db2 was 2.35 mm, 2.52 mm and 1.91 mm, respectively (Figure 2).

Table 1: Distribution of upper first and second molars according to the number of canals

NUMBER OF CANALS	FIRST MOLAR	SECOND MOLAR
1 canal	-	-
2 canals	-	-
3 canals	8	16
4 canals (mb2 ending separate apex)	12	14
4 canals (mb2 merging mb1)	20	12
5 canals (had mb2 and mb3)	5	4
5 canals (had mb2 and db2)	5	4

*mb1: first mesiobuccal canal,
mb2: second mesiobuccal canal,
mb3: third mesibuccal canal,
db2: second distobuccal canal.
Chi square test and fisher exact test will be applied.

Figure 3: First mesiobuccal and second mesiobuccal canal are merged

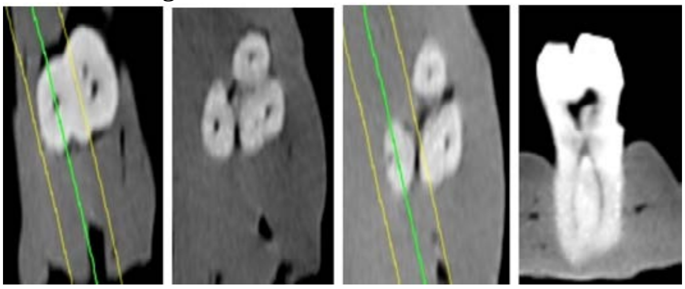
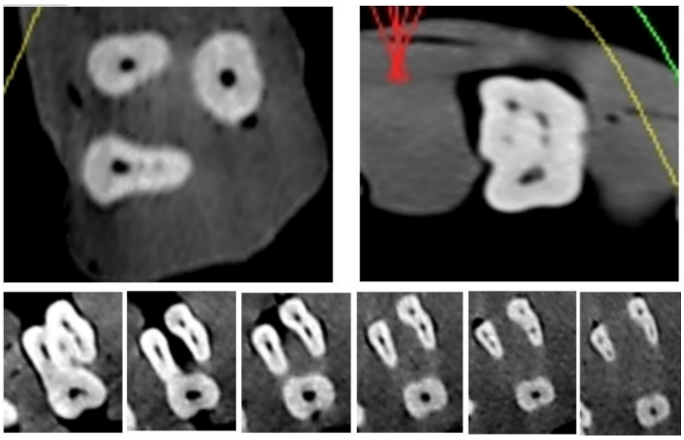
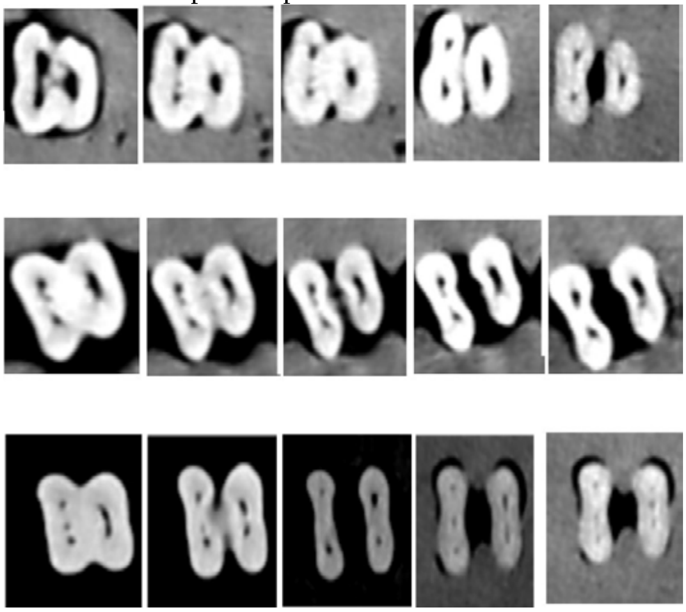


Figure 4: Second mesiobuccal canal, third mesiobuccal canal, second mesiobuccal canal and second distobuccal canal



Received date: 16 July 2024 / **Accept date:** 05 August 2024
DOI: 10.61139/ijdor.1517056

Figure 5: Midmesial canal merged with the mesiolingual canal, 20% merged with the mesiobuccal canal and 20% terminated in separate apices



Upper Second Molars

32% had three canals, 52% had four canals, and 16% had five canals (Table 1). In 28% of cases, mb2 terminated with a separate apex, while in 24%, it merged with mb1. In 8% of the teeth with five canals, mb2 and mb3 were observed, and mb2 and db2 were observed in 8% (Figure 4). 16% had type III and 8% had type VI mesial canal configuration (Table 3).

The distance between mb1-mb2 and db1-db2 was 2.14 and 2.01 mm, respectively. In 16% of cases, mb2 was observed at an average depth of 0.72 mm from mb1.

No significant difference was found between the number of canals and additional canals in the upper first molars and upper second molars teeth (p=0,275).

Lower First Molars

Two canals were detected in 8%, three canals in 20%, four canals in 28%, and five canals in 44% (Table 2). The midmesial canal was observed in 44% of cases. Sixty percent of the midmesial canal merged with the mesiolingual canal (ml), 20% merged with the mesiobuccal canal (mb), and 20% terminated in separate apices (Figure 5). In teeth with four canals, midmesial was not observed but db2 was present. Type III, type XVIII, type XVIII, and type XV mesial canal configurations were detected in 8% of the teeth, type III in 8 %, and type II distal canal configuration in 20% (Table 3).

Mb-midmesial and ml-midmesial distances were 1.81 and 1.76 mm, respectively.

Table 2: Distribution of lower first and second molars according to the number of canals

NUMBER OF CANALS	FIRST MOLAR	SECOND MOLAR
1 canal	-	2
2 canals	4	4
3 canals	10	30
4 canals (had midmesial)	-	6
4 canals (db2 ending separate apex)	14	8
5 canals (midmesial ending seperate apex)	6	-
5 canals (midmesial merging ml or mb)	16	-

*ml: mesiolingual,
mb: mesiobuccal,
db2: second distobuccal canal.
Chi square test and fisher exact test will be applied.

Lower Second Molars

4% had one canal, 8% had two canals, 60% had three canals and 28% had four canals (Table 2). In 16% of teeth with four canals, db2 terminated in a separate apex. In 24% of the cases, the mesial canals merged apically (type II), while in 16%, the canal that started as a single mesial canal ended in two (type V) (Table 3). Type III mesial canal configuration was observed in 12% of cases, and type XVX mesial canal configuration was observed in 16% of cases. No midmesial canal was observed in the lower second molars. There was a significant difference between the number of teeth with three canals in the lower first molars and lower second molars teeth (p=0,00).

Table 3: Classification of mesial canal variations of upper first second molars/lower first second molars according to the Vertuccis

MESIAL CANAL VARIATIONS	UPPER 1ST MOLAR	UPPER 2ND MOLAR	LOWER 1STMOLAR	LOWER 2ND MOLAR
1-2-1 (tip III)	6	8	8	6
2-1-2 (tip VI)	4	4	-	-
3-1 (tip XVIII)	-	-	4	-
3-2 (tip XV)	-	-	4	-
2-1 (tip II)	4	-	10	12
1-2 (tip V)	2	-	-	8
2-1-2-1 (tip XVX)	-	-	-	8

Discussion

Root canal configurations vary considerably and we observe these variations even within the same nationality. The outcomes of morphological research may be influenced by intranational variation. The primary objective of this study was to provide information regarding the root and canal morphology of maxillary and mandibular molars in the Turkish population through the using of in vitro CBCT images and to identify any additional canals that may exist. Furthermore, this study aimed to elucidate the interconnections between these canals, thereby providing valuable insights for clinicians. Thus, in this study, we aimed to help clinicians perform root canal disinfection more effectively by considering the results obtained.

Betancourt et al. (18) stated that the results of in vitro studies are not as reliable as those of in vivo studies because the alignment of the evaluated teeth in in vitro studies does not simulate the natural arch shape, thus making CBCT images difficult to evaluate. In this study, we placed the teeth in the arch position and aimed to provide images similar to in vivo conditions. We also conducted an in vitro study to obtain more precise results by eliminating the radiation emitted from the surrounding tissues in the field of view.

According to certain investigations, endodontic magnification equipment has revealed the existence of mb2 in the maxillary second molar in 19.7% to 51.1% (19). Although magnification systems are very useful in locating additional canals, they have disadvantages, such as inadequate opening of the access cavity, the presence of fluids in the environment during canal entry, and the inability to follow the canal morphology until apical (19).

In addition, in the case of inclined or rotational molars, magnification efficiency is lost because angulation of the tooth prevents a good view of the cavity floor. Finally, the expenses associated with equipment and the necessities for operator training are significant constraints that impact the practical application of augmentation. To overcome these limitations, CBCT, a straightforward diagnostic method that requires only a computer, is currently being employed.

Based on our research findings, it was observed that a significant proportion of maxillary first molars exhibited additional canal variations. Specifically, the rate of occurrence was 84%, which is relatively high. The mesiobuccal root of maxillary molars is one of the main foci of morphologic studies, as the incidence of multiple canals is significantly higher, and a wide variety of variations have been reported. This ratio was also reported by Kim et al. (13) and Betancourt et al. (20) and similar studies(28) it is higher than the ratio reported by Zhang et al. (21). Xin et al. reported The detection rate of mb2 was 48% in maxillary first molars and 32% in maxillary second molars (22). The frequency of mb2 in maxillary second molars was 68%, which surpassed the rates reported in previous studies by Lee et al. (23), Betancourt et al. (24) and Silva et al. (25).

In many studies (4, 26), Vertucci’s (1984) classification has been used as a reference. In this study, 12% of the first molars had an mb2 that started as a single canal similar to Vertucci type III, split into two canals, and then merged again, and 8% had an mb2 canal that merged with mb1 similar to Vertucci type II. Moreover, examination of the teeth revealed the presence of type IV and V canal configurations in 8% and 4% of the samples, respectively. In Vertucci's study (27), this frequency was 44% for Type II and 8% for Type IV in the second molars. Yang et al. reported the mesial root showed a Vertucci type II configuration in 28.9% cases followed by type IV (26). In our study, especially when the mesial canal structures of the upper first molar and lower first molar teeth were examined, it was determined that they had different types and many configurations. We believe that this may be related to innovations in CBCT imaging modalities, which have increased the number and configuration of the canals detected.

According to previous research, a considerable percentage of the lower first molars exhibited specific canal configurations. Specifically, 8% of the molars had a type III mesial canal configuration, 8% had type XVIII, and 8% had type XV. Additionally, 8% of the molars displayed a combination of type III and type XV mesial canal configurations and 20% showed a type II distal canal configuration (Table 3). Many studies have reported that palatal and distobuccal roots contain a single canal (1, 19). In our study, a similar result was reported for the palatal canal, but 16% of the first molars had two canals in the distal root.

By measuring the distance of the additional canals detected in our study to the main canal, we aimed to provide clinicians with knowledge and experience regarding this subject. The location of mb2 has been reported in in vitro and in vivo studies (28-31). In our study, we observed that the average distance between mb1-mb2, mb1-mb3 and db1-db2 in the upper first molars was 2.35 mm, 2.52 mm and 1.91 mm, respectively (Figure 5). However, the distance to the mb1 was found to be 2.2+0.54 mm by Betancourt et al. (24) and 1.65+0.72 mm by Gorduysus et al. (29).

The distance between the mb1-mb2 and db1-db2 in the upper second molars was 2.14 and 2.01 mm, respectively. In 16% of the cases, mb2 was detected at an average depth of 0.72 mm from mb1. This result is very important for finding the mb2 because it was found that the mb2, which could not be detected next to the other canals at the first access in the access cavity, can be detected when the cavity is deepened by an average of 0.72 mm from the base of the cavity and that the additional canal should be searched deeper than the other canal mouths for the upper second molars.

In the lower first molars, the mb-midmesial and ml-midmesial distances were 1.81 and 1.76 mm, respectively. It was observed that 60% of the mesiolingual canals merged with the mesiolingual canal, and 20% merged with the mesiobuccal canal. No midmesial canal was observed in the lower second molars.

In this study, 84% of the lower first molars had a single canal in the distal root, as in Vertucci type I, and 92% of the lower second molars had a single canal in the distal root. This result was higher than Vertucci et al. (27) and Calıskan et al. (32). In this study, the mesial roots of the mandibular first molars showed a wide variety of canal configurations. Caliskan et al. found the prevalence of a single distal canal to be 70% and two mesial canals to be 90%, with 41% of these mesial canals converging at the apex (32). However, this study shows that in 52% of lower first molars, the mesial root contains different canal configuration types (type III, XVIII, XV, and II). In 20% of cases, it starts as two canals, and the canals merge apically.

The number of teeth used in the study limits the data obtained from this study. We believe that increasing the number of teeth used in this study will increase the accuracy of the data obtained regarding the number, configuration, and location of the canals.

In light of the current and previous studies, it can be said that all canal accesses should be accurately identified during root canal treatment. Magnifiers such as loops and operating microscopes are useful to clinicians, but CBCT images are necessary when extra ducts are suspected. Using adequate light sources, checking the pulp floor with canal probes, and strengthening theoretical knowledge about the points where additional canals can be found can reduce the risk of missed canals.

Conclusion

Molars may exhibit morphological variations that lead to inadequate canal disinfection. Dentists' awareness of different anatomical structures gives them the advantage of performing better treatment.

Disclosure Statement
The author has no conflicts of interest to declare
Ethical Approval
This study was approved by the local ethics committee of Kahramanmaras Sutcu Imam University (2024/06).
Acknowledgement
None.

Authors' contributions to the article

E.B. and Z.Ş. constructed the main idea and hypothesis of the study. E.B. developed the theory and arranged/edited the material and method section. E.B. and Z.Ş. have done the evaluation of the data in the Results section. Discussion section of the article written by E.B. and Z.Ş. reviewed, corrected and approved. In addition, E.B. and Z.Ş. discussed the entire study and approved the final version.

References

1. Ahmed H, Versiani M, De-Deus G, Dummer P. A new system for classifying root and root canal morphology. Int Endod J 2017;50(8):761-70.
2. Vizzotto MB, Silveira PF, Arus NA, Montagner F, Gomes BP, da Silveira HE. CBCT for the assessment of second mesiobuccal (MB2) canals in maxillary molar teeth: effect of voxel size and presence of root filling. Int Endod J 2013;46(9):870-6.
3. Tabassum S, Khan FR. Failure of endodontic treatment: The usual suspects. Eur J Dent 2016;10(1):144-7.
4. Mashyakhy M, AlTuwaijri N, Alessa R, Alazzam N, Alotaibi B, Almutairi R, et al. Anatomical evaluation of root and root canal morphology of permanent mandibular dentition among the Saudi Arabian population: a systematic review. BioMed Res Int. 2022;2022(1):2400314.
5. Sert S, Bayirli GS. Evaluation of the root canal configurations of the mandibular and maxillary permanent teeth by gender in the Turkish population. J Endod 2004;30(6):391-8.
6. Wu YC, Su CC, Tsai YC, Cheng WC, Chung MP, Chiang HS, et al. Complicated Root Canal Configuration of Mandibular First Premolars Is Correlated with the Presence of the Distolingual Root in Mandibular First Molars: A Cone-beam Computed Tomographic Study in Taiwanese Individuals. J Endod 2017;43(7):1064-71.
7. Nikoloudaki GE, Kontogiannis TG, Kerezoudis NP. Suppl 2: M3: Evaluation of the root and canal morphology of maxillary permanent molars and the incidence of the second mesiobuccal root canal in Greek population using cone-beam computed tomography. Open Dent J 2015;9:267.
8. Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. Int Endod J 2007;40(10):818-30.
9. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. J Endod 2007;33(9):1121-32.
10. Wang Y-L, Chang H-H, Kuo C-I, Chen S-K, Guo M-K, Huang G-F, Lin C-P. A study on the root canal morphology of primary molars by high-resolution computed tomography. J Dent Sci 2013;8(3):321-7.
11. Filpo-Perez C, Bramante CM, Villas-Boas MH, Hungaro Duarte MA, Versiani MA, Ordinola-Zapata R. Micro-computed tomographic analysis of the root canal morphology of the distal root of mandibular first molar. J Endod. 2015;41(2):231-6.
12. Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast

medium-enhanced digital radiography in studying root canal morphology. J Endod. 2010;36(9):1547-51.
13. Kim Y, Lee SJ, Woo J. Morphology of maxillary first and second molars analyzed by cone-beam computed tomography in a korean population: variations in the number of roots and canals and the incidence of fusion. J Endod. 2012;38(8):1063-8.
14. Yu X, Guo B, Li KZ, Zhang R, Tian YY, Wang H, D DST. Cone-beam computed tomography study of root and canal morphology of mandibular premolars in a western Chinese population. BMC Med Imag. 2012;12:18.
15. Plotino G, Tocci L, Grande NM, Testarelli L, Messineo D, Ciotti M, et al. Symmetry of root and root canal morphology of maxillary and mandibular molars in a white population: a cone-beam computed tomography study in vivo. J Endod. 2013;39(12):1545-8.
16. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984;58(5):589-99.
17. Sert S, Şahinkesen G, Tunca Ym, Aslanalp V, Altinova M. Türk Toplumunda Erkek Alt Ve Üst Çene Sürekli Diş Kanal Şekillerinin Şeffaflaştirma Yöntemi İle Belirlenmesi. Gülhane Tıp Dergisi 2004;46(2):106-114.
18. Betancourt P, Navarro P, Munoz G, Fuentes R. Prevalence and location of the secondary mesiobuccal canal in 1,100 maxillary molars using cone beam computed tomography. BMC Med Imaging 2016;16(1):66.
19. Betancourt P, Navarro P, Cantín M, Fuentes R. Cone-beam computed tomography study of prevalence and location of MB2 canal in the mesiobuccal root of the maxillary second molar. Int J Clin Med. 2015;8(6):9128.
20. Betancourt P, Fuentes R, Aracena Rojas S, Cantín M, Navarro Cáceres P. Prevalencia del segundo canal en la raíz mesiovestibular de los primeros molares maxilares mediante tomografía computarizada de haz de cono. Av Odontoestomatol. 2013;29(1):31-6.
21. Zheng QH, Wang Y, Zhou XD, Wang Q, Zheng GN, Huang DM. A cone-beam computed tomography study of maxillary first permanent molar root and canal morphology in a Chinese population. J Endod. 2010;36(9):1480-4.
22. Qiao X, Xu T, Chen L, Yang D. Analysis of root canal curvature and root canal morphology of maxillary posterior teeth in Guizhou, China. Med Sci Monit.2021;27:e928758-1.
23. Lee JH, Kim KD, Lee JK, Park W, Jeong JS, Lee Y, et al. Mesiobuccal root canal anatomy of Korean maxillary first and second molars by cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;111(6):785-91.
24. Betancourt P, Navarro P, Cantin M, Fuentes R. Cone-beam computed tomography study of prevalence and location of MB2 canal in the mesiobuccal root of the maxillary second molar. Int J Clin Exp Med. 2015;8(6):9128-34.
25. Silva EJNL, Nejaim Y, Silva AI, Haiter-Neto F, Zaia AA, Cohenca N. Evaluation of root canal configuration of maxillary molars in a Brazilian population using cone-beam computed tomographic imaging: an in vivo study. J Endod. 2014;40(2):173-6.
26. Yang L, Han J, Wang Q, Wang Z, Yu X, Du Y. Variations of root and canal morphology of mandibular second molars in Chinese individuals: a cone-beam computed tomography study. BMC oral health. 2022;22(1):274.
27. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984;58(5):589-99.
28. Peeters HH, Suardita K, Setijanto D. Prevalence of a second canal in the mesiobuccal root of permanent maxillary first molars from an Indonesian population. J Oral Sci. 2011;53(4):489-94.
29. Görduysus MÖ, Görduysus M, Friedman S. Operating microscope improves negotiation of second mesiobuccal canals in maxillary molars. J Endod. 2001;27(11):683-6.
30. Tuncer AK, Haznedaroglu F, Sert S. The location and accessibility of the second mesiobuccal canal in maxillary first molar. Eur J Dent. 2010;4(1):12.
31. Degerness R, Bowles W. Anatomic determination of the mesiobuccal root resection level in maxillary molars. J Endod. 2008;34(10):1182-6.
32. Caliskan MK, Pehlivan Y, Sepetcioglu F, Turkun M, Tuncer SS. Root canal morphology of human permanent teeth in a Turkish population. J Endod. 1995;21(4):200-4.