Assessing The Prevalence of Anatomical Variations in Root Canals of Maxillary Molars and Premolars Using Cone Beam Computed Tomography in Erbil City: Retrospective CBCT Study

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ABSTRACT

Background and objective: Root canal variations can be a challenge to detect and manage when performing root canal therapy, and failure to detect these variations in the root canals of the teeth will lead to unsatisfactory results of the treatment. An important tool for observing the root canal anatomy of teeth that are indicated for root canal treatment is cone beam computed tomography (CBCT). The objective of this study is to find out the rate of anatomical variations in the root canals of maxillary premolars and molars using CBCT among a Kurdish subpopulation in Erbil, Iraq.

Materials and methods: Data were collected from five dental clinics and radiographic centers in Erbil City. A total of about 690 CBCT images were used for the study, after applying the exclusion criteria, 205 CBCT images were included for the study. maxillary premolars and molars were examined for the number of roots, number of canals, and presence of root canal variations.

Results: The prevalence of the second mesiobuccal (MB2) canal in maxillary first molars (MFM) was 47.8%, while in maxillary second molars (MSM), it was 18.05%. The prevalence of the second distobuccal (DB2) canal in (MFM) was 1.46%, with three recorded cases, while none of the (MSM) had a (DB2) canal. Additionally, only 2 cases (0.98%) in MSM had two palatal canals, whereas no such cases were recorded in MFM. A single case of MFM (0.49%) was recorded with two roots and canals, whereas in (MSM), 10 cases (4.88%) had two canals. In maxillary first premolars, five cases (2.44%) were reported with three roots and canals (molarized premolars). Similarly, five cases (2.44%) had a single canal, while 195 cases (95.12%) had two canals: one buccal and one palatal. In maxillary second premolars, 135 cases (65.85%) had two canals (buccal and palatal), and 70 cases (34.15%) had a single canal.

Conclusion: There is a wide range of variations among maxillary molars and premolars, which need careful diagnostic evaluation to prevent missing canals during root canal treatment.

Keywords: Anatomical variations, second mesiobuccal canal (MB2), Second distobuccal canal (DB2), Three rooted premolars (Molarized premolars), Second palatal canal (P2), cone beam computed tomography (CBCT), Erbil city

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INTRODUCTION

The efficacy of root canal treatment depends on the knowledge and understanding of root canal morphology and its anatomical variations, along with cautious cleaning, shaping, and sealing of the entire root canal system.[1] Detecting all of the canals within the root canal system is crucial for gaining favorable outcomes, as untreated or missing canals are associated with the failure of root canal treatment and are frequently detected in retreatment cases.[2] Previously, many techniques have been used to assess and evaluate the anatomy of the root canal system.[3] The majority of these techniques were performed in vitro on extracted teeth by using tooth clearing, canal staining techniques, scanning electron microscopy, transverse cross-sectioning, and a stereomicroscope, which are invasive techniques for assessing the anatomy of the root canals.[4] However, the preferred method should be precise, non-invasive, and applicable.[3] Many studies have evaluated the use of cone-beam computed tomography (CBCT) in diagnosis, treatment planning, and assessing outcomes in root canal treatment.[5] Numerous studies have confirmed that CBCT plays an important role in assessing the anatomy of the root canal system, such as identifying variations like the two mesiobuccal canals (MB2) in maxillary molars.[6] Generally, there are three roots in maxillary molars: mesiobuccal (MB), distobuccal (DB), and palatal (P). There may be more than one canal in each root; for example, the mesiobuccal root can have up to three canals, the distobuccal root can contain two canals, and there may be two palatal roots and canals.[7] In maxillary molars, missing the second mesiobuccal canal (MB2) will affect the prognosis of the endodontic therapy.[8] In rare cases, maxillary molars are reported to have two palatal roots, and it is difficult to detect them radiographically because the buccal roots most of the time, overlap the other canals. This will create a challenge in root canal treatment and increase the failure rate.[9] The root canal configuration in premolars is complex, and usually, there is a correlation between the number of roots and canals. Most of the time, they have multiple roots and canals.[10] These variations in the root canal systems will be a challenge for dentist during root canal treatment. Additionally, maxillary premolars are regarded as the second most treated teeth in endodontics after the maxillary first molars.[11] In maxillary first premolars, only 2.6% of cases were reported to have three roots. Regarding bifurcation, it was most commonly found in the coronal third of the root (44.2%), followed by the middle third (40.5%), and less commonly in the apical third (15.3%).[12] To date, the root canal system in all maxillary molars and premolars has not been examined in a single study among the Kurdish subpopulation. Thus, the purpose of this study is to assess the prevalence of anatomical variations in root canals of maxillary molars and premolars using CBCT among the Kurdish subpopulation in Erbil city.

METHODS

Study Design

The study was conducted between August 2024 and April 2025. Data were collected from five private dental clinics and radiographic centers in Erbil City: iDent Polyclinic, Smart Center, Hollywood Smile Center, Pearl Dental Center, and M Center. CBCT images were obtained from patients who underwent CBCT examination as a part of their dental assessment or treatment plan between March 2021 and February 2025.

All CBCT images were examined by three calibrated examiners.

Ethical approval for this study was obtained from the Research Ethics Committee, Ministry of Health, Kurdistan Region–Iraq. The reference number is HMUD 2425037, and the date of approval is 26/10/2024.

The Following Variables were Assessed:

1. Number of roots in maxillary molars and premolars.
2. Number of canals in maxillary molars and premolars with identification of each canal.
3. Three rooted (molarized) premolars.
4. Second mesiobuccal canal (MB2) in molars.
5. Second distobuccal canal (DB2) in molars.
6. Second palatal canal (P2) in molars.
7. Age and Gender.

Inclusion and Exclusion Criteria:

The selected CBCT images contained maxillary first and second premolars and molars with fully developed, intact roots, without resorptions, calcifications, fractures or post-and-core restorations. Additionally, the teeth had no metallic restorations and no previous root canal treatment, and the exams exhibited good image quality in the area of interest.

Criteria of CBCT Image:

The CBCT images were taken using a NewTom VGi CBCT device (QR SRL Co., Verona, Italy) with the following settings: FOV 8x11 cm and 5x5 cm, voxel size of 150 μm, tube voltage 90 kVp, tube current 3.00 mA, and exposure time 9.0 s.

The images were evaluated using NewTom Navigation Technology (NNT) Viewer. Each tooth was evaluated in all planes (coronal, sagittal, axial) in multiplanar reconstruction (MPR). The contrast and brightness of each image were adjusted using tools in the program to ensure optimum visualization. All cases were documented by using a structured Excel sheet, which is designed for data collection. The recorded parameters were: patient age and gender, number of roots, number of canals and their respective identifications

Statistical Analysis:

Data distribution was presented using cross-tabulation with numbers of cases and percentages. The chi-square test was used at a 0.05 significance level to assess variable associations. Additionally, a pie charts was used to visualize some of the figures to detect patterns. All statistical analyses were conducted using SPSS v.27 and Power BI for this study.

RESULTS

The study included 205 cases in total, and there were slightly more women than men in the sample population, with 111 (54.15%) being female and 94 (45.85%) being male. This distribution indicates a rather balanced gender ratio, as shown in Figure 1.

The sample's age distribution as illustrated in Figure 2, revealed that the largest percentage of participants were in the 20–29 years age range (78 cases, 38.05%), followed by those aged 40 years or older (64 cases, 31.22%) and those aged 30–39 years (52 cases, 25.37%). The smallest group being those under the age of twenty (11 cases, 5.37%). The maxillary first molar, maxillary first premolar, maxillary second molar, and maxillary second premolar were the four types of maxillary teeth for which the dataset displayed various canal configurations.
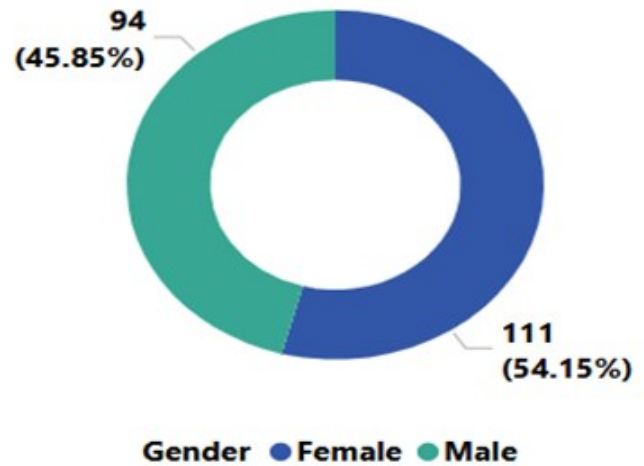

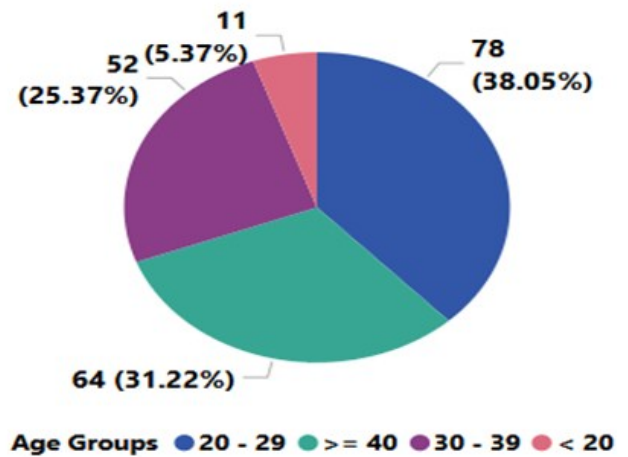**Figure 1.** Gender distribution of the study sample

Figure 2. Age group distribution of the study sample

Different root and canal configurations of maxillary teeth were displayed in Table 1 and 2. In maxillary first premolars, 138 cases (67.32%) had two roots, and 62 cases (30.24%) had just one root. Only five cases (2.44%) presented with three roots (molarized premolar; Figure 3). In maxillary second premolars, 165 cases (80.49%) had a single root while 40 cases (19.51%) had two roots. None of the maxillary second premolars had three roots. On the other hand, 203 cases (99.02%) of the maxillary first molars had three roots, while only one case (0.49%) had two roots (Figure 4).

Another case (0.49%) had four roots. In maxillary second molars, three roots were present in 190 cases (92.68%); however, compared to the first molar, the number of single-rooted cases (four cases, 1.95%) and two-rooted cases (six cases, 2.93%) was relatively higher (Figure 5). Additionally, five cases (2.44%) had four roots.

A chi-square test revealed a highly significant association between tooth type and the number of the roots and canals(p=0.000), confirming that the variations were consistent and non-random (Table 3). Among maxillary first molars, 106 cases (51.71%) had three canals, and 95 cases (46.34%) had four canals. Three cases (1.46%) had five canals, which was rare. None of the cases had a single canal, and only one case (0.49%) had two canals. Two mesiobuccal canals (MB2) were present in 47.8% of cases (Figure 6),
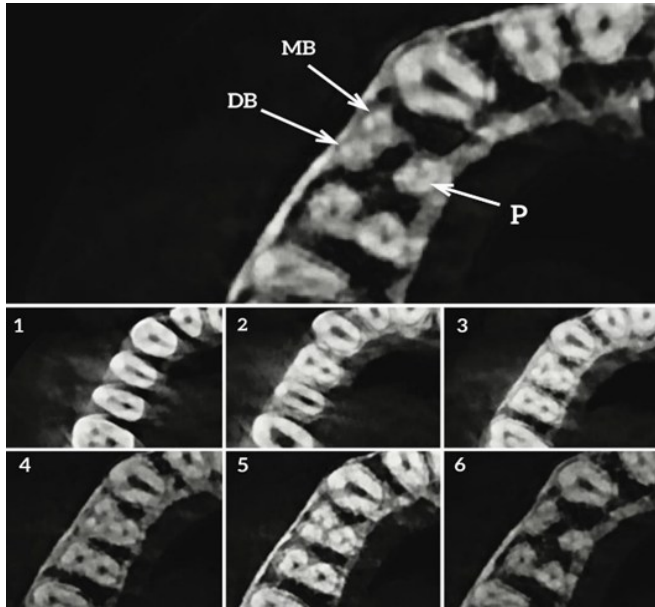

Figure 3. axial view showing three root canals (MB, DB, P) of a maxillary first premolar (Molarized Premolar) with arrows and different Axial sections from (1 to 6) from coronal to apical

Figure 4. axial section on the left side and coronal section on the right side showing a two rooted maxillary right first molar
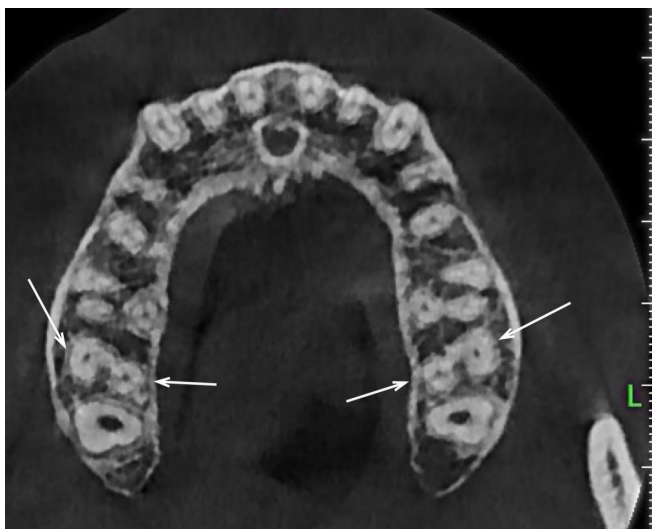

Figure 5. axial view showing two rooted maxillary second molars (arrows)
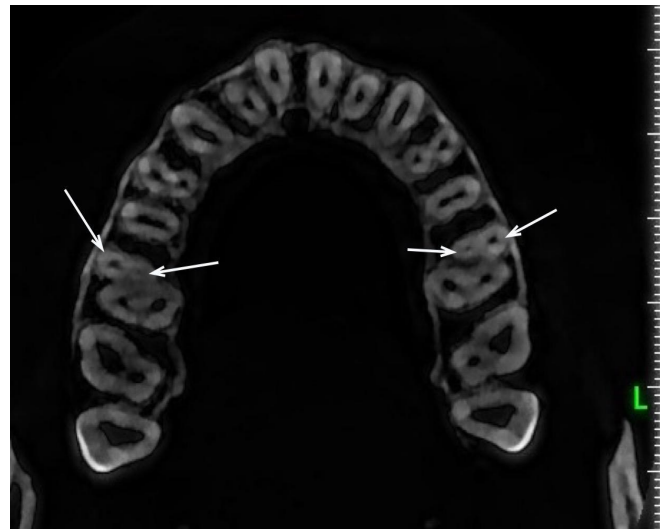

Figure 6. axial view showing maxillary right and left first molars with two canals in the Mesiobuccal root (arrows)

Table 1. Distribution of canal configurations in maxillary premolars and molars

Canal Identification	Maxillary First Molar	Maxillary First Premolar	Maxillary Second Molar	Maxillary Second Premolar	Chi-square (p-value)
B, P	1 (0.49%)	195 (95.12%)	10 (4.88%)	135 (65.85%)	976.11 (0.000)
MB, DB, P	106 (51.71%)	5 (2.44%)	156 (76.10%)	0 (0.00%)	
Single Canal	0 (0.00%)	5 (2.44%)	0 (0.00%)	70 (34.15%)	
MB, MB2, DB, P	95 (46.34%)	0 (0.00%)	37 (18.05%)	0 (0.00%)	
MB, MB2, DB, DB2, P	3 (1.46%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	
MB, DB, P, P2	0 (0.00%)	0 (0.00%)	2 (0.97%)	0 (0.00%)	
Grand Total	205 (100.00%)	205 (100.00%)	205 (100.00%)	205 (100.00%)	

Abbreviations: B: buccal canal, P: palatal canal, P2: second palatal canal, MB: first mesiobuccal canal, MB2: second mesiobuccal canal, DB: first distobuccal canal, DB2: second distobuccal canal,

Tables 2–3. Distribution of root and canal numbers in maxillary premolars and molars

Number Roots	Maxillary First Molar	Maxillary First Premolar	Maxillary Second Molar	Maxillary Second Premolar	Chi-square (p-value)
1 root	0 (0.00%)	62 (30.24%)	4 (1.95%)	165 (80.49%)	959.98 (0.000)
2 roots	1 (0.49%)	138 (67.32%)	6 (2.93%)	40 (19.51%)	
3 roots	203 (99.02%)	5 (2.44%)	190 (92.68%)	0 (0.00%)	
4 roots	1 (0.49%)	0 (0.00%)	5 (2.44%)	0 (0.00%)	
Grand Total	205 (100.00%)	205 (100.00%)	205 (100.00%)	205 (100.00%)	

		Female n (%)	Male n (%)	Chi-square (p-value)	
Number of Roots					
Maxillary First Premolar	1	36 (32.43%)	26 (27.66%)	6.290 (0.0431)	
	2	75 (67.57%)	63 (67.02%)		
	3	0 (0.00%)	5 (5.32%)		
	Total	111 (100.00%)	94 (100.00%)		
Maxillary Second Premolar	1	93 (83.78%)	72 (76.60%)	2.519 (0.284)	
	2	18 (16.22%)	22 (23.40%)		
	3	0 (0.00%)	0 (0.00%)		
	Total	111 (100.00%)	94 (100.00%)		

Figure 7. axial view showing a maxillary left first molar with two canals in the distobuccal root (DB, DB2)

Figure 8. axial view showing maxillary right and left second molars with MB2 (arrows)
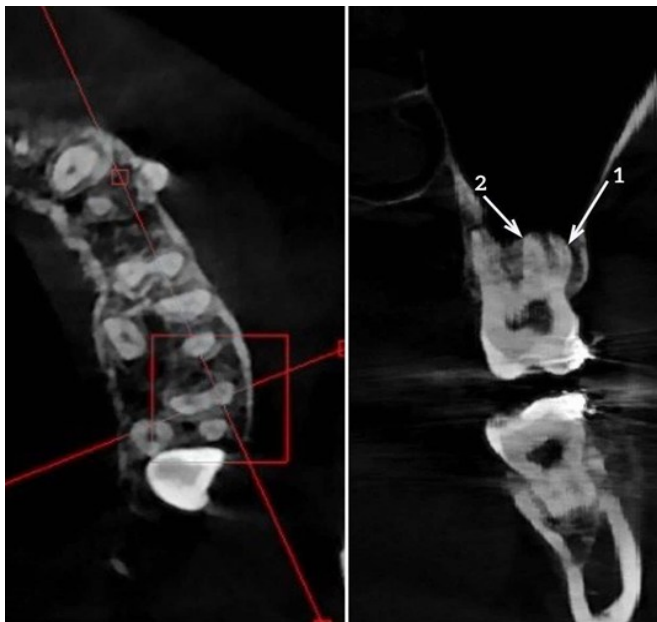

Figure 9. axial section on the left side and coronal section on the right side showing a maxillary left second molar with two separated mesiobuccal root canals. Arrows indicate the mesiobuccal root: 1=MB, 2=MB2
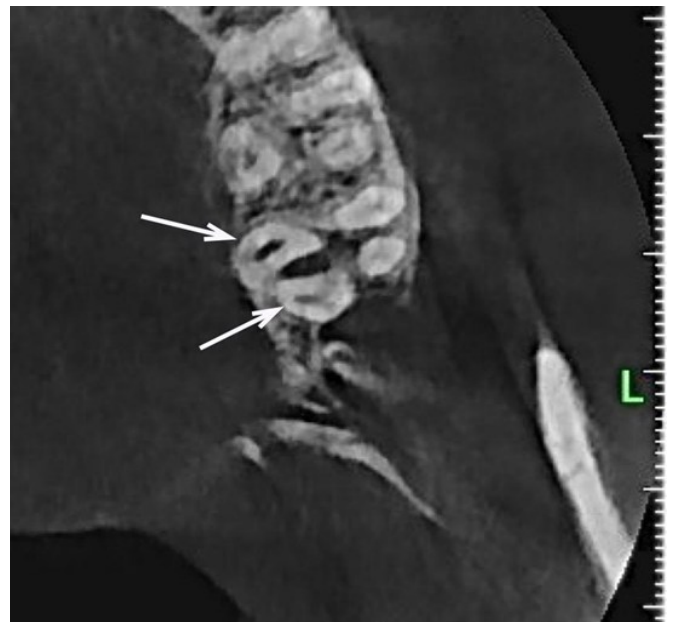

Figure 10. axial view showing a maxillary left second molar with two palatal roots (arrows)

There was a slight gender difference in the distribution of root numbers in the maxillary first and second premolars, as shown in Table 4. The ma-
jority of maxillary first premolars, 75 (67.57%) of females and 63 (67.02%) of males had two roots, whereas 36 (32.43%) of females and 26 (27.66%)

of males had a single root. Among the males, only 5 (5.32%) had three roots. The gender difference in root distribution was statistically significant, according to a chi-square test (p = 0.0431). For the maxillary second premolar, two roots were found in 18 (16.22%) of females and 22 (23.40%) of males, whereas a single root predominated 93 (83.78%) in females and 72 (76.60%) in males. A chi-square test revealed no significant gender difference in root distribution, and none of the cases had three roots (p = 0.284).

Table 4. Comparison of Root Numbers and Canals in Maxillary Premolars by Gender

Number of Canals	Maxillary First Molar	Maxillary First Premolar	Maxillary Second Molar	Maxillary Second Premolar
1	0 (0.00%)	5 (2.44%)	0 (0.00%)	70 (34.15%)
2	1 (0.49%)	195 (95.12%)	10 (4.88%)	135 (65.85%)
3	106 (51.71%)	5 (2.44%)	156 (76.10%)	0 (0.00%)
4	95 (46.34%)	0 (0.00%)	39 (19.02%)	0 (0.00%)
5	3 (1.46%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Grand Total	205 (100.00%)	205 (100.00%)	205 (100.00%)	205 (100.00%)

DISCUSSION

This study provides novel data and a careful analysis of the root canal variations in maxillary molars and premolars by using cone beam computed tomography (CBCT). The most common root canal configuration and variations for each molar and premolar are well recorded among a Kurdish subpopulation in Erbil city. The results show differences in the prevalence of these variations among different populations. Additionally, the study highlights that the root canal configuration may vary by age and gender. Many studies have reported the prevalence of MB2 canal in maxillary first molars using CBCT, which ranges between 30.88% and 87% depending on the population. In comparison with the findings of this study, a study conducted in Korea reported that 71.8% of maxillary first molars had a second mesiobuccal canal,[13] while in China, it was about 30.88% of the cases.[14] In India, 52.6% of the records.[15] In the Middle East, the reported prevalences include 70.2% of the Iranian population,[17] 33.5% of the Turkish population,[18] 72.89% of the Egyptian population,[19] and 87% of the Jordanian population.[20]

Compared to the outcomes of the present study, the prevalence of MB2 in maxillary second molars was significantly lower than the 42.2% reported in a Korean study.[13] while in China it was about 13.87% of the cases,[14] other reported rates are, 38% among the Indian population.[16] 43.4% in an Iranian populations,[17] and 55.13% in an Egyptian populations.[19] Another study in a Saudi population recorded prevalence of MB2 in MFM and MSM by 51.3% and 19.7%, respectively.[21]

It is quite rare to detect a second distobuccal canal in maxillary molars, in a study among Korean population in 802 MFM only 1.25% reported to have two distal canals while it was only 0.3% in 660 maxillary second molars.[22] In the Chinese population, it was 1.12% in maxilarry first molars.[23] The results of both mentioned studies were close to the present study. Regarding the second palatal canal, in relation to the records of this study, an in vivo study conducted among a Brazilian population reported 0.65% of cases with two palatal canals in maxillary first molars.[24] In the Korean population, the prevalence was 12 cases out of 660 (1.82%) in maxillary second molars.[22] In another study, the prevalence was 1.76% which was done on 775 CBCT scans of MFM among the population of China.[23]

In premolars, many variations recorded in studies; the variations are in the number of roots and canals. Compared with the results of the present study, a research conducted on a Japanese population recorded three rooted configuration in 9 cases out of 642 cases (1.2%) in maxillary first premolars, and two cases out of 642 (0.3%) in

maxillary second premolars,[25] the rate was close to that of the present study, as well as to another study which recorded 1.8% in maxillary first premolars and 0.4% in maxillary second premolars.[26] Variations that present between populations may come from genetic, ethnic, or environmental factors, as well as from differences in imaging resolution, voxel size, sample size, methodology, examiner interpretation. Additionally, factors such as age distribution, gender differences, and the type of CBCT machine or the software that used may influence the recorded prevalence of the root canal variations.

The variations in the root canals of the molars and premolars emphasize the need for cautious evaluation of the canal systems before endodontic therapy, and larger sample sizes are recommended for future studies for more precise assessment.

LIMITATIONS

The limitations of this study that should be considered when evaluating the results are, first, its retrospective design and sample collected only from five private clinics in Erbil city, limit the generalizability of the results. As the study was limited to a single city, the results may not fully represent the broader national or regional population, as root canal morphology is known to change with geography and ethnicity. Second, the diagnostic findings are dependent on CBCT images. While it offers superior visualization, its cost and limited accessibility may restrict its practical application in all dental clinics. Finally, the root canal anatomy can change over time and this will make a challenge in determining the ideal patient age to best represent a population.

CONCLUSION

- The most common variations in the root canals of molars are in the MB root
- The second mesiobuccal canal is more frequent in MFM than in MSM
- The prevalence of the second palatal canal and the second distobuccal canal is below 2%.
- It is very rare to detect a Second distobuccal canal in MSM.
- In rare cases, two-rooted MFM can be detected while single and two-rooted MSM can happen in about 5% of cases.
- Presence of Three roots (molarization of premolar) is more in maxillary first premolars than maxillary second premolars.
- CBCT is a crucial tool in endodontic diagnosis.

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