ORIGINAL ARTICLE

ANNALS OF PUNJAB MEDICAL COLLEGE

Evaluation of Maxillary Molar Root Canal Morphology in a Tertiary Care Setting in Lahore, Pakistan

Faiza Awais[1], Maliha Shahbaz[2], Farhat Kazmi[3], Hanna Abdul Majeed[4], Saadia Manzar[5], Naauman Zaheer[6], Hazik Bin Shahzad[7]

1 *Associate Professor, Department of Community Dentistry, Rashid Latif Dental College/Rashid Latif Medical Complex, Lahore Pakistan*
Manuscript writing

2 *Assistant Professor, Department of Oral Biology, Lahore Medical and Dental College, Lahore Pakistan*
Conceptualization & Design of study, Data creation

3 *Professor, Department of Oral Pathology, Rashid Latif Dental College/Rashid Latif Medical Complex, Lahore Pakistan*
Conceptualization, Design of Study, Critical analysis

4 *Professor, Department of Operative Dentistry, Rashid Latif Dental College/Rashid Latif Medical Complex, Lahore Pakistan*
Data creation, Manuscript writing

5 *Associate Professor, Department of Oral & Maxillofacial Surgery, Rashid Latif Dental College/Rashid Latif Medical Complex, Lahore Pakistan*
Data collection, Critical analysis

6 *Professor, Department of Oral Biology, Institute of Dentistry, CMH Lahore Medical College, Lahore Pakistan*
Data creation

7 *Assistant Professor, Department of Community Dentistry, Rashid Latif Dental College/Rashid Latif Medical Complex, Lahore Pakistan*
Data analysis

CORRESPONDING AUTHOR
Dr. Faiza Awais
Associate Professor, Department of Community Dentistry, Rashid Latif Dental College/Rashid Latif Medical Complex, Lahore Pakistan
Email: faiza.awais@rlmc.edu.pk

Submitted for Publication: 05-06-2024
Accepted for Publication 28-06-2025

How to Cite: Awais F, Kazmi F, Shahbaz M, Majeed HA, Manzar S, Zaheer N, Shahzad H. Evaluation of Maxillary Molar Root Canal Morphology in a Tertiary Care Setting in Lahore, Pakistan. APMC 2025;19(2):127-131. **DOI: 10.29054/APMC/2025.1627**

ABSTRACT

Background: Successful endodontic procedures rely on a comprehensive understanding of tooth anatomy and meticulous canal preparation, cleaning, and filling. Failures can occur due to missed canals and complex canal morphology despite the general success of these procedures. **Objective:** This study aimed to evaluate the root and canal morphology on cone beam computed tomography (CBCT) of maxillary molars among the population of Lahore. **Study Design:** Retrospective cross-sectional study. **Settings:** Rashid Latif Khan University, Lahore Pakistan. **Duration:** Six months from June 2022 to January 2023. **Methods:** Root number, canal number, and configurations were analyzed in 206 CBCT images of maxillary molars from 55 patients. **Results:** The majority of maxillary first molars had three roots and four canals (66.7%), whereas the second molars commonly had three roots and three canals (72.5%). The maxillary third molars showed variable root forms. Type I and IV patterns were prevalent in the mesiobuccal (MB) roots of the second and first molars, respectively. Palatal roots mostly showed Type I configuration, though the first molars displayed more variation. The occurrence of C-shaped canals was low (1.8%). These findings align with previous studies, confirming the commonality of three roots in maxillary molars. **Conclusion:** CBCT imaging provides a detailed analysis of endodontic morphology, improving endodontic treatment outcomes by offering a comprehensive understanding of complex anatomy, in cases with variations like C- configured canals.

Keywords: *Cone beam computed tomography (CBCT), Maxillary molars, C-configured canals.*

INTRODUCTION

Endodontic procedure success depends on a deep understanding of tooth structure and expert root canal shaping, debridement, and obturation. Although the prognosis for root canal treatment (RCT) is generally favorable, failures can occur due to open apices, missed canals, complex root canal configurations, and more. A comprehensive knowledge of root canal configuration is critical for positive outcomes, as this varies significantly among populations.[1] Although root canal treatment (RCT) generally has a favorable prognosis rate ranging from 86% to 98%, there is still a possibility of failure.[2] Endodontic treatment is considered unsuccessful when clinical symptoms such as pain, swelling, and periapical radiolucency persist. Common causes of failure in root-treated teeth include open apices, missed canals, complex root canal configurations, instrument separation, residual caries, root fractures, perforations, and transportation, with missed canals being the most prevalent reason.[3] Therefore, a comprehensive understanding of root canal conformation is crucial for achieving positive endodontic

outcomes, as it exhibits significant diversity among various populations worldwide.[4]

Maxillary molars, especially second molars with two mesial canals (MB1 and MB2), are often associated with higher rates of RCT failures due to their complex canal structures.[5] The MB2 canal's variations contribute significantly to these failures.[6] The concurrence rate of the MB2 canal is approximately 77.8% in maxillary first molars and 35.97% in second molars.[7] Additionally, a challenging anatomical variation called a C-configured canal is often located in mandibular first molars and occasionally in first premolars and maxillary molars. Properly identifying and obturating this variation can be problematic.[8]

Various methods exist to study radicular canal morphology, employing a combination of experimental (in vitro) and clinical (in vivo) approaches, with CBCT being a reliable and accurate tool for clinical practice.[9] In vitro techniques include tooth clearing, canal staining, and advanced imaging techniques using micro CT scans and contrast-enhanced X-rays.[3,10] However, these methods have limited clinical applicability as they can only be performed on extracted teeth.[11] In vivo, assessment options include periapical X-rays and cone beam CT scans as commonly used modalities to calibrate root canal morphology.[9] However, 2-dimensional periapical radiographs can cause superimposition and distortion of structures.[1] To overcome these limitations, the more reliable and accurate 3-dimensional CBCT imaging is utilized. CBCT offers high-resolution, distortion-free results with minimal radiation exposure, making it a feasible tool in clinical practice.[12]

There is a lack of significant data regarding the complex anatomical variations in maxillary molars among the Pakistani population diagnosed with CBCT. Therefore, the objective of our study was to utilize CBCT to evaluate the complexity of maxillary molar anatomy and to assess the number of roots, number of canals, and their configurations, which are integral components of the tooth root complex.

METHODS

Endorsed by the Institutional Review Board (IRB) of Rashid Latif Dental College (RLDC/000517/22), this retrospective cross-sectional study analyzed the Promax 3D CBCT scanner (Planmeca, Finland, version 4.6.4, Finland) to obtain high-resolution images. Images were assessed using Romexis software. The imaging parameters were set as follows: field of view (FOV) of 8 x 8 cm, voxel size 0.2 mm, exposure settings of 90 kVp and 10 mA, with a scan time of 12 seconds.

The study included 206 CBCT scans of maxillary molars from 55 patients who were permanent residents of Lahore, Pakistan, collected between June 2022 and January 2023. This study was conducted by a non-probability sampling technique. The inclusion criteria were: CBCT scans of upper first, second, and/or third molars with fully formed roots, absence of caries, resorption, calcification, root canal fillings, or posts. Exclusion criteria included previously treated teeth, poor-quality scans, and incomplete root formation.

The analysis focused on root number, canal number, and configurations were analyzed using axial, sagittal, and coronal CBCT planes. Vertucci's classification was employed for canal configuration categorization. All evaluations were performed by an experienced examiner trained in CBCT analysis. To ensure reproducibility, 10% of the images were re-evaluated after one week, and intra-examiner reliability was confirmed.[13]

Data analysis was performed using SPSS software (version 24), with frequency distributions calculated for categorical variables and summary statistics (mean, standard deviation) computed for quantitative variables. A chi-square test assessed the significant difference in phenomena' presence.

RESULTS

A total of 206 maxillary molars from 52 individuals with a mean age of 48.37 ± 13.4 years were examined. The majority of maxillary molars exhibited three roots, with 100% of first molars, 70% of second molars, and 59% of third molars displaying this characteristic. However, a small percentage of second molars (3.8%) had a single root, while 8.8% had two roots. The maxillary third molar typically has a variable root form, with around 25% being single-rooted, 13% double-rooted, and 2.5% with four roots.

The maxillary third molar showed variable root forms. Maxillary first molars predominantly had four canals (66.7%), whereas second molars mostly had three canals (72.5%). The palatal roots generally exhibited Type I configuration, though the first molars showed more variation. C-configured canals were relatively rare, occurring in only 1.8% of cases.

Table 1: Canal Distribution in Maxillary Molars.

Tooth type		No. of Canals				
		1	2	3	4	5
Max. first molars	N	0	0	25	58	4
	%	0.0	0.0	28.7	66.7	4.6
Max. second molars	N	0	3	58	17	2
	%	0.0	3.8	72.5	21.3	2.5
Max. third molars	N	5	2	30	2	0
	%	12.8	5.1	76.9	5.1	0.0

When analyzing the maxillary molars at a coronal level for root canal outline, Maxillary second molars exhibited the highest incidence of type 1 root form in the MB root, while most maxillary first molars had two canals in the MB root (MB1 and MB2) with type IV configuration (Figure 2). Whereas the highest percentage of DB root-Type I was found in the maxillary first molar. Type I root pattern in the palatal root was commonly prevalent in all the molars. In contrast, maxillary first molars showed a greater diversity in palatal canal morphology compared to other molar teeth (Table 2)

Table 2: Classification of root canal configurations in maxillary molars (1st, 2nd and 3rd) based on Vertucci's system

Tooth type	Root		Canal configuration							
			Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII
Maxillary first molar	MB root	N	25	21	-	41	-	-	-	-
		%	28.7	24.1	-	47.1	-	-	-	-
	DB root	N	87	-	-	-	-	-	-	-
		%	100%		-	-		-	-	-
	P root	N	83	2	-	-	2	-	-	-
		%	95.4	2.3	-	-	2.3	-	-	-
Maxillary second molar	MB root	N	54	5	-	13	-	1	-	-
		%	67.5	6.3	-	16.3	-	1.3	-	-
	DB root	N	73	-	-	-	-	-	-	-
		%	91.3	-	-	-	-	-	-	-
	P root	N	74	2	-	-	-	-	-	-
		%	92.5	2.5	-	-	-	-	-	-
Maxillary third molar	MB root	N	27	-	-	1	-	-	-	-
		%	69.2	-	-	2.6	-	-	-	-
	DB root	N	26	-	-	-	-	-	-	-
		%	66.7	-	-	-	-	-	-	-
	P root	N	27	-	-	-	-	-	-	-
		%	69.2	-	-	-	-	-	-	-

Figure 1: CBCT scans (Romexis software) reveal the region of interest from various perspectives: axial (A & B), sagittal (C), and coronal (D) views. The images display the MB1 and MB2 canals in both maxillary first (M1) and second (M2) molars, showcasing a type IV configuration. Notably, the palatal root (P) of M1 features two canals with a type V configuration (D), which bifurcate into separate canals at the apical third of the root (B)

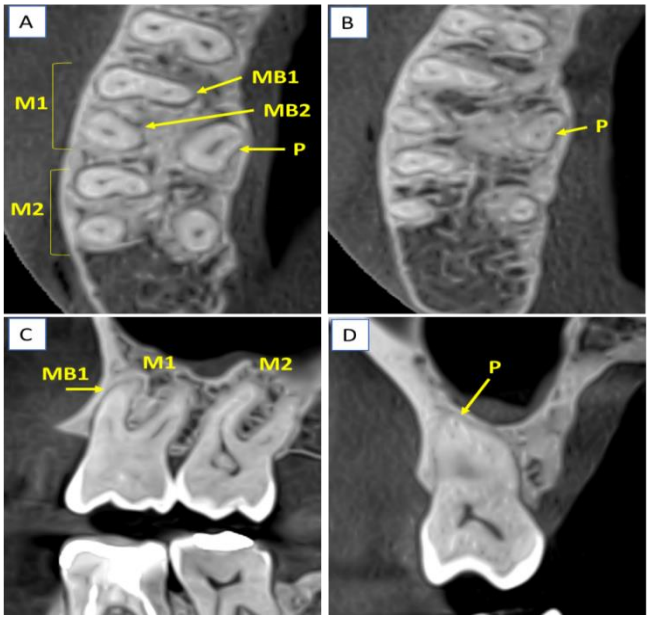


Figure 3: CBCT scans (Romexis software) provide a detailed view of the region of interest from multiple perspectives: axial (A), sagittal (B), and coronal (C) views. The images reveal the presence of palatal (P) P1 and P2 canals with a type IV configuration in both right and left maxillary first molars. Notably, the palatal canals converge to form a single canal at the midpoint of the root (B and C).

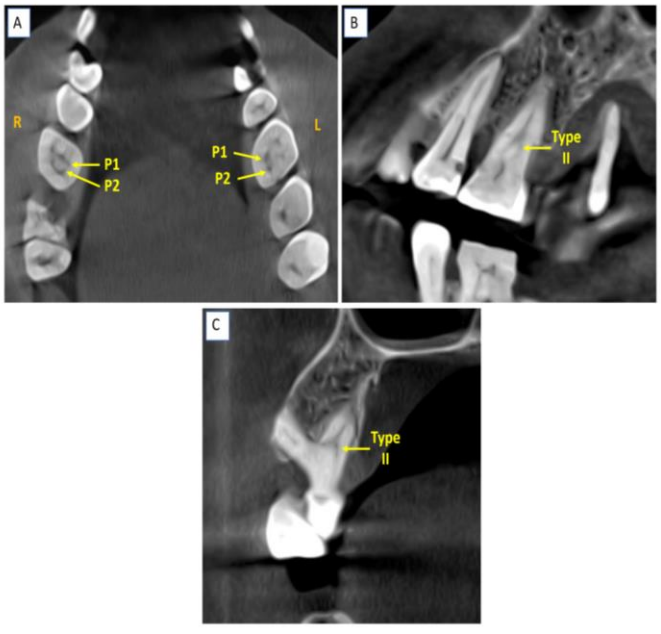
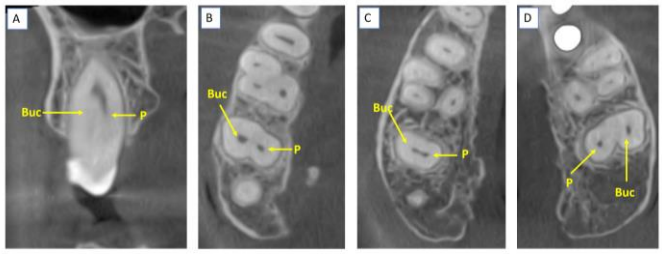


Figure 4: CBCT images showing region of interest coronal view (A) and axial view (B, C & D) (Romexis software). The right mandibular 2nd molar (M2) has one root and two canals (Buc & P) of type II configuration (A) and the two canals at the middle-third of root (B) can be seen joining towards the apical third (C). The left M2 (D) is shown to have two roots (Buc and P roots) with one canal in each root (Type I configuration).



Maxillary second molars (M2) exhibited the highest frequency of type II single root/fused configuration (Table 3). Additionally, C-shaped canals were observed in only 1.8% of maxillary molars.

Table 3: Vertucci's system of root canal morphology in single/fused roots of maxillary second and third molars

Tooth Type		Single Root/Fused						
		Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII
Maxillary second molar	N	0	4	-	2	0	-	1
	%	0.0	18.2	-	9.1	0.0	-	4.5
Maxillary third Molar	N	7	0	-	3	2	-	3
	%	31.8	0.0	-	13.6	9.1	-	13.6

DISCUSSION

This study offers valuable insights into the root and canal morphology of maxillary molars in a Pakistani population, as analysed using CBCT. The assessment of canal number and configurations was performed by carefully examining CBCT scans in axial, sagittal, and coronal planes using Romexis software. Canal configurations were classified following Vertucci's system, which is widely accepted in endodontic literature.

Our findings indicate that maxillary molars most commonly have three roots, with first molars exhibiting a higher prevalence of four canals (66.7%), and second molars typically presenting with three canals (72.5%). These anatomical variations are consistent with previous studies conducted in diverse populations and underscore the complexity inherent in maxillary molars.[3,10,14,15] CBCT has proven to be a reliable imaging modality in endodontics due to its ability to generate high-resolution, three-dimensional images, which eliminate the superimposition and distortion commonly encountered with two-dimensional radiographs. Multiple studies have validated the superiority of CBCT in detecting additional canals, particularly the second mesiobuccal (MB2) canal, and in identifying rare anatomical variations such as C-shaped canals.[5,12]

Our results also corroborate previous CBCT-based studies from Korea, India, Brazil, and Saudi Arabia, all of which reported a predominance of three-rooted molars and highlighted the frequent occurrence of the MB2 canal.[3,7,14–16] Furthermore, the diversity in root anatomy detected in upper second molars coincided with the findings of Kim's study, which identified an extra buccal root and an additional palatal root.[14]

In our study, the mesiobuccal roots of maxillary first and second molars predominantly demonstrated Vertucci's Type IV and Type I canal configurations, respectively. The DB and palatal roots of all molars were most frequently associated with Type I morphology, indicating a single canal. However, a higher degree of anatomical variation was observed in the palatal roots of first molars, including Type II and Type V configurations—an important finding that highlights the necessity of detailed examination during clinical procedures. Notably, the distribution of Vertucci types in our sample closely mirrors the classification patterns observed in other populations, where Type I, Type IV, and Type II configurations were most commonly reported.[15,17]

The maxillary second molars exhibited a notable frequency of fused and single-root forms. This aligns with Tzeng *et al*., who reported a high incidence of root fusion in second molars in their CBCT-based study.[7] Similarly, Candeiro *et al*. observed single-rooted second molars in a Brazilian cohort, supporting the existence of anatomical variability across ethnic groups.[15]

The presence of C-shaped canals in our sample was low (1.8%), consistent with previous studies indicating that this configuration is rare in maxillary molars.[8,18] Nonetheless, even their infrequent occurrence warrants clinician awareness, as their complexity can challenge cleaning and obturation during root canal therapy.

CONCLUSION

This study sheds important light on the root canal anatomy of maxillary molars in patients treated at a tertiary care hospital in Lahore. The findings confirm that maxillary first molars most frequently present with three roots and four canals, with a high prevalence of Type IV canal configuration in the mesiobuccal root.

On the other hand, maxillary second molars displayed more variation in root number, including instances of single and fused roots and predominantly had three canals with simpler Type I canal configuration. This suggests that while second molars are generally less

complex than first molars, their root structure is less predictable.

Maxillary third molars demonstrated the greatest anatomical variability in both root number and canal morphology, reflecting their unpredictable structure. Across all molar types, the distobuccal and palatal roots most commonly exhibited a single canal (Type I), although the palatal root of the first molar showed a higher frequency of variation. C-shaped canals were rare, but their identification remains critical due to their clinical significance.

LIMITATIONS

All the participants in this study were long-term residents of Lahore, which may limit the generalizability of the findings to populations from other regions with varying ethnic, environmental, or genetic influences. While 206 maxillary molars were analyzed, they were obtained from only 52 individuals. This relatively small sample may not fully represent the range of anatomical variations across different age groups and between genders. Additionally, the exclusion of teeth affected by caries, resorption, calcifications, prior endodontic treatments, or restorations means that the study does not reflect the full diversity of root canal morphology typically encountered in routine clinical practice.

SUGGESTIONS / RECOMMENDATIONS

These findings highlight the need for detailed clinical and radiographic evaluation, especially for first and second maxillary molars, where complex root canal systems are more likely. Being familiar with the typical patterns and possible variations in root canal morphology can greatly improve the accuracy and success of root canal treatment, ultimately benefiting patient outcomes in our local context.

CONFLICT OF INTEREST / DISCLOSURE

No potential conflicts of interest were disclosed.

REFERENCES

1. Ratanajirasut R, Panichuttra A, Panmekiate S. A cone-beam computed tomographic study of root and canal morphology of maxillary first and second permanent molars in a Thai population. J Endod. 2018 Jan;44(1):56–61.
2. Tabassum S, Khan FR. Failure of endodontic treatment: The usual suspects. Eur J Dent. 2016 Jan;10(1):144–7.
3. Alamri HM, Mirza MB, Riyahi AM, Alharbi F, Aljarbou F. Root canal morphology of maxillary second molars in a Saudi sub-population: A cone beam computed tomography study. Saudi Dent J. 2020 Sep;32(5):250–4.
4. Abarca J, Gómez B, Zaror C, Monardes H, Bustos L, Cantin M. Assessment of mesial root morphology and frequency of MB2 canals in maxillary molars using cone beam computed tomography. Int J Morphol. 2015 Dec;33(4):1333–7.
5. Gaêta-Araujo H, Alzoubi T, Vasconcelos KF, Orhan K, Pauwels R, Casselman JW, et al. Cone beam computed tomography in dentomaxillofacial radiology: a two-decade overview. Dentomaxillofac Radiol. 2020 Oct;49(8):20200145.
6. Colakoglu G, Kaya Buyukbayram I, Elcin MA, Garip Berker Y, Ercalik Yalcinkaya S. Association between second mesiobuccal canal and apical periodontitis in retrospective cone-beam computed tomographic images. Aust Endod J. 2023 Mar;49(1):20–6.
7. Tzeng LT, Chang MC, Chang SH, Huang CC, Chen YJ, Jeng JH. Analysis of root canal system of maxillary first and second molars and their correlations by cone beam computed tomography. J Formos Med Assoc. 2020 May;119(5):968–73.
8. Fernandes M, De Ataide I, Wagle R. C-shaped root canal configuration: A review of literature. J Conserv Dent. 2014 Jul–Sep;17(4):312–9.
9. Quero L, Schianchi G, Obino FV, Galli M, Testarelli L, Gambarini G. Root canal morphology of lower lateral incisors: a CBCT in vivo study. G Ital Endod. 2020 Jan;34(1).
10. Tian XM, Yang XW, Qian L, Wei B, Gong Y. Analysis of the root and canal morphologies in maxillary first and second molars in a Chinese population using cone-beam computed tomography. J Endod. 2016 May;42(5):696–701.
11. Ahmed HMA. A critical analysis of laboratory and clinical research methods to study root and canal anatomy. Int Endod J. 2022 Feb;55:229–80.
12. Weiss R, Read-Fuller A. Cone beam computed tomography in oral and maxillofacial surgery: an evidence-based review. Dent J. 2019 Jun;7(2):52.
13. de Lima CO, de Souza LC, Devito KL, do Prado M, Campos CN. Evaluation of root canal morphology of maxillary premolars: a cone-beam computed tomography study. Aust Endod J. 2019 Aug;45(2):196–201.
14. 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 Aug;38(8):1063–8.
15. Candeiro GTM, Gonçalves SS, Lopes LLA, Lima ITF, Alencar PNB, Iglecias EF, et al. Internal configuration of maxillary molars in a subpopulation of Brazil's Northeast region: A CBCT analysis. Braz Oral Res. 2019;33:e082. [Month not specified]
16. 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 Sep;36(9):1547–51.
17. Alhujhuj RR, Jouhar R, Ahmed MA, Almujhim AA, Albutayh MT, Adanir N. Evaluation of root canal configuration of maxillary and mandibular first molar by CBCT: a retrospective cross-sectional study. Diagnostics (Basel). 2022 Sep;12(9):2121.
18. Qian Y, Li Y, Song J, Zhang P, Chen Z. Evaluation of C-shaped canals in maxillary molars in a Chinese population using CBCT. BMC Med Imaging. 2022 Jan;22(1):1–7.