DOI: https://doi.org/10.54393/pjhs.v5i08.1622

PAKISTAN JOURNAL OF HEALTH SCIENCES
https://thejas.com.pk/index.php/pjhs
ISSN (P): 2790-9352, (E): 2790-9344
Volume 5, Issue 8 (August 2024)

Original Article

OPEN ACCESS

Exploring Variation in Root Canal Morphology of Maxillary Second Premolars: A Cone-Beam Computed Tomography Study in a Pakistani Subpopulation

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ARTICLE INFO

Keywords:
Maxillary Second Premolars, Dental Anatomy, Bilateral Symmetry, Root Canal Number

How to Cite:
Bano, S., Asif, S. M., Shehzad, F., Idrees, N., Ihsan, A., & Anwar, M. A. (2024). Exploring Variation in Root Canal Morphology of Maxillary Second Premolars: A Cone-Beam Computed Tomography Study in a Pakistani Subpopulation: Root Canal Morphology of Maxillary Second Premolars. Pakistan Journal of Health Sciences, 5(08), 60–65. https://doi.org/10.54393/pjhs.v5i08.1622

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Received Date: 13th July, 2024
Acceptance Date: 28th August, 2024
Published Date: 31st August, 2024

ABSTRACT

A comprehensive knowledge of anatomy of roots and root canals was a key for successful treatment outcomes. Maxillary second premolars often display variability in root and canal numbers. Traditional 2-dimensional imaging techniques have limitations in exact diagnosis of dental anatomy, encouraging the practice of Cone Beam Computed Tomography (CBCT) for comprehensive three-dimensional imaging. **Objective:** To explore the variations in the number of roots and root canals in maxillary second premolars using CBCT. **Methods:** The current study was a retrospective and conducted at the Radiology department of Fatima Memorial Hospital College of Dentistry, Lahore. A total of 143 CBCT scans with completely formed roots were included. Data were analyzed using Planmeca Romexis imaging software and statistical analysis was performed using SPSS version 23.0. **Results:** Among 143 individuals, the majority exhibited one root and one canal in maxillary second premolars. In terms of root number, 77% of the 2nd premolars had a single root and 23% had two roots. In relevance of root canals, 62.5% were found to have a single canal and 37.5% had two root canals. However, no any case was found having three roots and canals. Bilateral symmetry in root canal patterns was observed in most cases, with statistically significant differences between genders. **Conclusions:** The findings of this study may contribute to the understanding of variations in dental anatomy in Pakistani population and emphasize the importance of one's treatment approaches for optimal patient care.

INTRODUCTION

The most frequent dental problems for which the patients visit the dental Outpatient Department (OPD) is complaint of painful and carious dentition that may require Root Canal Treatment (RCT) or extraction of a tooth. One of the most considerable causes of root canal failure is missed canal and simple extraction leading to surgical extraction is Broken Down Root (BDR) during extraction [1]. For successful RCT and safe extractions, a comprehensive knowledge of the number of canals and roots is important. In addition to molars, premolars especially maxillary second premolars, are well known for their variability in root and canal numbers [2]. Maxillary 2nd premolars are expected to erupt between 10-12 years of age with roots development completed approximately at the age of 12-14 years. The maxillary second premolars are commonly known to have one canal in one root. However, studies conducted on various populations of the world disclosed that roots and canals in maxillary 2nd premolar may vary from one to three [3]. This variation is not only observed between various populations but also among individuals within the same population. Therefore, accurate knowledge of the root canal system is mandatory to prevent treatment failures [2]. Two-dimensional imagining technique that is routinely used in dental practice may result into challenging situations because of superimposition, distortion, and limited magnification,

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hindering accurate diagnosis and treatment planning [4]. To overcome such situations, Cone Beam Computed Tomography (CBCT) was emerged in 1988. It served as a revolutionary technique that has contributed to precise and accurate three-dimensional imaging of the oral and maxillofacial regions [1]. CBCT has additional advantages over conventional 2-dimentional imaging as it has the ability to reproduce more detailed images with accurate geometrical dimensions having less ionizing radiation exposure [4]. It enables detailed evaluation of pathologies of jaws, periapical lesions, root fractures, joint dysfunctions, and periodontal bone defects. By offering dentists incomparable insights, CBCT helps significantly to prevent the failure of root canal treatment [2, 5]. Therefore, the current study aims to explore the variability in the number of roots and root canals of the maxillary second premolar. This research is designed to enhance our understanding of population-specific variations of Pakistani population. To achieve this, CBCT was employed in this study as an observational tool to precisely identify variations in the number of roots and root canals in the maxillary second premolar.

METHODS

The current study was a retrospective study and it was conducted in the Radiology department of Fatima Memorial College of Dentistry, Shadman, Lahore. This study was approved by the Institutional Review Board of Fatima Memorial Hospital College of Medicine and Dentistry, having reference number FMH-16/05/2024-IRB-1408. The record of previously done CBCTs of the patients who had visited the radiology department of FMH college of Dentistry from October 2022 till March 2023 was taken. This study was retrospective and the collected record was anonymous only having information of gender and age of the patient. Therefore, the consent of the patient was not taken. The data were obtained by simple random sampling technique and sample size was obtained from the following formula: n=p(1-p) (Z/e)2, Effect size = 10%, 1-β at Desired Power of 0.9(90%)=1.28 A at desired level of significance of 0.05 (5%) =1.96, Constant proportion of 2nd root canal = 74.5%. The sample size according to above mentioned formula was 141. Patient selection criteria focused on individuals who had undergone CBCT scans and exhibited fully formed maxillary second premolars. Consequently, participants aged 12 years and above, with maxillary second premolars intact for dental treatment purposes, were included. Exclusions were made for patients lacking maxillary second premolars or falling below the age threshold of 12 years. Imaging procedures relied on CBCT technology calibrated to 90kV and 10 mA, with an exposure duration of 12 seconds. Scan dimensions were standardized to a diameter and volume of 100mm and 80mm, respectively, with a slice thickness of 0.35mm. Images were evaluated using Planmeca Romexis imaging software version 6.0.0.3 on a 24 inches monitor in a dim light. The CBCT images of maxillary premolars were observed in axial, coronal and sagittal planes by all the investigators of this study having interval of few days between the assessments. The proforma documented patient demographics, including age and gender, as well as the number of roots and root canals for both right and left Maxillary 2nd premolars. After the completion of data collection, statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 23.0. Categorical variables were presented as frequencies and percentages to provide a comprehensive overview of the dataset. To assess the significance of differences between genders and between the right and left sides, the Chi-square test was employed. A significance level of 0.05 or lower was considered statistically significant, adhering to standard conventions in hypothesis testing

RESULTS

In the present study, 143 individuals participated, with a mean age of 36 years and standard deviation of 13.83. Among them, five patients lacked a right 2nd premolar, and nine lacked left 2nd premolar, leaving 138 right and 134 left premolars, totaling 272, for analysis. Of the participants, 40% (n=57) were male and 60% (n=86) were female. In terms of root configuration, 77% (n=209) of the 272 maxillary 2nd premolars had a single root, while 23% (n=63) exhibited two roots; none presented with three roots (Table 1).

Table 1: Variation in Number of Roots of Maxillary 2nd Premolar

Root/s	Left N (%)	Right N (%)	Total N (%)
One Root	104 (78)	105 (76)	209 (77)
Two Roots	30 (22)	33 (24)	63 (23)
Three Roots	0	0	0
Total	134	138	272

Upon examination of the root canals of the maxillary 2nd premolar, it was observed that 62.5% (n=170) had a single canal, while 37.5% (n=102) exhibited two root canals. Notably, no instances of three root canals were detected in any of the maxillary 2nd premolars analyzed (Table 2).

Table 2: Variation in Number of Canals of Maxillary 2nd Premolar

Canal/s	Left N (%)	Right N (%)	Total N (%)
One Canal	87 (65)	83 (60)	170 (62.5)
Two Canal	47 (35)	55 (40)	102 (37.5)
Three Canal	0	0	0
Total	134	138	272

While the predominant observation revealed one root and one canal, variations were noted in the presence of one or two canals within a single root (Table 3).

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Table 3: Root Number and Root Canal Pattern in Left and Right Quadrants

Root/s and Canal/s	Left N (%)	Right N (%)	Total N (%)
One Root One Canal	87 (65)	83 (60)	170 (62.5)
One Root Two Canals	18 (13.4)	22 (16)	40 (14.7)
Two Roots Two Canals	29 (21.6)	33 (24)	62 (22.7)
Total	134	138	272

Among the 272 premolars examined, 62.5% (n=170) exhibited one root and one canal, 14.7% (n=40) displayed two canals within a single root (Figure 1),

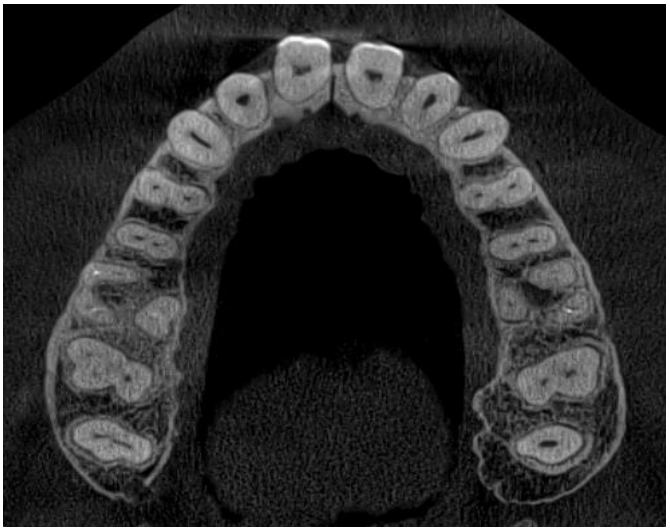

Figure 1: Maxillary Second Premolars Exhibiting a Single Root with Two Canals in Both Quadrants

In the study, 22.7% (n=62) of the maxillary second premolars were found to have two roots, each containing two root canals (Figure 2).

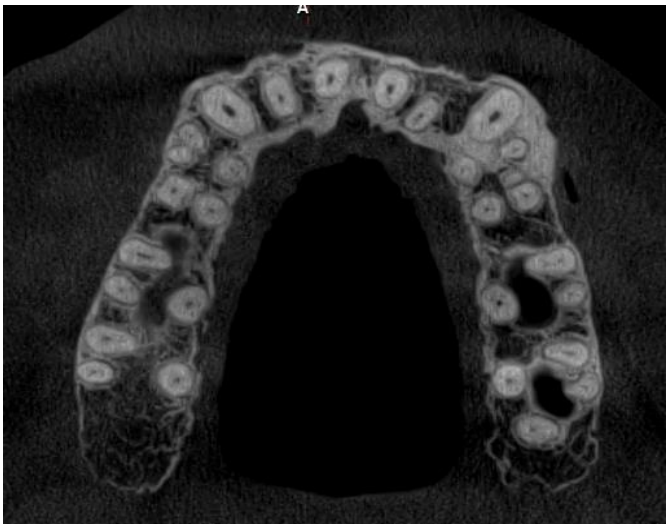

Figure 2: Maxillary Second Premolars Exhibiting Two Roots With Two Canals Each In Both Quadrants

Bilateral variation in root canal patterns was evident in only 14% (n=20) of individuals, with 76% (n=110) exhibiting bilaterally consistent patterns of root canals and root numbers on both sides. A statistically significant p-value of 0.000 was obtained upon comparison of right and left quadrants. The most prevalent pattern observed was one root with one canal in both males and females. Among the 111 maxillary second premolars of males examined, 56% (n=62) featured one root with one canal, 18% (n=20) displayed one root with two canals, and 26% (n=29) exhibited two roots with two canals each. Conversely, among the 161 maxillary second premolars of females, 67% (n=108) had one root with one canal, 12.4% (n=20) had one root with two canals, and 20.4% (n=33) had two roots with two canals. Although not statistically significant (p=0.12), females showed a higher tendency toward a single root with one canal, whereas males exhibited a greater tendency toward two canals in one root and two roots with two canals each (Table 4).

Table 4: Comparison of Root Number and Canal Pattern between Male and Female

Root/s and Canal/s	Male N (%)	Female N (%)	Total N (%)
One Root One Canal	62 (56)	108 (67)	170 (62.5)
One Root Two Canals	20 (18)	20 (12.4)	40 (14.7)
Two Roots Two Canals	29 (26)	33 (20.4)	62 (22.7)
Total	111	161	272

DISCUSSION

Dental morphology and root canal anatomy play a crucial role in dentistry, supplying valuable insights into the complex and diverse anatomy of teeth [6]. The first step in achieving a successful endodontic result was the evaluation of the root canal system and its anatomical variations. Therefore, sufficient knowledge should be there to avoid the failure of root canal treatment and a traumatic extraction. Usually, it was considered that maxillary 2nd premolars have one root and one canal only. But there was probability of this tooth to be having more than one root and canal [7]. The present study was designed to evaluate the prevalence of extra roots and canals in maxillary 2nd premolar among the population of Lahore by using CBCT. In this study, Cone Beam Computed Tomography (CBCT) served as the primary assessment tool for evaluating root canal morphology and numbers. This technology enables detailed visualization of anatomical structures in axial, coronal, and sagittal planes, facilitating more precise observations compared to conventional radiographs. Additionally, CBCT obviates the need for tooth extraction, allowing for comprehensive comparisons of both dental quadrants within individual subjects [8]. Significant variations in root canal morphology and numbers were known to exist among diverse global populations, as well as within specific national demographics. However, limited data regarding these parameters were available for the Pakistani population. Therefore, the present investigation aimed to explore the variability in root and canal configurations within the

DOI: https://doi.org/10.54393/pjhs.v5i08.1622

Pakistani subpopulation residing in Lahore. The results of the present study showed that single root was the most common finding (77%) followed by two roots (23%) while no case was found to have three roots. Regarding the number of root canals, 62.5% of the sample population had 1 canal, 37.5% had two canals while no case of three canals in maxillary 2nd premolar was found. These results were in line with another study conducted by Yan Y *et al.*, in 2021 who also reported that a single root was the most prevalent finding, accounting for 94.2% of cases, with only 5.8% of teeth exhibiting two roots. Additionally, they observed that single canals were present in 55.1% of cases, while two canals were found in 44.7% of cases, and three canals were detected in only 0.2% of cases [5]. The finding of three canals is not in line with the current study. The results of another study conducted by Al-Zubaidi SM *et al.*, on Saudi Arabian population in 2021 were also in consistent with the results of present study as they also described that one root was found most frequently in 83.2%, two roots in 15.8% and only 1% sample population had three roots [9]. Similarly, Asheghi B *et al.*, in Brazil in 2019 reported one root in 71.2% of cases, two roots in 28.4% of cases, and three roots in 0.4% of cases using CBCT imaging [10]. Furthermore, Alqedairi A *et al.*, conducted a study in Saudi Arabia in 2018, where 85.2% had one root, 14.5% had two roots, and 0.3% had three roots [11]. Although the results of the above-mentioned studies were consistent with the present study in terms of the most frequent finding. But in many populations, three roots and canals were also found diverging from our results. However, a study by Martins JN *et al.*, in 2018 on the Portuguese population and Felsypremila G *et al.*, in 2015 in India Indian population reported that no cases exhibited three roots, consistent with the findings of the current study [12, 13]. Neither this study nor theirs observed any radiographs with three roots and canals. Abella F *et al.*, in 2015 studied a population in Spain (n=374), where one root was observed in 82.9% of cases, two roots in 15.5% of cases, and three roots in 1.6% of cases [14]. Yang L *et al.*, in their 2014 study on the Chinese population (n=392), found that 86.5% of individuals had one root, 13.5% had two roots, and no cases exhibited three roots, aligning with our findings [15]. The results of the present study showed that males exhibited a higher tendency to have two canals as compared to the females. Similar results were found in Turkey in 2014 by Ok E *et al.*, and one canal was more frequently found on the left side, while two canals were more common on the right side [16]. Many populations worldwide have been assessed for the root number and morphology of the maxillary 2nd premolar, including studies conducted on the Pakistani population. However, variations were observed, particularly concerning the presence of three roots. Although, the most prevalent root number was one root, typically with one canal. But a clear variation was observed in percentage for these entities in Pakistani sub-population. The current study aimed to have knowledge of variation in root number and canals in various populations of the world. However, variation was observed within the Pakistani population. Various areas of Pakistan showed variation in results. For instance, three roots were not found in current study but Shah SA conducted a study in 2023 in Peshawar, reporting that among the study population, 58.27% were single-rooted, 41.35% were two-rooted, and 0.37% were three-rooted [1]. On the other hand, Hanif F *et al.*, conducted a study in Islamabad in 2022, and explored one root as the most common finding and one canal as the most common canal configuration, consistent with the present study [17]. Furthermore, Dil F *et al.*, in 2022 found out that the population in Peshawar had most commonly one canal (54%), followed by two canals (46%) and only 1% had three canals [18]. However, Alkahtany MF *et al.*, studied the number of roots and canals in Peshawar in 2021, reporting that 96.7% of teeth had a single root, 3.3% were two-rooted, and no teeth had three roots. Contrary to the current study, they found a higher prevalence of having two canals instead of one, with 73.3% of teeth having two root canals, while 26.7% had one canal. However, similar to the present study, no maxillary second premolar was found to have three roots or three canals [19]. The findings of a study in Peshawar regarding the prevalence of root canals were comparable to those of Hussain SM *et al.*, in 2020 in Rawalpindi. Both studies observed that the majority of patients, with 150 cases (75%), exhibited a two-canal system, while 50 cases (25%) showed a single canal configuration [20]. Moreover, similar to current study, Nazeer MR *et al.*, conducted a study in 2018 in Karachi, Pakistan, showing that out of 115 cases, one root was observed in 84.3%, two roots in 15.7% and no cases had three rooted premolars. Additionally, they reported one canal in 49.6% of cases, two canals in 48.7% and three canals in 1.7% [21]. Another study in Karachi by Sardar KP *et al.*, in 2006, utilizing the shift cone technique during root canal treatment, found that out of 43 males, 63% had two canals, and out of 57 females, 53% had two canals, with no significant difference between the two groups contradicting the frequent one canal finding in the current study [22].

CONCLUSIONS

Understanding the intricate anatomy of teeth, particularly the root canal system, was essential for successful dental treatments like root canal therapy and extractions. Variability in the number of roots and canals, especially in premolars like the maxillary second premolar, underscores the importance of precise diagnostics. Our study enhances the understanding of root canal morphology in maxillary second premolars, aiding clinicians in providing more precise and effective dental care. This knowledge can help prevent treatment complications and ensure better outcomes for patients undergoing dental interventions.

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Additionally, this study concluded that variations in dental anatomy are not only observed among different populations worldwide but can also be found within the same country's population across different ethnic groups. Specifically, variations were observed in the Punjabi, KPK, and Sindhi populations. Further research with broader population samples and more geographical areas can deepen our understanding of dental anatomy and its clinical implications.

Authors Contribution

Conceptualization: SB
Methodology: SMA, SB
Formal analysis: SB, FS
Writing, review and editing: SMA, NI, AI, MAA, SB

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Source of Funding

The authors received no financial support for the research, authorship and/or publication of this article.

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