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ORIGINAL RESEARCH ARTICLE

CONE BEAM COMPUTED TOMOGRAPHIC ANALYSIS OF ROOT AND ROOT CANAL MORPHOLOGY OF MANDIBULAR PREMOLARS IN A TERTIARY CARE CENTRE OF NEPAL

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ABSTRACT

Background: Mandibular premolars are challenging to treat endodontically due to their varied root and canal morphology, impacting treatment prognosis. This study aimed to assess the root and canal morphology of mandibular premolars in a Nepalese subpopulation using Cone Beam Computed Tomography (CBCT) images.

Methods: A descriptive cross-sectional study was performed by obtaining 65 CBCT images of patients from the Department of Oral Medicine and Radiology of Chitwan Medical College, Chitwan, Nepal. A total of 130 untreated mandibular first and second premolars of both right and left side with completely developed roots were analyzed. The number of roots, root canals, their configurations per Vertucci's classification, C-shaped canals, and the influence of gender and tooth position on morphology were evaluated.

Results: Significant variations in root morphology were observed in mandibular premolars, with most having one root (85.4% in first premolars, 97.7% in second premolars) and one canal (78.5% in first premolars, 94.6% in second premolars). Type I configurations were most common (78.5% in first premolars, 94.6% in second premolars), followed by Type V (15.4% in first premolars, 2.3% in second premolars). C-shaped canals were more frequent in first premolars (20.8%) than second premolars (4.6%). Significant gender differences were noted in root and canal morphologies, with males showing more variability, but no significant differences were found based on tooth position.

Conclusions: This CBCT study in a Nepalese subpopulation revealed significant root and canal morphology variations in mandibular premolars, emphasizing the importance of CBCT in endodontic diagnosis and treatment planning for better outcomes.

INTRODUCTION

Successful root canal treatment requires thorough cleaning, shaping, and three-dimensional obturation of the entire root canal system, achievable only through a complete understanding of root canal morphology and its variations. Knowledge of root and canal morphology is crucial for effective endodontic therapy, as failing to recognize canal variations can lead to untreated infections and treatment failure.[1-2] Hoen and Pink[3] found a 42% incidence of missed roots or canals in teeth requiring retreatment. Mandibular premolars, due to their wide variation in roots and canals, are particularly challenging and have higher failure rates.[4-5]

Various techniques, including staining and clearing, transverse cross-sectioning, conventional radiography, micro-CT imaging, a contrast medium enhanced digital radiography, and Cone Beam Computed Tomography (CBCT), have been used to study canal morphology.[6] Conventional periapical radiography, although common, provides only two-dimensional images and is limited by superimposition and distortion. Cone Beam Computed Tomography offers three-dimensional scans and is more accurate in determining root canal morphology, despite slightly higher radiation exposure, which is outweighed by its diagnostic benefits.[6-8]

Previous studies on root canal anatomy have been conducted in various populations, including Egyptian, Iranian, South Indian, Saudi, Bangladeshi, Taiwanese, German, Kuwaiti, and Chinese groups. While some regions in Nepal have been studied,[9] no research has focused on the Chitwan district. This study aims to evaluate the root and canal morphology of mandibular premolars in the residents of Chitwan district using CBCT, considering the impact of gender and tooth side on morphological variations.

METHODS

A descriptive, cross-sectional study was conducted in the Department of Conservative Dentistry and Endodontics, Chitwan Medical College, Bharatpur, Nepal. The CBCT images of mandibular premolars from patients who were referred from Oral & maxillofacial Surgery, Prosthodontics

and Endodontics of School of Dental Sciences (SODS), Chitwan Medical College (CMC) for diagnostic and treatment planning purposes, and attending the Radiology unit at the Department of Oral Medicine and Radiology were collected by convenient sampling method for a duration of 6 months (July 2023-December 2023). The identities of the patients were not revealed and only information regarding gender and age were collected.

The study was conducted after getting the ethical clearance from the Institutional Review Committee of Chitwan Medical College (Ref: CMC-IRC/079/080-225).

The sample size was calculated using a formula $n = Z^2pq/e^2$ where, n = sample size, z=standard deviation set at 1.96 (95% confidence level), p=prevalence of condition (according to Al-Zubaidi et al.[10] prevalence of type I canal of second premolar=91.1%), q=100-p, e=permissible error=5%. Placing these values, we got a sample size of 125. For the assessment of 125 second premolars, 63 CBCT images had to be taken. To ensure a safe representative sample, 65 CBCT images were taken to analyze 260 mandibular premolars. Thus, 65 CBCT images including those of mandibular premolars and fulfilling the following inclusion criteria were selected: age 18 to 65 years; fully mature (closed) root apices; teeth without periapical lesions, resorption and calcification; endodontically untreated teeth; and good quality CBCT images.

The CBCT images were obtained using Planmeca ProMax 3D CBCT unit (Helsinki, Finland); at 90 kV and 10 mA with an exposure time of 12 s. The voxel size of the images was 0.3 mm; and the slice thickness was 200 µm. The CBCT images were evaluated by experienced endodontist. All the CBCT images were analyzed using Planmeca Romexis Viewer.

The number of roots and root canals, root canal configuration, existence of C-shaped root canal; and the influence of gender and tooth position on each of these were evaluated. Vertucci's Classification[11] was used to determine the type of root canal configuration. Vertucci's classification is defined as follows: type I (1), type II (2-1), type III (1-2-1), type IV (2), type V (1-2), type VI (2-1-2), type VII (1-2-1-2), and type VIII (3). C-shaped root canal were evaluated using Fan et al.[12] classification that include: category-I (C1): a continuous "C" with no separation or division; category II (C2): a discontinuation in the "C" outline (semicolon-like); category III (C3): two or three separate round, oval, or flat canals; category IV (C4): only one round, oval, or flat canal in that cross-section; category V (C5): no canal lumen could be observed.

All statistical analyses were performed using version 29 of Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA). Chi-square test was used to evaluate and compare the significant variation in the distribution root number and canal morphology based on the gender and tooth's position. Differences were statistically significant when P-value was < 0.05. The results were presented in the form of table.

RESULTS

CBCT images of 65 subjects, comprising 38 males and 27 females aged between 18 to 65 years, were collected. The number of roots and canal configurations of 260 mandibular premolars (130 first premolars and 130 second premolars) were evaluated.

The study found significant differences (P < 0.05) in the root morphology of mandibular premolars. It was observed that 85.4% of first premolars and 97.7% of second premolars had a single root. Similarly, 78.5% of first premolars and 94.6% of second premolars had only one root canal (Table 1).

Table 1: Distribution of number of roots and root canals in mandibular first and second premolars

Type of tooth	Number of roots			Number of root canals		
	One root n (%)	Two roots n (%)	Total n (%)	One canal n (%)	Two canals n (%)	Total n (%)
Mandibular first premolars n=130 (100.0%)	111 (85.4)	19 (14.6)	130 (100.0)	102 (78.5)	28 (21.5)	130 (100.0)
Mandibular second premolars n=130 (100.0%)	127 (97.7)	3 (2.3)	130 (100.0)	123 (94.6)	7 (5.4)	130 (100.0)
Total	238 (91.5)	22 (8.5)	260 (100.0)	225 (86.5)	35 (13.5)	260 (100.0)

Chi-square tests: p< 0.05

Table 2: Distribution of number of roots and root canals in mandibular premolars according to gender and tooth position

Number of roots	Gender			Tooth Position		
	Male	Female	Total	Right	Left	Total
One root n (%)	133 (87.5)	105 (97.2)	238 (91.5)	120 (92.3)	118 (90.8)	238 (91.5)
Two roots n (%)	19 (12.5)	3 (2.8)	22 (8.5)	10 (7.7)	12 (9.2)	22 (8.5)
Total n (%)	152 (100.0)	108 (100.0)	260 (100.0)	130 (100.0)	130 (100.0)	260 (100.0)
Number of root canals						
One root canal n (%)	124 (81.6)	101 (93.5)	225 (86.5)	113 (86.9)	112 (86.2)	225 (86.5)
Two root canals n (%)	28 (18.4)	7 (6.5)	35 (13.5)	17 (13.1)	18 (13.8)	35 (13.5)
Total n (%)	152 (100.0)	108 (100.0)	260 (100.0)	130 (100.0)	130 (100.0)	260 (100.0)

Chi-square tests for gender: p< 0.05; for tooth position p > 0.05

This study also revealed significant differences in the distribution of root and canal numbers in mandibular premolars based on the patient's gender ($P < 0.05$). Among the 152 mandibular premolars in male patients, 133 (87.5%) had one root, with 39.5% in first premolars and 48% in second premolars, and 124 (81.6%) had one root canal, with 34.9% in first premolars and 46.7% in second premolars. Similarly, out of the total 108 mandibular premolars in female patients, 105 (97.2%) had one root, with 47.2% in first premolars and 50% in second premolars, and 101 (93.5%) had one root canal, with 45.2% in first premolars and 48.1% in second premolars, as shown in Table 2.

There were no statistically significant differences between tooth position and the number of roots and root canals ($P > 0.05$). On the right side, 92.3% of mandibular premolars had one root (43.1% in first premolars and 49.2% in second premolars), and 86.9% had one root canal (40% in first premolars and 46.9% in second premolars), while on the left side, 90.8% of mandibular premolars had one root (42.3% in first premolars and 48.5% in second premolars), and 86.2% had one root canal (38.5% in first premolars and 47.7% in second premolars) (Table 2).

This study showed significant differences in the root canal configuration types according to Vertucci's classification concerning the tooth type. Type I configurations were the most prevalent in mandibular premolars (78.5% in first premolars and 94.6% in second premolars) (Table 3).

In mandibular first premolars, the type V configuration (15.4%) was the second most common canal configuration. In mandibular first premolars, one tooth (0.8%) presented with type IV and VI configurations. In mandibular second premolars, one tooth had a type II configuration (0.8%). Type VI, VII, and VIII were not found in mandibular second premolars (Table 3). Based on the gender, Type I (81.6% in males and 93.5% in females) was the most common among all types, followed by type V (12.5% in males and 3.7% in females). Type II, VII, and VIII configurations were absent in male patients, whereas type VI, VII, and VIII were absent in female patients (Table 4). Based on tooth position, Type I was more common on both sides (86.9% on the right side and 86.2% on the left side), followed by type V (7.7% on the right side and 10% on the left side). Type VII and VIII configurations were absent on the right side, whereas types II, VII, VII, and VIII were absent on the left side (Table 4).

Table 3: Distribution of root canal configuration types according to Vertucci's classification in mandibular first and second premolars

Type of Tooth	Types of Root Canal Configuration							
	Type I n (%)	Type II n (%)	Type III n (%)	Type IV n (%)	Type V n (%)	Type VI n (%)	Type VII n (%)	Type VIII n (%)
Mandibular First Premolar n=130 (100.0%)	102 (78.5)	0 (0.0)	6 (4.6)	1 (0.8)	20 (15.4)	1 (0.8)	0 (0.0)	0 (0.0)
Mandibular Second Premolar n=130 (100.0%)	123 (94.6)	1 (0.8)	1 (0.8)	2 (1.5)	3 (2.3)	0 (0.0)	0 (0.0)	0 (0.0)
Total	225 (86.5)	1 (0.4)	7 (2.7)	3 (1.2)	23 (8.8)	1 (0.4)	0 (0.0)	0 (0.0)

Table 4: Distribution of root canal configuration types according to Vertucci's classification in mandibular premolars based on gender and tooth position

Variables	Types of Root Canal Configuration								
	Type I n (%)	Type II n (%)	Type III n (%)	Type IV n (%)	Type V n (%)	Type VI n (%)	Type VII n (%)	Type VIII n (%)	Total n (%)
Gender									
Male	124 (81.6)	0 (0.0)	5 (3.3)	3 (2.0)	19 (12.5)	1 (0.7)	0 (0.0)	0 (0.0)	152 (100.0)
Female	101 (93.5)	1 (0.9)	2 (1.9)	0 (0.0)	4 (3.7)	0 (0.0)	0 (0.0)	0 (0.0)	108 (100.0)
Total n (%)	225 (86.5)	1 (0.4)	7 (2.7)	3 (1.2)	23 (8.8)	1 (0.4)	0 (0.0)	0 (0.0)	260 (100.0)
Tooth Position									
Right	113 (86.9)	1 (0.8)	4 (3.1)	1 (0.8)	10 (7.7)	1 (0.8)	0 (0.0)	0 (0.0)	130 (100.0)
Left	112 (86.2)	0 (0.0)	3 (2.3)	2 (1.5)	13 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)	130 (100.0)
Total n (%)	225 (86.5)	1 (0.4)	7 (2.7)	3 (1.2)	23 (8.8)	1 (0.4)	0 (0.0)	0 (0.0)	260 (100.0)

Table 5: Distribution of C-shaped canal according to Fan et.al classification in mandibular first and second premolars

Type of Tooth	Types of C-shaped canal						
	Absent n (%)	C1 n (%)	C2 n (%)	C3 n (%)	C4 n (%)	C5 n (%)	Total n (%)
Mandibular First Premolar	103 (79.2)	2 (1.5)	1 (0.8)	22 (16.9)	2 (1.5)	0 (0.0)	130 (100.0)
Mandibular Second Premolar	124 (95.4)	0 (0.0)	1 (0.8)	4 (3.1)	1 (0.8)	0 (0.0)	130 (100.0)
Total n (%)	227 (87.3)	2 (0.8)	2 (0.8)	26 (10.0)	3 (1.2)	0 (0.0)	260 (100.0)

C-shaped canals were more commonly found in mandibular first premolars (20.8%) than in mandibular second premolars (4.6%). Category 3 (C3) type C-shaped canal had the highest prevalence (16.9% in first premolars and 3.1% in second premolars) among all the types (Table 5).

Table 6: Distribution of C-shaped canal according to Fan et.al classification in mandibular premolars based on gender and tooth position

Variables	Type of C-Shaped Canal						
	Absent n (%)	C1 n (%)	C2 n (%)	C3 n (%)	C4 n (%)	C5 n (%)	Total n (%)
Gender							
Male	125 (82.2)	2 (1.3)	2 (1.3)	23 (15.1)	0 (0.0)	0 (0.0)	152 (100.0)
Female	102 (94.4)	0 (0.0)	0 (0.0)	3 (2.8)	3 (2.8)	0 (0.0)	108 (100.0)
Total n (%)	227 (87.3)	2 (0.8)	2 (0.8)	26 (10.0)	3 (1.2)	0 (0.0)	260 (100.0)
Tooth Position							
Right	115 (88.5)	1 (0.8)	1 (0.8)	11 (8.5)	2 (1.5)	0 (0.0)	130 (100.0)
Left	112 (86.2)	1 (0.8)	1 (0.8)	15 (11.5)	1 (0.8)	0 (0.0)	130 (100.0)
Total n (%)	227 (87.3)	2 (0.8)	2 (0.8)	26 (10.0)	3 (1.2)	0 (0.0)	260 (100.0)

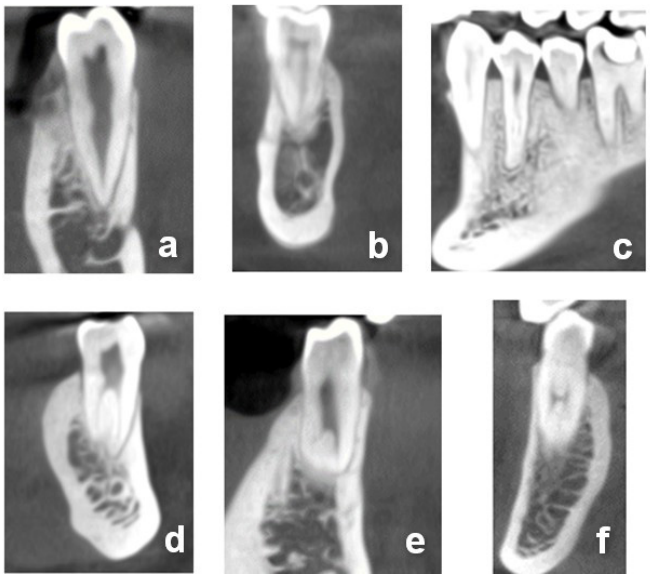

Figure 1: Examples of different sections of CBCT images showing Vertucci's root canal configuration in mandibular premolars (a. Type I, b. Type II, c. Type III, d. Type IV e. Type V and Type VI)

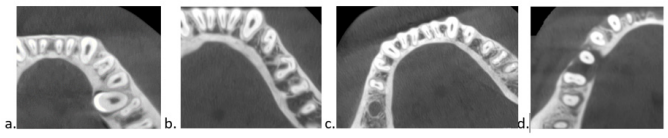

Figure 2: Examples of axial CBCT showing C-shaped canal types in mandibular premolars [a. C1 type (left mandibular first premolar), b. C2 type (left mandibular second premolar and C3 type (left mandibular first premolar), c. C3 type (right mandibular first premolar) and d. C4 type (right mandibular first premolar)]

DISCUSSION

Endodontic treatment aims to clean, shape, and fill the root canal system three dimensionally. The inability of the clinician to detect, carry out proper biomechanical preparation, and seal one or more of the root canals contributes to treatment failure.[13]

Mandibular premolars present significant challenges in root canal treatment due to their variable root canal morphology, crucial for endodontic success.[4] Comprehensive knowledge of this morphology and an accurate diagnosis are essential for successful treatment.[14,15]

Various studies (ex vivo and in vivo) have examined root canal morphology using different techniques. The most common method for evaluating root canal configuration, diagnosis, and treatment planning is intraoral periapical radiography. However, this two-dimensional technique often lacks sufficient detail and is prone to superimposition and distortion. Cone Beam Computed Tomography offers a superior alternative, providing three-dimensional high-resolution images that accurately determine root canal morphology.[6]

The American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) recommend using CBCT in endodontics to detect abnormalities or variations when complex morphology is suspected from conventional radiographs.[16]

In Nepal, only a few studies have investigated the root canal anatomy of mandibular premolars using CBCT. To date, no published study has examined the root canal morphology of mandibular premolars in the Chitwan district population. Therefore, this study utilized a database from a tertiary care center of Chitwan district to analyze anatomical variations and their characteristics. This study's report identifies significant variations in the root canal anatomy of mandibular premolars in a subpopulation of Nepal.

In this study, mandibular first premolars demonstrated significant variation in the root canal morphologies compared to second premolar. The prevalence of single-rooted premolars was higher, with 85.4% in first premolars and 97.7% in second premolars, compared to double roots, which were found in 14.6% of first premolars and 2.3% of second premolars. Similar

findings have been reported in other literature as well; however, their results were not statistically significant.[6,9,17,18]In contrast to other studies [9-10, 19-22], this research found a greater incidence of two roots in mandibular first premolars. This variation might be attributed to the differences in racial backgrounds, study design and smaller sample size of this study. This study did not consider the prevalence of three roots because of its rare occurrence which was found to be 0.0% in a study conducted by Al-Zubaidi et al.[10]

This study also found a significant variation in the number of root canals between the two premolars. The mandibular first premolar exhibited a single canal in 78.5% of cases, consistent with findings from other studies.[5,23-24] Additionally, 21.5% of samples displayed two canals, aligning with results reported in other studies. [23-25]

This study identified significant gender differences in root and root canal numbers, with females exhibiting a higher prevalence of single-rooted and single-canal premolars compared to males, contrasting with existing research.[26-28] This could be attributed to anatomical variations between genders and the small sample size of the current study. The study found that 97.2% of female mandibular premolars (47.2% in first premolar and 50.0% in second premolar) had one root, compared to 87.5% (39.5% in first premolar and 48% in second premolar) in males, and 93.5% of female mandibular premolars (45.4% in first premolar and 48.1% in second premolar) had one root canal, compared to 81.6% (34.9% in first premolar and 46.7% in second premolar) in males. These findings suggest a possible influence of genetic and developmental factors on root and canal morphology. However, no significant variation was observed in root and canal numbers based on tooth position, consistent with the findings of other studies.[29,30]

This study discovered a significant difference in the root canal configuration types among mandibular premolars. The analysis based on Vertucci's classification showed Type I configurations as the most common in both first (78.5%) and second (94.6%) mandibular premolars which was similar to the findings of another research.[9,31] In this study, the mandibular first premolar most commonly exhibited a type V configuration as the second most frequent (15.4%), similar to findings of another studies,[6,18,28] followed by type III (4.6%). In the mandibular second premolar, type V was also the second most common (2.3%) consistent with the findings of previous studies,[18,28] followed by type IV (1.5%). A study on Iranian subpopulation showed type III configuration (11%) as the second most prevalent canal configuration which was in contrast with the findings of this study.[26] These variations can be attributed to differences in ethnicity, study methods, sample sizes, gender, and geographic distribution, which can all affect root canal configuration. Type VII and VIII configurations were not identified in this study, consistent with findings from other similar study.[26] However, a few studies have reported the prevalence of type VII canal configuration.[9,32]

Understanding the canal configurations is crucial for predicting the course of root canal treatment. In Vertucci's classification, type I and IV are relatively simple with distinct orifices and apices, while types II, III, V, VI, VII, and VIII are more complex and challenging to treat, often leading to higher failure rates.[9,23] Clinicians should be aware of these complexities and possess the skills necessary to achieve successful outcomes.

The current study observed that bifurcations in mandibular premolar roots commonly occur in the middle and apical thirds, aligning with findings in other literature.[5,9,18] This suggests a high probability of canal variation in these areas. During root canal treatment, the number of canals or the canal configuration is more relevant than the number of roots. Therefore, while classifying the canal configuration, this study considered bifurcations in the middle or apical third as a single root, whereas each root was classified individually if there were two distinct roots.

C-shaped canal is a unique and complex root canal configuration primarily found in mandibular second molars; however various studies[5,18,32] showed the prevalence of C-shaped canal in mandibular premolars too. It is characterized by a continuous C-shaped groove or isthmus that connects multiple canals within the root. This configuration results from the failure of Hertwig's epithelial root sheath to fuse on the buccal or lingual side. C-shaped canals present significant challenges in endodontic treatment due to their complex and variable anatomy, requiring advanced diagnostic tools and specialized techniques for thorough cleaning, shaping, and obturation. Accurate identification and management are crucial to prevent treatment failures and ensure successful outcomes.[33]

In the present study, a C-shaped configuration was identified in 20.8% of first premolars, consistent with previous findings.[18,32] However, it was found in 4.6% of second premolars, which is higher than reported in other studies.[32,34] Conversely, Brea et al. reported a higher prevalence of C-shaped canals (28.94% in first premolars and 7.14% in second premolars) compared to our findings. This variation could stem from differences in racial demographics and sample sizes. This study identified the C3 type C-shaped canal configuration, according to Fan's criteria,[12] as the most prevalent (16.9% in first premolars and 3.1% in second premolars), consistent with earlier research.[5,35]

This study has several limitations. Firstly, the samples were collected from a single tertiary center, limiting the generalizability of the findings to the entire Nepalese population. Therefore, we recommend conducting similar studies across multiple centers with larger sample sizes. Additionally, future studies should consider investigating the prevalence of fused teeth in mandibular premolars and the level of bifurcation in roots, which were not addressed in this study. Moreover, employing advanced methods such as micro-CT for evaluating root canal morphology in mandibular premolars can help overcome the limitations of the current study.

CONCLUSION

This study examined the root and canal morphology of mandibular premolars in a Nepalese subpopulation using CBCT,

revealing significant variations. Most premolars had a single root and canal, with notable differences between tooth types and genders but not tooth positions. Mandibular first premolars showed more variation in root canal anatomy compared to second premolars. Vertucci's Type I configuration, followed by Type V, was more prevalent in both premolars, especially in the first premolars. C-shaped canals were also more common in mandibular first premolars. Clinicians should be aware of these anatomical variations and evaluate each case carefully using clinical and radiographic assessments to improve the outcome of root canal treatment. The findings of this study highlight the importance of CBCT in accurate diagnosis and treatment planning for endodontics.

CONFLICT OF INTEREST: None

FINANCIAL DISCLOSURE: None

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