Root Canal Morphology of Mandibular Premolars in a Nepalese Population: A Cone-Beam Computed Tomographic Study

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ABSTRACT

Background

Mandibular premolars are the most challenging teeth to treat endodontically because of their variability in morphological and internal anatomical features. The knowledge of root canal morphology and its variation is crucial for the endodontic success.

Objective

To evaluate the root and canal morphology of mandibular premolars in a Nepalese population by using Cone Beam Computed Tomography.

Method

A total of 1924 mandibular first and second premolar teeth from 481 patients were evaluated. The number of roots and canal configuration were identified and categorized according to Vertucci's classification. An association between number of roots and root canal configuration with gender and ethnic group was evaluated. Also, the bilateral symmetrical occurrence of root and canal configuration were investigated.

Result

Majority of mandibular first premolars (86.7%) and second premolars (98.7%) were single rooted with type I root canal configuration followed by type V (8.6%) in first premolars and type III (0.6%) in second premolars while 3.8% of first premolars and 0.6% of second premolars were two rooted. In first premolars, there was an association between gender with number of roots (p-value = 0.007) and root canal configuration (p-value < 0.001). High degree of bilateral symmetry was seen in both first (85.4%) and second premolars (96.9%) in terms of the number of roots and canal configuration.

Conclusion

Most of the mandibular premolars were single rooted with Type I canal configuration. However, clinicians should be aware of the variations that may be encountered during routine endodontics which may influence the success behind treatment.

KEY WORDS

Cone-beam computed tomography, Mandibular premolars, Root canal configuration

INTRODUCTION

Root canal treatment is a complex procedure and an error in a single step can make treatment failure. The knowledge of root canal morphology and its variation is crucial for the endodontic success.[1-6] Difficulty in finding a canal or missing a canal altogether results in flare-ups and poor outcome.[1,2,5-7]

Mandibular premolars are known to have frequent root canal variations with multiple roots and canals, C-shaped canal, bifurcations and trifurcations without consistency in the level of bifurcation and trifurcation.[1,2,5,6,8] These teeth are said to be the most challenging teeth with high failure rate of 11.45%.[9] Moreover, the lingual inclination of the crown makes it difficult to locate canals, mostly the lingual one.[2,10] This variation is said to be dependent on factors like age, gender, ethnicity, genetics and study design. It might vary within the same person as well.[1-3,5,6,11-15]

Various in-vitro and in-vivo methods are used to study these morphologies including teeth-sectioning, radiography, clearing, teeth de-calcification and computed tomography.[1,3,8,10] Traditional methods like sectioning, clearing, and de-calcification often damage the tooth and radiographic images represent only the 2-dimensional image of a complex structure. Cone-beam computed tomography (CBCT) on the other hand can represent the complex anatomies in 3-dimensional format with the possibility of viewing small sections in detail without superimposition.[1,2] It has higher accuracy and have lower radiation exposure.[3,6,10]

Considering the significance of knowledge about root canal morphology in mandibular premolars, the aim of this study was to evaluate root and root canal morphology, their bilateral symmetry and variations with gender and ethnicity using CBCT.

METHODS

This retrospective, cross-sectional quantitative study was done in 481 patients (246 female and 235 male). A total of 1924 CBCT images of mandibular premolars of patients aged between 15 to 67 years taken as a part of examination, diagnosis and treatment planning from June 2022 to May 2023 were retrieved from the database of Department of Oral Medicine and Radiology, Dhulikhel Hospital, Kathmandu University Hospital. Ethical approval for this study was obtained from the Institutional Review Committee of Kathmandu University School of Medical Sciences. The samples were selected based on the following criteria.

1. CBCT images of patients who had all permanent mandibular premolar teeth with complete root formation.

2. Bilateral presence of mandibular premolars.

3. Absence of root canal treatment.

4. Absence of calcifications, root resorption or periapical lesions.

Sample size calculation

Sample size = $Z_{1-\alpha/2}^2\ p\ (1-p)/d^2$

Here,

$Z_{1-\alpha/2}$ = Is standard normal variate, at 5% type 1 error ($P < 0.05$) it is 1.96

p = Expected prevalence based on previous studies is 28%.[15]

d = Absolute error or precision = 5%

Thus, the minimum sample size was calculated to be 310.

All the CBCT images were acquired using Rainbow™ CT device (Dentium, South Korea) with maximum KVp of 120 and 150 mA. The X-ray specifications for the images were constant with peak voltage 100KVp and tube current 12 mA, field of view 16 cm *18 cm, Voxel size 300 µm, and scan time 20 seconds. The 3D axial cross-sections (coronal, middle, and apical-third root section) of roots and root canals were prepared with the Rainbow™ image viewer software program, version 1.0.0.0 (Dentium, South Korea) for analyzing the images. The CBCT images were evaluated on a 34-inch LED screen in a dark room.

The images were evaluated by two endodontists together twice with an interval of 2 weeks between evaluations. The examiners evaluated a maximum of 15 images per day not to impair the result of the analysis. A professional radiologist was consulted to perform a third decisive evaluation and reach a final consensus when there were disagreements. All the images from 1924 mandibular premolar teeth were evaluated and following information were recorded:

1. Ethnicity, age and gender of subjects

2. Tooth position

3. The number of root and canal for each tooth

4. The root canal configuration for each tooth; according to following criteria of Vertucci.[16]

Type I: a single canal is observed, from the pulp chamber to the apex.

Type II: two separate canals leave the pulp chamber, but unite near the apex forming a single canal.

Type III: one canal leaves the pulp chamber, but divides into two in the middle of the root, and unite again forming a single canal.

Type IV: two separate and distinct canals are present from the pulp chamber to the apex.

Type V: a single canal leaves the pulp chamber, but divides into two canals.

Type VI: two separate canals leave the pulp chamber, unite in the middle third and then divide again into two canals with two separate foramina.

Type VII: one canal leaves the pulp chamber, divides into two canals, become one canal again and divides into two separate canals with two distinct apical foramina.

Type VIII: three separate and distinct canals begin from the pulp chamber to the root apex.

All other canal configurations, different from above mentioned types were collectively categorized as unusual.

The data were entered in excel and analyzed by using SPSS-22 IBM, Inc., USA statistical software. The categorical data were expressed in the frequency (%). The comparisons for categorical data were done by chi-square test, p-value < 0.05 was considered as statistically significant.

RESULTS

A total of 1924 mandibular premolar teeth obtained from CBCT images of 481 patients comprising 246 (51.1%) females and 235 (48.9%) males were evaluated and classified based on root number and canal configuration. The age of participants ranged from 15-67 years with the mean age of 30.20±11.81 years.

Table 1 depicts, the majority of mandibular premolars were single rooted; 925 (96.2%) in first premolars and 956 (99.4%) in second premolars. However, two rooted premolars were present in 37 (3.8%) patients in first premolars and it was rarely present in second premolar 6 (0.6%). Two-rooted mandibular first premolars were found in 26 (5.5%) male patient which was higher than that of female 11 (2.2%). There was statistically significant difference between gender and number of roots (p=0.0078) in mandibular first premolars.

Table 1. Frequency and percentage of number of roots in mandibular premolars (N=962)

Gender	Mandibular First Premolar		p-value	Mandibular Second Premolar		p-value
	One root n(%)	Two roots n (%)		One root n(%)	Two roots n (%)	
Female (n = 492)	481 (97.8)	11 (2.2)	0.0078	490 (99.6)	2 (0.4)	0.381
Male (n = 470)	444 (94.5)	26 (5.5)		466 (99.1)	4 (0.9)	
Total = 962	925 (96.2)	37 (3.8)		956 (99.4)	6 (0.6)	

The frequency and percentage of canal configuration in mandibular first and second premolar teeth are shown in table 2 and 3 respectively. Type I was the most prevalent canal configuration in both mandibular first and second premolar teeth. In mandibular first premolars, 835 (86.7%) had type I, 83 (8.6%) had type V, 34 (3.5%) had type III, 4 (0.4%) had type VII, 2 (0.2%) had type VIII and 4 (0.4%) had unusual canal morphology. The occurrence of all variable canal configurations was higher in male except for Type VIII which was seen only in female. In mandibular second premolars, 949 (98.7%) had type I, 6 (0.6%) had type III, 5 (0.5%) had type V, 1 (0.1%) had type II and 1 (0.1%) had unusual canal morphology (Fig. 1). Chi-Square test demonstrated significant difference between gender and root canal configuration (P < 0.001) in mandibular first premolars (Table 4).

Table 2. Frequency and percentage of canal configuration in mandibular first premolars (N=962)

	Canal Configuration						
Gender	Type I	Type III	Type V	Type VII	Type VIII	Unusual	Total
Female n(%)	440 (89.4)	14 (2.8)	34 (6.9)	2 (0.4)	2 (0.4)	0 (0.0)	492 (100)
Male n(%)	395 (84)	20 (4.3)	49 (10.4)	2 (0.4)	0 (0.0)	4 (0.9)	470 (100)
Total n(%)	835 (86.7)	34 (3.5)	83 (8.6)	4 (0.4)	2 (0.2)	4 (0.4)	962 (100)

Table 3. Frequency and percentage of canal configuration in mandibular second premolars (N=962)

	Canal Configuration					
Gender	Type I	Type II	Type III	Type V	Unusual	Total
Female n(%)	487 (99)	1 (0.2)	2 (0.4)	2 (0.4)	0 (0.0)	492 (100)
Male n(%)	462 (98.3)	0 (0.0)	4 (0.9)	3 (0.6)	1 (0.2)	470 (100)
Total n(%)	949 (98.7)	1 (0.1)	6 (0.6)	5 (0.5)	1 (0.1)	962 (100)

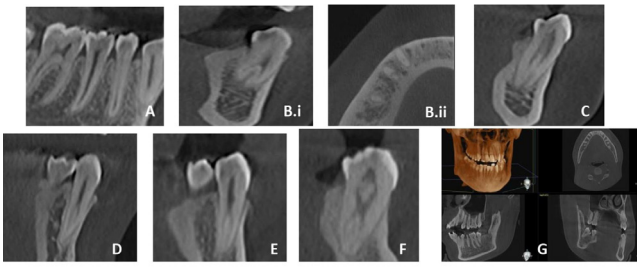

Figure 1. (A-G). Number of roots and root canal configuration types. A. One root with Type I. B.i. and B.ii. Sagittal section and axial section of two roots, each with type I. C. Type II. D. Type III. E. Type V. F. Type VII. G. Unsual type in axial, coronal and sagittal sections.

Table 4. Gender wise variations in mandibular first and second premolars (N=962)

Gender	Mandibular First Premolar		p-value	Mandibular Second Premolar		p-value
	Normal n (%)	Variation n (%)		Normal n (%)	Variation n (%)	
Female (n=492)	429 (87.2)	63 (12.8)	<0.001	485 (98.6)	7 (1.4)	0.208
Male (n= 470)	369 (78.5)	101 (21.5)		458 (97.4)	12 (2.6)	

Regarding bilateral symmetry in mandibular first premolars, 411 (85.4%) of teeth showed a symmetrical number of roots and canal configuration, 45 (9.4%) showed a symmetrical number of roots but different canal configuration and

3 (0.6%) showed a symmetrical canal configuration but different number of roots. However, 22 (4.6%) did not show any type of symmetry. Likewise, in mandibular second premolars, 466 (96.9%) of teeth showed a symmetrical number of roots and canal configuration, 11 (2.3%) showed a symmetrical number of roots but different canal configuration and 4 (0.8%) showed a symmetrical canal configuration but different number of roots.

Table 5 illustrates the frequency and percentage of mandibular premolars with normal and variable root and root canal configuration based on the ethnicity. Variation in mandibular first premolars was present in 91 (17.6%) Aryans and 73 (16.4%) Mongoloids. In mandibular second premolar, 11 (2.1%) Aryans and 8 (1.8%) Mongoloids showed variation. No statistically significant differences were found while comparing Aryans and Mongoloids in both mandibular premolars.

Table 5. Ethnical variation in mandibular first and second premolars (N=962)

Ethnicity	Mandibular First Premolar		p-value	Mandibular Second Premolar		p-value
	Normal n (%)	Variation n (%)		Normal n (%)	Variation n (%)	
Aryans (n = 518)	427 (82.4)	91 (17.6)	0.643	507 (97.9)	11 (2.1)	0.721
Mongoloids (n = 444)	371 (83.6)	73 (16.4)		436 (98.2)	8 (1.8)	

DISCUSSION

Root canal treatment is one of the common treatment procedures done in dentistry and its successful outcome is expected if all the canals are located, negotiated to full length, debrided, shaped, disinfected and three dimensionally obturated. Untreated canals, incomplete disinfection, and inadequate obturation might lead to failure of root canal treatment.[17] Hence, proper knowledge and radiographic evaluation of root canal morphology is of utmost importance for successful outcome of the treatment.

In this study, 96.2% of mandibular first premolars were single rooted and only 3.8% were two rooted. The findings are in accordance with the study done in Nepalese population by Shrestha et al., Alfawaz et al. in Saudi population and Jain et al. in Indian Gujrati population.[3,15,18] The study done by Kazemipoor et al. in Iran and Burklein et al. in Germany showed higher frequency for two roots in mandibular first premolars; 15.69% and 9.34%, respectively.[8,19] This variation may be due to racial differences. However, the frequency is little higher than one another study done by Bantawa et al. in Nepalese population.[20] This might be due to the difference in sample size and study site. Three rooted mandibular first premolar was not present in our study which is comparable to other studies.[15,18,20,21] In a literature review, the presence of three and four rooted mandibular first premolar is only 0.2% and 0.1% respectively.[22]

In this study, majority of mandibular second premolar were single rooted and two-rooted was found only in 0.6% cases and three-rooted second premolar was not found which is comparable to study done in Nepalese population by Bantawa et al.[20] However, systematic review done by Wolf et al. revealed two and three rooted mandibular premolars in 0.1 to 8% and 0.1 to 3.5% respectively.[23]

For many years, the classification described by Vertucci has been the most commonly used system to categorise root canal configurations. Vertucci type I configuration is the most common finding of all types with variable percentage in different group of population. In the current study, type I canal configuration was found in 86.7% and 98.7% of mandibular first and second premolars respectively, which was similar to the study done in Nepalese population by Bantawa et al. (83.88% and 96.65% of mandibular first and second premolars respectively) and in South Indian population by Shetty et al. (83.91% and 93.48% in mandibular first and second premolars respectively).[20,24] However, the findings were higher than the study done in Iranian population by Hajihassani et al. (62.2% and 78% in mandibular first and second premolar respectively).[25] In the current study, type V (8.6%) configuration was the second most common configuration followed by type III (3.5%) configuration in first premolar whereas in second premolar both type III (0.6%) and type V (0.5%) were almost equally prevalent. Similar results to that of our study were reported by Bantawa et al. with Type V (9.89%) being the second most common followed by type III (4.03%) in first premolar and type III (1.86%) and type V (1.49%) for second premolar.[20] Also, Shrestha et al. applying different methodology, i.e. the clearing technique reported Type V canal configuration as second most common in first premolar but with higher frequency (18.6%).[15] In contrast to our result, study conducted in Saudi population by Alfawaz et al. found type II as second commonest configuration in both mandibular first (3.6%) and second premolars (4.4%).[3] One another in-vitro study conducted in South Asian Indian by Singh et al. had also shown type II as second commonest configuration in both mandibular first (6%) and second premolars (30%).[26] Some in-vitro studies conducted in USA by Baisden et al. and in India by Parekh et al. had shown type IV as the second most common canal configuration.[27,28] Interestingly, in this study type II configuration was found in only 0.1% of second premolar and type IV was not found in any of the premolars. These variations can be attributed by the difference in racial factor, methods of study and sample size.

Type VII and VIII being a rare canal configuration, our study found four mandibular first premolar with type VII configuration and two with Type VIII configuration. Unusual configuration was observed in 0.4% of mandibular

first premolars and 0.1% of second premolar. In literature, uncommon configurations have been reported to vary from 0.4 - 3.7%.[15]

The results of the current study showed that both mandibular first and second premolars showed variations in number of roots as well as in root canal configurations, mostly the first premolar. Type II, III, V, VII and VIII are difficult to appreciate and treat than type I and IV because of their complexity. Hence, an endodontist and general dentist should be aware of those complexities and skilled enough to identify and treat properly for successful outcome.

In the current study, there was an association between gender and number of roots (P = 0.0078), and gender and root canal configuration (P < 0.001) in mandibular first premolars which is in an agreement with the study done by Ok et al., Burklein et al. and Alfawaz et al.[1,3,8] There was neither association between gender and number of roots nor gender and root canal configuration (P > 0.05) in the second premolars which is in accordance with study done by Alfawaz et al.[3] Bantawa et al. found no gender-wise differences in the number of roots in both premolars but regarding canal configuration, male showed more variation than female in first premolars while female showed more variation than male in second premolars.[20]

Johnsen et al. conducted a study to assess the symmetry of contralateral premolars using micro-Computed Tomography and concluded that contralateral premolars can be viewed as a mirror image of each other on the basis of geometrical analysis.[29] The study done by Xu et al. using CBCT found only few matching contralateral premolars.[30] In this study, however, a high degree of symmetry was seen in both mandibular first and second premolars in terms of the number of roots and canal configuration (85.4% and 96.9% respectively) which is similar to that of study done by Alfawazet al. which reported 93.8% and 97.8% symmetry in first and second premolar respectively.[3]

Nepal is culturally diverse and multi-ethnic nation, with many castes under two main races: Aryans and Mongoloids. In this study, variation in mandibular first premolars was found in 17.6% of Aryans and 16.4% of Mongoloids. In mandibular second premolar, 2.1% Aryans and 1.8% Mongoloids showed variation. A review of the literature done by Cleghorn et al. shows a higher incidence of bifurcated root canals in African Americans (16-33%), Turkish populations (36-40%), Kuwaiti populations (40%), and Chinese populations (22-36%) as compared to Caucasians (6-14%).[22]

Study done by Bantawa et al. reported the presence of C-shaped canal in 1.46% of population.[20] Few C-shaped canals were found in this study as well which were categorized under unusual morphology. C-shaped configuration is more prevalent in Mongoloid tribe thus more study is recommended in this tribe of Nepalese population.

This study has some limitations. The study was conducted in the single tertiary care centre of Nepal located in Bagmati Province; thus, the results of this study cannot be generalized to overall population. Also, the influence of age group on variation of canal morphology has not been taken into consideration in this study.

CONCLUSION

Within the limitation of this study, the majority of mandibular first and second premolar teeth exhibited a single root with type I canal configuration followed by type V in mandibular first premolar and type III in mandibular second premolar. Further multicentric studies with a larger sample size are still recommended. Clinicians should be aware of the possible anatomical variations and their complexities to achieve successful treatment outcomes.

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