

Assessment of Root Morphology and Canal Configuration of Human Mature Permanent Maxillary Canines using Cone Beam Computed Tomography: An Institutional Retrospective Study

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Abstract

Background: Thorough knowledge of root morphology which varies in different population is very important for successful endodontic management. The objective of the present retrospective study is to observe the root morphology of permanent mature maxillary canine in Eastern Indian subpopulation. **Materials and Methods:** In this study, 212 permanent maxillary canines of both male and female patients (14–50 years age group) collected from a tertiary health care Centre in Kolkata, West Bengal were processed through iRYS NNT viewer software and evaluated for the root morphology, canal configuration with its variation, effect of gender on these variables. **Results:** The statistical analysis revealed that 99.1% of maxillary canines have a single root with a single canal. Root diameter and dentine thickness were higher in males than females. Labial surfaces showed the highest dentin thickness while mesial and distal surfaces exhibited the least. The most common shape of canal cross section reported oval at CEJ, flat shape at middle 3rd, oval at apical 3rd. Majority of root apex deviated distally (55.2%) with laterally positioned apical foramen (59.4%). Accessory canals were reported in 40% of cases mostly at the apical third. **Conclusion:** Root morphology of permanent maxillary canines varies widely and endodontist should be aware of it due to the success of root canal treatment.

Keywords: Canal configuration, Cone beam computed tomography, Permanent maxillary canine, Root morphology

INTRODUCTION

Canines act as a transition point from anterior teeth to posterior teeth. They have a unique role in esthetics and function. As canines maintain normal facial expression at corner of mouth and defines the character of smile, they are considered as cornerstone of dental arches.^[1] Functionally, the position of canines guides the entire dentition into intercusp relation.^[2] Hence, considering the esthetic and functional significance, the preservation of fractured, traumatized, or carious permanent maxillary canines by endodontic treatment and proper restoration is very important.

The success of endodontic treatment relies on proper disinfection and complete sealing of the entire root canal for which dentist should know the internal morphology of the root canal system with its variation.^[3,4] Various studies have been shown that the root morphology of a particular tooth varies with races, population, and gender.^[5,6] Hence, the assessment of these variations in the different ethnic group of population is very important for long-term prognosis after endodontic treatment. It prevents the chance of missed canals which if untreated leads to failure of root canal treatment due

to remaining microbes and necrosed tissues. Evaluation of the average root diameter and dentine thickness of a tooth in different population may avoid the chance of root fracture due to excessive preparation of root canal and improper post placement. With the advancement of technology, 3-D imaging tool, cone beam computed tomography (CBCT) has become very efficient for the evaluation of root morphology. It uses cone-shaped beam of radiation and collects data in a single 360° rotation. *In vitro* study by Neelakantan *et al.* stated the accuracy of CBCT similar to the modified canal staining and clearing technique which is considered as gold standard for exploring root canal anatomy.^[7]

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Though canines are usually considered as a single rooted tooth with 1 canal, recently many variations regarding the root morphology of human permanent mature maxillary canine have been reported worldwide in different populations study.^[8] To the best of our knowledge, limited researches are there on canine root morphology among Eastern Indian subpopulation.

Hence, the aim of our study was the CBCT assessment of the root morphology with canal configuration of maxillary canines in the Eastern Indian subpopulation which will contribute to the structural knowledge prerequisite for successful endodontic management.

MATERIALS AND METHODS

It was an institutional retrospective study based on the data collected from a tertiary health care center, Kolkata, West Bengal. In this study, CBCT scans of 212 human permanent maxillary canines of both male and female patients (aged between 14 and 50 years) were processed through iRYS NNT viewer software.

Institutional Ethics Committee clearance (Reg.no.-EC/NEW/INST/2023/3191) was obtained before conducting this study.

Only those CBCT scans presenting distinct visual representations of bilateral permanent maxillary canines with fully developed roots were included in this study. Any unclear or distorted CBCT images were avoided. Candidates with previously treated canines, presence of crown or post, carious canine, periarticular pathology, and canine open apex were not considered for this study. In addition, CBCT scans with missing of one side canine were excluded from the study.

Ten morphological features of permanent maxillary canines were recorded from the above-mentioned CBCT scans (Figure 1).

1. Configuration of root canal based on VERTUCCI classification (3)
2. Root length (in coronal section from CEJ to radiographic apex)
3. Root diameter (Both labiolingual and mesiodistal diameters were measured at the level of CEJ, middle 3rd [5 mm beyond CEJ] and apical 3rd [10 mm apical to CEJ])
4. Dentinal thickness of all 4 surfaces (labial, lingual, mesial, distal) measured at CEJ level, middle 3rd (5 mm apical to CEJ) and apical 3rd (10 mm apical to CEJ)
5. Shape of canal cross-section at the level of CEJ, middle third (5 mm apical to CEJ), and apical 3rd (10 mm apical to CEJ)
6. Number of accessory canal if any
7. Direction of root apex curvature
8. Position of the apical foramina which was classified as central (at the tip of root apex) or lateral (off-centered)
9. Comparison between right and left side
10. Effect of gender on each variable.

Statistical analysis

Microsoft Excel 2021 was used to tabulate collected data on a spreadsheet for statistical analysis using IBM Statistical Package for the Social Sciences Statistics for Windows, Version 27.0. (Armonk, NY: IBM Corp). The categorical variables were analyzed by the Chi-square test. Intra-group analysis was carried out using Paired *t*-test repeated measures analysis of variance with *post hoc* Bonferroni's test for pairwise comparisons-inter-group comparisons with the unpaired *t*-test. Pearson's correlation coefficient was utilized to find the correlation between age and the quantitative variables. ≤ 0.05 was considered for *P* value as the level of significance.

RESULTS

Fifty-two males and 58 females were included in the study (mean age of 25.7 ± 7.77 years ranging from 14 to 49 years).

Root length, root diameter, and dentin thickness at various locations

Comparisons between the right and left sides

For maxillary canines, the average root length was greater significantly on the right side (15.8 ± 1.48 mm) compared to the left (15.6 ± 1.35 mm, $P = 0.005$). Similarly, root diameter at CEJ was significantly larger on the right side (7.33 ± 0.863 mm) compared to the left (7.25 ± 0.756 mm, $P = 0.03$). However, no significant differences were observed for root diameters at the middle and apical 3rds ($P = 0.96$ and $P = 0.8$, respectively).

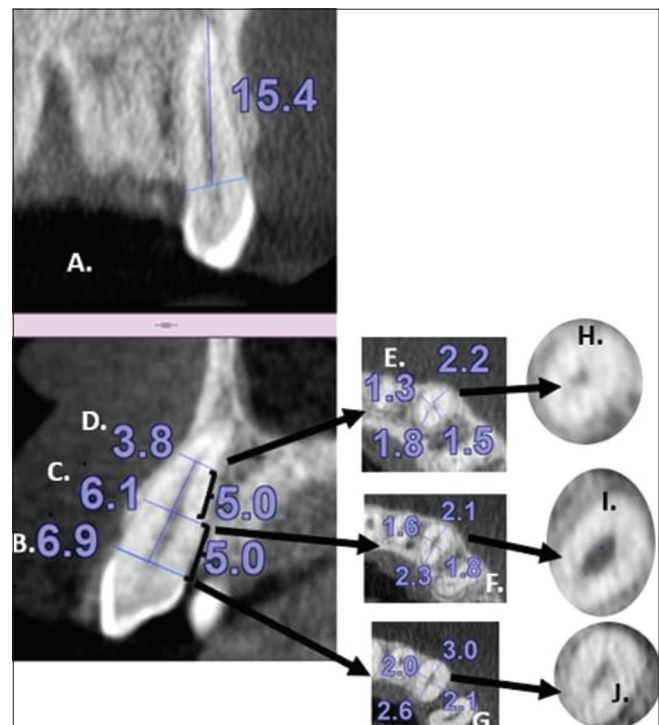


Figure 1: (A) Root length measurement (B) Root diameter at CEJ (C) Root diameter at 5 mm apical to CEJ (D) Root diameter 10 mm apical to CEJ (E-G) Dentine thickness at apical 3rd, middle 3rd, CEJ respectively (H-J) Shape of root canal cross-section-Oval, Long oval, Flattened, respectively

For dentin thickness, the apical 3rd (Mesial Side) was significantly greater on the right side (1.32 ± 0.316 mm) compared to the left (1.28 ± 0.265 mm, $P = 0.03$). Similarly, the lingual side of the apical 3rd showed a significant difference, with higher values on the right (1.78 ± 0.333 mm) than the left (1.72 ± 0.337 mm, $P = 0.02$). Other regions, including the labial side at the apical 3rd and all CEJ and middle 3rd measurements, showed no statistically significant differences between sides ($P > 0.05$).

Comparisons between gender

The root length was comparable between males (15.7 ± 1.47 mm) and females (15.7 ± 1.37 mm, $P = 0.95$). However, males had significantly larger root diameter at the CEJ (7.48 ± 0.771 mm) than females (7.12 ± 0.812 mm, $P = 0.0012$), while the root diameter at the middle 3rd (6.23 ± 0.782 mm vs. 6.1 ± 0.877 mm, $P = 0.25$) and the root diameter at the apical 3rd (4.2 ± 0.8 mm vs. 4.22 ± 0.925 mm, $P = 0.85$) were similar between genders.

For dentin thickness at the CEJ, males demonstrated significantly greater thickness than females on both the mesial side (2.31 ± 0.349 mm vs. 2.08 ± 0.282 mm, $P < 0.0001$) and distal side (2.43 ± 0.311 mm vs. 2.18 ± 0.334 mm, $P < 0.0001$). No significant differences were observed on labial ($P = 0.06$) or lingual Side ($P = 0.22$).

At the middle 3rd, males exhibited significantly higher dentin thickness on the mesial side (1.81 ± 0.294 mm vs. 1.73 ± 0.303 mm, $P = 0.05$) and the lingual side (2.52 ± 0.391 mm vs. 2.38 ± 0.375 mm, $P = 0.006$). No differences were observed on the distal side ($P = 0.1$) or labial side ($P = 0.28$).

At the apical 3rd, males had significantly greater dentin thickness on the distal side (1.28 ± 0.274 mm vs. 1.2 ± 0.248 mm, $P = 0.04$), labial side (1.8 ± 0.341 mm vs. 1.68 ± 0.337 mm, $P = 0.01$), and lingual side (1.83 ± 0.309 mm vs. 1.67 ± 0.342 mm, $P = 0.0006$). The mesial side showed no significant difference ($P = 0.16$).

In summary, males consistently exhibited larger root dimensions and dentin thickness at various locations compared to females for maxillary canines.

Difference of the dentin thickness between the sides: (Figure 2)

The dentin thickness for maxillary canines revealed significant differences ($P < 0.05$) between the sides at CEJ, middle third and apical third levels for the left, right, and total datasets.

At the CEJ, the labial side was thicker significantly than the mesial, distal, and lingual sides ($P < 0.05$) across all datasets. The lingual side was thinner compared to the labial side ($P < 0.05$) in all cases, while the mesial and distal sides showed no significant difference from each other.

For the middle third, the labial side exhibited significantly greater dentin thickness than the mesial and distal sides ($P < 0.05$). Lingual side was significantly thicker than the mesial and distal sides but thinner than the labial side ($P < 0.05$) across the left, right, and total datasets.

At the apical third, the labial and lingual sides were thicker significantly than the mesial and distal sides ($P < 0.05$). The labial side was marginally thicker than the lingual side, though not statistically significant in all datasets, while the mesial and distal sides showed similar thickness.

These findings emphasize that the labial side consistently displayed the highest dentin thickness across all cross-sectional levels, while the mesial and distal sides remained the thinnest.

Canal configuration (Table 1 and Figure 3)

Vertucci Type I canal configuration was significantly predominant (99.1%). Study showed bilateral symmetry in 99.1% of cases.

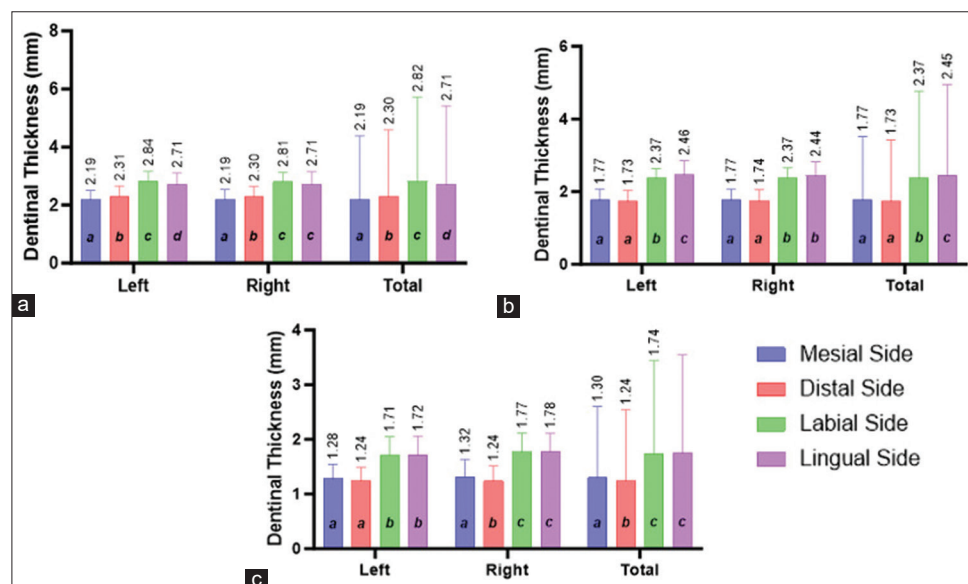


Figure 2: Bar Graph showing difference between the dentin thickness between the sides of maxillary canines- (a) CEJ level (b) Middle 3rd (5 mm apical to CEJ), (c) Apical 3rd (10 mm apical to CEJ) (Note: Different subscript letter indicate statistically significant differences between the sides)

Cross-sectional shape of canals at various levels

At the CEJ level, the most common canal shape was oval, observed in 55 (51.9%) left and 54 (50.9%) right, totaling 109 (51.4%) followed by long shape (45.3%). The flat shape was least common, found in a total of 7 (3.3%).

In the middle third, the flat shape was predominant, seen in 50 (47.2%) left and 51 (48.1%) right canines, contributing to 101 (47.6%) overall. The long shape was identified in 30 (28.3%) left and 26 (24.5%) right canines, totaling 56 (26.4%). The oval shape was present in 19 (17.9%) left and 23 (21.7%) right canines, making up 42 (19.8%), while the round shape was the least frequent, found in 7 (6.6%) left and 6 (5.7%) right canines, totaling 13 (6.1%).

At the apical third, the oval shape dominated, observed in 61 (57.5%) left and 62 (58.5%) right canines, totaling 123 (58.0%). The round shape was the next most common, noted in 68 (32.1%). The flat shape was identified in 9 cases (4.2%), while the long shape was the least observed contributing to 12 (5.7%).

Presence of accessory canals

Accessory canals were absent in 86 (81.1%) left and 86 (81.1%) right canines, accounting for a total of 172 (81.1%). Accessory canals were identified in 20 (18.9%) on both left and right, totaling 40 (18.9%), primarily at middle and apical 3rd. 88% of accessory canals located at apical third while 10% were found at the middle third. At the CEJ level, only one accessory canal was found, observed exclusively on the right side.

Apical curvature and location of apical foramen

Distal curvature was significantly higher ($P < 0.01$), observed in 57.5% of the left and 52.8% of the right sides, contributing

to 55.2% overall. No curvature, present in 21.7% and 17.9% of the left and right sides respectively, totaled 19.8%. Palatal curvature, seen in 17.9% on the left and 14.2% on the right, accounted for 16%. Mesial (6.6%) and labial (2.4%) curvatures were much less frequent.

The apical foramen was most commonly laterally positioned, observed in 59.4% on both the left and right sides. Central positioning was observed in 40.6% of the cases on both sides.

DISCUSSION

Since 1870, literature provided periodic updates regarding root morphology variation of different teeth which enriched clinicians' knowledge and increased success rate of endodontic treatment. Conventional 2D imaging can be misleading whereas CBCT provides internal root morphology in three different planes (axial, coronal, sagittal) which is accurate with higher resolution and lower radiation doses than conventional CT.^[7] All these advantages encouraged us to choose CBCT as an assessment tool for this study.

According to this study result, the most common canal configuration is Type I (99.1%) same as the findings by Somalinga Amardeep *et al.* study (81.6%),^[9] Vertucci^[3] (100%), Pineda and Kuttler^[10] (100%), Çalışkan *et al.*^[11] (93), Jain *et al.* (96%).^[12] This report also supported by a systematic review in Saudi Subpopulation (97.94%)^[13] and Malaysian population (100%).^[14] However, the prevalence of other canal configurations according to our study was much lower (1%) compared to studies by Somalinga Amardeep *et al.* (18.4%),^[9] Çalışkan *et al.* (6.52%),^[15] Sert and Bayirli (6.5%),^[16] Büyükbayram *et al.* (2.44%).^[17] Higher bilateral symmetry (99.1%) was found which is consistent with two Saudi Arabian subpopulation studies (98.9%).^[18] One patient with Type VII canal configuration was found which is very rare in literature.

Our study found the average root length 15.7 mm which is comparatively less than that of Somalinga Amardeep *et al.* (16.82 mm)^[9] and Ash and Nelson (17 mm).^[1]

Mesial and distal sides showed here least overall dentin thickness whereas according to Somalinga Amardeep *et al.*

Table 1: Distribution of subjects according to Vertucci's classification of canal configuration in Maxillary Canines

Vertucci's type	Left (n=106) (%)	Right (n=106) (%)	Total (n=212) (%)
I	105 (99.1)	105 (99.1)	210 (99.1)
III	1 (0.9)	0 (0.0)	1 (0.5)
VII	0 (0.0)	1 (0.9)	1 (0.5)

n: Sample size per group, n: Total sample size

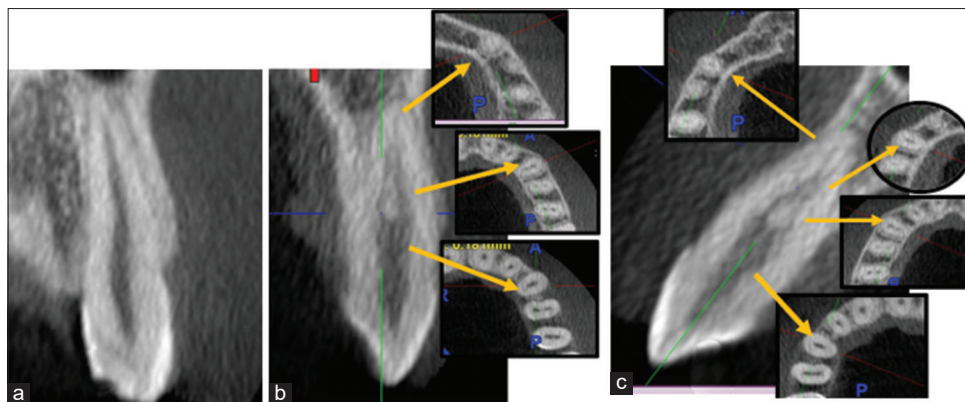


Figure 3: Variation in canal configuration in maxillary canines found in this study according to Vertucci classification – (a) Type I (Single canal) (b) Type III (1-2-1) (c) Type VII (1-2-1-2)

study it was mesial side.^[9] Pre-operative evaluation of dentin thickness is necessary for post space preparation because preservation of 1mm remaining dentin thickness is needed after post placement according to preservative concept of post diameter determination otherwise it increases the risk of fracture.^[19] Furthermore, fracture resistant of root canal-treated tooth depends on the residual dentin thickness. Hence, dentin thickness should be carefully assessed specially at mesial and distal sides before biomechanical preparation. Minimum enlargement of the canal should be done when dentin thickness on mesial or distal side is close to 1 mm.

Comparison of root morphology based on gender was focused in this study which showed that males consistently exhibited larger root dimensions and dentin thickness at various locations compared to females. Best of our knowledge this gender-based comparison is less reported in the literature.

This study reported 18.9% presence of accessory canals which is higher compared to Somalinga Amardeep *et al.*^[9] and Green study^[20] (12%).

This study also included the position of apical foramen which was most commonly reported laterally positioned (59.4%) which is similar to Somalinga Amardeep *et al.* study (70.4%)^[9] but inconsistent with Özlem Okumuş *et al.* study (reported centrally positioned (70.2%).^[21] In case of laterally positioned apical foramen proper care is needed during working length determination and biomechanical preparation.

CONCLUSION

Variation of root morphology in different studies is attributed to the difference in sample size and ethnic background of study samples. This retrospective study concluded that most of permanent maxillary canines have single root with Type I canal configuration with distally directed root apex and laterally positioned apical foramen. All cases have the highest dentin thickness on the labial side and least on mesial and distal sides. About 18.9% of cases have accessory canals mostly at the apical 3rd region. Hence, our study adds some new information related to root anatomy of permanent maxillary canine in Eastern Indian population which enhances awareness of dentists during endodontic treatment and increases the success rate of the treatment which has a significant role to preserve the cornerstone of our mouth.

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