Evaluation of the Root Canal Morphology of Mandibular Permanent Anterior Teeth Using Cone-beam Computed Tomography in Central Indian population: A Retrospective Study

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Abstract: ***Aims: This study aims to evaluate and compare variations in root canal morphology of mandibular anterior teeth in the Central Indian population using CBCT. Methods and Material: This retrospective study included 50 CBCT images comprising 300 mandibular anterior teeth. Teeth fulfilling the inclusion and exclusion criteria were selected. Vertucci's classification was used to determine the number of root canals and root canal morphology (RCM). The frequency of RCM according to gender was also assessed. The collected data were recorded and subjected to statistical analysis. Results: The sample included 42.5% males and 57.5% females, with a mean age of 37.61 ± 14.36 years. Type I canal configuration was most common, observed in 79.4% of central incisors, 72.75% of lateral incisors, and 91.35% of canines. Significant differences were noted between the right and left mandibular anterior teeth. However, no significant gender-based differences in RCM were observed. A significant age-related difference was identified only in the RCM of the right mandibular canine. Conclusions: Type I canal configuration was most prevalent in mandibular anterior teeth. Type VI canals were least common in central and lateral incisors, whereas type II and type IV configurations were least frequent in canines. Significant differences were found in the presence of multiple canals between right and left mandibular anterior teeth.***

Keywords: Cone-beam computed tomography, Central Indian population, root canal morphology.

1. Introduction

The failure of root canal treatment (RCT) remains a significant concern for both clinicians and patients. Inadequate understanding of the internal and external anatomy of the root canal system, along with anatomical variations, is a major contributor to endodontic failure. Therefore, comprehensive knowledge of root canal morphology (RCM) is essential for achieving predictable and successful RCT outcomes.[1] Previous studies have reported that inadequately treated canals account for 12.2% and 17.4% of periapical lesions in mandibular central and lateral incisors, respectively.[2] Untreated canals and the presence of isthmuses are among the primary factors implicated in endodontic failures.[3]

Permanent mandibular anterior teeth are generally described as having a single root with a single canal; however, several studies have documented variations such as additional canals, lateral canals, and apical deltas.[4,5] Various methods have been used to evaluate RCM, including clinical assessment and in-vitro techniques such as dye penetration, decalcification, ex vivo macroscopic examination, and scanning electron microscopy. Conventional periapical radiographs are commonly used in clinical practice but have limitations due to distortion, anatomical superimposition, and the two-dimensional nature of imaging.[1,6]

Cone-beam computed tomography (CBCT) has emerged as a valuable diagnostic tool in dentistry, providing three-dimensional visualization of teeth and surrounding structures in orthogonal planes. Integration of multiple plane views reduces anatomical overlap and allows accurate identification of RCM, including canal number, convergence or divergence, and curvature, while delivering lower radiation doses than conventional computed tomography. Studies evaluating mandibular incisors consistently report Vertucci Type I configuration as the most prevalent, followed by Vertucci Type III.[8] Several authors have highlighted the importance of considering gender and ethnicity during preoperative planning, as variations in RCM among different populations may influence canal detection and management.[9–12]

Although numerous studies have described the endodontic anatomy of American[5], Iranian[12], Egyptian[9], Saudi Arabian, and Turkish populations[4,11], limited research has explored gender-based differences within specific ethnic groups. Therefore, the present study aimed to determine the distribution of Vertucci canal configurations in mandibular permanent central incisors, lateral incisors, and canines in a central Indian population using CBCT imaging and to assess the association between gender and the presence of multiple canals in mandibular anterior teeth

2. Materials and Methods

This retrospective investigation was conducted over a period of 6 months, from April to September 2025, at a tertiary healthcare institution. The sample size was calculated using the formula $N = (Z\alpha^2pq)/d^2$, where p represents the prevalence of multiple canals in lower central incisors (0.49816), $q = 1 - p$ (0.502), and d denotes the level of precision set at 10% of p.

Based on this calculation, a minimum sample of 50 CBCT images comprising 300 mandibular anterior teeth that satisfied the inclusion and exclusion criteria was selected for the study.

All images were obtained using a Carestream CS 9600 CBCT machine with exposure parameters of 120 kV, 10 mA, an average exposure time of 10 seconds per scan, and a voxel size of 0.075 mm^3. Radiographic evaluation was performed independently by two endodontists, and in cases of disagreement, a third expert was consulted to reach a final decision.

The inclusion criteria consisted of high-quality CBCT images of patients above 18 years of age with fully developed root apices of mandibular anterior teeth. Exclusion criteria included teeth with root canal fillings, posts, or crowns; fractured teeth; calcified canals; CBCT images with missing mandibular incisors; and teeth showing root resorption.

Root canal morphology of mandibular central incisors, lateral incisors, and canines was evaluated in axial, sagittal, and coronal planes. The number of canals and canal configurations were recorded according to Vertucci's classification, which categorized root canal morphology into eight types.

3. Statistical Analysis

Data entry and analysis were performed using SPSS Version 26.0 (IBM Inc., Chicago, USA). Descriptive statistics were used to summarize the frequency of root and canal configurations. Chi-square test evaluated associations between: Tooth type and canal configuration; Gender and canal configuration; Age groups and canal variation prevalence. Significance threshold was $p < 0.05$

4. Results

This study evaluated the root canal morphology (RCM) of mandibular anterior teeth in 50 individuals using CBCT. The sample included 44% males (n = 21) and 56% females (n = 29), aged 19–70 years, with a mean age of 37.61 ± 14.36 years. No significant differences were observed in age or gender distribution (p = 0.297).

Type I canal configuration was most prevalent, observed in 79.4% of central incisors, 72.75% of lateral incisors, and 91.35% of canines. Type III was the second most common morphology. Significant differences were found between right and left mandibular anterior teeth ($p < 0.01$), while no significant gender differences were noted. Younger individuals showed greater canal variations, and most mandibular anterior teeth had a single conical root tapering to a blunt apex. All the results are shown in following tables.

Table 1: Comparison of various types of root canals in the study sample among right and left sides of mandibular anteriors

Teeth		Vertucci Canal Configuration Classification						Chi-square test	p-value
		I	II	III	IV	V	VI		
Central Incisor	Right	39	0	5	2	4	0	463.4	0.000**
	Left	40	1	5	2	2	0		
Lateral Incisor	Right	35	1	6	2	6	0	517.13	0.000**
	Left	36	1	7	0	6	0		
Canine	Right	45	0	5	0	0	0	227.51	0.000**
	Left	45	0	4	0	1	0		
Total (%)		80	6.33	10.66	2	1	0		

Table 2: Distribution of root and root canal morphology of Right and left mandibular central incisor

Teeth			Vertucci classification						Total	Chi-squared test	p-value
			I	II	III	IV	V	VI			
Rt CI	Female	Count	23	0	3	1	2	0	29	7.07	0.15
		% within gender	82.2%	0.4%	10.4%	0.4%	6.1%	0.4%	100%		
	Male	Count	16	0	2	1	2	0	21		
		% within gender	74.7%	0%	12.4%	1.8%	11.2%	0%	100%		
Total		Count	39	0	5	2	4	0	50		
		%	79%	0.2%	11.2%	1%	8.2%	0.2%	100%		
Lt CI	Female	Count	24	0	2	1	1	0	29	6.94	0.11
		% within gender	83.9%	0.9%	9.1%	0.4%	5.7%	0	100%		
	Male	Count	16	1	3	1	1	0	21		
		% within gender	74.1%	0.6%	13.5%	1.2%	10.6%	0	100%		
Total		Count	43	1	5	2	2	0	50		
		%	79.8%	0.8%	11%	0.8%	7.8%	0	100%		

Teeth			Vertucci classification						Total	Chi-squared test	p-value
			I	II	III	IV	V	VI			
Rt LI	Female	Count	21	0	4	1	3	0	29	4.00	0.57

		% within gender	73.5%	0.4%	14.3%	0.9%	10.4%	0.4%	100%		
	Male	Count	14	1	2	1	3	0	21		
		% within gender	70%	1.2%	12.4%	1.2%	15.3%	0%	100%		
Total		Count	35	1	6	2	6	0	50		
		%	72%	0.8%	13.5%	1%	12.5%	0.2%	100%		
Lt LI	Female	Count	22	1	4	0	2	0	29	4.05	0.56
		% within gender	76.1%	0.9%	12.6%	0.4%	9.6%	0.4%	100%		
	Male	Count	14	0	3	0	4	0	21		
		% within gender	70%	1.2%	13.5%	1.2%	14.1%	0%	100%		
Total		Count	36	1	7	0	6	0	50		
		%	73.5%	1%	13%	0.8%	11.5%	0.2%	100%		

Table 3: Distribution of root and root canal morphology of Right and left mandibular Lateral incisor

Teeth			Vertucci classification						Total	Chi-squared test	p-value
			I	II	III	IV	V	VI			
Rt C	Female	Count	26	0	3	0	0	0	29	3.47	0.51
		% within gender	89.6%	0.9%	7.8%	0.9%	0.9%	0.4%	100%		
	Male	Count	19	0	2	0	0	0	21		
		% within gender	93.5%	0%	5.3%	0%	1.2%	0%	100%		
Total		Count	45	0	5	0	0	0	50		
		%	91.2%	0.5%	6.8%	0.5%	1%	0.2%	100%		
Lt C	Female	Count	26	0	2	0	1	0	29	3.27	0.55
		% within gender	90.0%	0.9%	6.5%	0.9%	1.7%	0.4%	100%		
	Male	Count	19	0	2	0	0	0	21		
		% within gender	93.5%	0%	5.9%	0%	0.6%	0%	100%		
Total		Count	45	0	4	0	1	0	50		
		%	91.5%	0.5%	6.2%	0.5%	1.2%	0.2%	100%		

Chi-Square Test Results

A Chi-square test assessing the relationship between tooth type and canal configuration indicated:

- Statistically significant association between tooth category and Vertucci type distribution ($p < 0.05$)
- Lateral incisors showed significantly more variation than central incisors and canines
- Type I was statistically the most prevalent configuration across all tooth groups

5. Discussion

This study provides valuable insights into the root canal morphology (RCM) of mandibular anterior teeth in the Central Indian population and highlights the usefulness of CBCT in improving the success of root canal treatment (RCT). The prevalence of multiple canals observed in this study (20.6% in central incisors, 27.25% in lateral incisors, and 8.65% in canines) was lower than that reported in Turkish population studies by Arslan et al.[11] (47.6%), Çoban Kanyılmaz et al.[12] (41%), and Sert and Bayirli[13] (67.75%). Literature indicates that the prevalence of two-rooted canines ranges from 0–15.1% across ethnic groups, and variations among studies may be attributed to differences in methodology and sample selection.

Type I canal configuration was the most prevalent in the present study, followed by Type III. Similar findings were reported by Milanezi de Almeida et al.[14] in a Brazilian population. Studies by Altunsoy et al.[15] observed that multiple canals were more common among Turkish males; however, the present study found no significant gender-based differences in RCM, consistent with several earlier reports. In contrast, Karobari et al.[16] reported greater canal complexity in males in the Malaysian population. Such discrepancies may be related to genetic variations, methodology, or sample size.

Age-related differences in RCM were not significant in this study except for the right mandibular canine. Similar observations were made by Magat and Uzun[17] in Turkish subpopulations. Age-related calcification of the root canal system may lead to canal narrowing and reduced detection of secondary canals.

Studies in Indian populations show comparable findings. Boruah et al.[18] reported Type I configuration as predominant (63.75%) in mandibular incisors, whereas Kurumboor et al.[19] found a second canal in 11% of cases. Similarly, Verma et al.[20] observed Type I as the most common configuration, with Type V prevalent among two-canal teeth.

Understanding variations in canal morphology is crucial for effective endodontic therapy, as it aids in locating additional canals and ensuring complete debridement while preserving root structure. CBCT imaging proved clinically useful in identifying additional canals and canal bifurcations in mandibular incisors. However, CBCT has lower spatial resolution compared with micro-CT and nano-CT, which may influence the evaluation of complex canal systems. Although Vertucci's classification is widely used, the system proposed by Ahmed et al.[21] provides a more precise representation of root and canal morphology. Future use of CBCT in endodontics may further enhance the evaluation of complex root canal systems and related conditions.

6. Conclusion

Within the limitations of this study, Vertucci Type I canal configuration was the most prevalent morphology in mandibular anterior teeth in the Central Indian population.

Lateral incisors showed the highest frequency of canal variations and additional canals. Age influenced canal morphology, with greater variations observed in younger individuals. CBCT proved to be a valuable tool for evaluating root canal anatomy, and recognition of anatomical variations is essential for successful root canal therapy.

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