Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.47750/jptcp.2023.30.14.021

Variations in the root canal anatomy of mandibular anterior teeth in the South Indian population

Astha Bramhecha[1], Manish Ranjan[2*], Srujana Hemmanur[3]

[1]Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India

[2]Professor, Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India

[3]Senior Lecturer, Department of Conservative Dentistry and Endodontics, SRM Dental College, SRM Institute of Science and Technology, Ramapuram, Chennai

***Corresponding author:** Manish Ranjan, Professor, Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India

Submitted: 24 March 2023; Accepted: 12 April 2023; Published: 21 May 2023

ABSTRACT

Aim: The objective of this study was to use CBCT to assess the variations in root canal anatomy of the mandibular central and lateral incisors and canines in the South Indian population.

Materials and methods: This retrospective CBCT study was done to investigate 1152 permanent mandibular anterior teeth (378 centrals, 384 laterals, and 390 canines) acquired from 200 CBCT images, of which 96 were males and 104 were females, with ages ranging from 20-65 years, acquired from the AxeosTM Imaging System (Dentsply Sirona). Slices of 0.2 mm thickness in the axial, sagittal and coronal planes were then selected. Galileos software (Dentsply Sirona) was used to study the images on a computer in a semi-dark room with a constant intensity of light. After this, the incisors and canine root canals were classified based on Vertucci's classification and tabulated.

Results: Statistical analysis was done by chi square test and Mann-Whitney U test to assess the prevalence of various canal configurations. Out of 1152 assessed mandibular anterior teeth, 51.85% central incisors(193/368), 61.45% lateral incisors (236/376) and 44.10% canines had type III canal configuration. The most common canal configuration observed in mandibular central and lateral incisors was Type III, followed by Type I. On the other hand, Type I configuration was more prevalent in canines, particularly in the left mandibular canines, followed by Type III.

Conclusion: A higher number of participants had Vertucci's type III classification, followed by type I. A higher prevalence of two canals was seen in males compared to females.

Keywords: *Cone beam computed tomography, Mandibular incisors, Mandibular canines, Root canal anatomy*

INTRODUCTION

What is endodontics? It is an integral part of dentistry that deals with the structure, physiological functions, as well as the pathology of the pulpal and periradicular tissue. A thorough knowledge of the physiology and biology of the pulp is essential for the practice of endodontics. A complete understanding of the etiological factors causing pulpal diseases, as well as means of diagnosis and measures for prevention and treatment of these injuries or diseases of the pulp, forms the basis of the practice and study of endodontics. (1) The basic goal of this treatment is debridement of the canal, followed by cleaning of the canal in order to remove any infected pulp tissue (2). The cleaned and debrided canal space is then shaped and prepared to receive an inert material filling, which helps prevent reinfection in the future. (3) Approximately 68%- 85% was noted to be the pooled rate of success of endodontic treatments that were completed at least 1 year prior. (4) Nevertheless, inadequately following the standard clinical principles of endodontic treatment may result in higher failure rates. (3)

Visualizing the internal anatomical relationship before the procedure begins and having knowledge of the same cannot be overstated. An insufficient understanding of pulpal space anatomy may be the cause of problems or failures encountered during endodontic treatment (5,6). This problem is most commonly seen with the treatment of the lower incisors, where many fail to identify and recognize the presence of a second canal. Leaving this second canal untreated has been identified as the reason for the higher failure rates seen with these teeth. (7,8) According to a study conducted by Azhar Iqbal, underfilled canals (33.3%) were found to be the most common cause of treatment failure. The second most common cause was found to be missed and unfilled canals (17.7%). (9)Another study assessing reasons for treatment failure concluded with similar results, where they found that the most prevalent reason was inadequate filling of the root canal (36.8%), followed by missed canals (14.4%).

The various ethnic populations exhibit wide variations in the morphology of the root canal systems; it is therefore necessary to study the anatomy of the canals across the various populations in order to successfully complete root canal treatment in them. (10,11) Various morphological and anatomical variations are seen among the root canal systems of lower incisors, in contrast to what it may seem on periapical radiographic examination of these teeth. The most common variations seen include the presence of apical deltas, 2nd canals, as well as presence of lateral canals. (12–15)

In order to examine the morphology of these canal systems, we can use a wide variety of methods, which are divided into two broad categories: clinical and laboratory methods. The laboratory methods encompass decalcification (16), dye injection (17), conventional radiographs (18), micro-computed tomography (Micro-CT) techniques (19), and observing the floor of the pulp chamber by using scanning electron microscopy. (20)The clinical methods: magnification tools can be used to assess the quality of endodontic treatment (21), routine periapical or other radiographs (22), as well as examination of the patient's previous dental records if available.

Although periapical radiography is considered one of the most useful diagnostic aids for the assessment of the anatomy and morphology of the root canals (21), the use of this radiographic technique has its own set of limitations. These drawbacks include errors in magnification, the presence of superimposed structures, or even distortion of the radiographic image, all of which will eventually lead to a decrease in the reliability of this technique. Three-dimensional (3D) images that are produced with the help of cone beam computed tomography (CBCT) systems can considerably reduce the superimposition of the surrounding structures. In comparison to micro-CT scans, these imaging systems are significantly more suitable, efficient, and justified for a patient's diagnostic examination. This is because micro-CT scans are only suitable for use in in vitro studies. Currently, the exclusive usage of cone beam computed tomography for root canal treatments is widely done. This aids in providing accurate diagnostic and anatomical studies of the root canal system (23).

Among the various advantages seen with respect to CBCT, the most important are that it enables low-dose radiation, the exposure time is short, and it is also cost-effective. This being said, panoramic and conventional radiography still play a very crucial role in endodontic treatments and cannot be completely replaced by CBCT,

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which, however, can be used as a complementary method to these (23,24) The use of CBCT in endodontic treatment aids in the identification of accessory canals, if present, and tuberous root canals, as well as identifying presence of root resorption, fractures, or curvatures of roots. (24,25)

As per the AAE position statement regarding its use in endodontics, for the initial endodontic treatment of teeth that might have a prevalence for the presence of any accessory canals or even a suspected complex anatomy(e.g., premolars, molars, mandibular anteriors), CBCT with limited FOV must be the imaging modality chosen (26). Due to the limited availability of data in the Indian population, this study was designed to evaluate the variations in the root canal anatomy of the mandibular anteriors in the South Indian population by using CBCT.

MATERIAL AND METHODS

This study has been cleared by the Ethical Committee of Saveetha Dental College for Research, and its Ethical Approval No. is IHEC/SDC/ENDO-2002/22/098. An informed consent was formed due to the study being retrospective in nature and cleared for use in this study by the Ethical Committee of Research, Saveetha Dental College, Chennai, Tamil Nadu. Patients were also required to sign a general consent form prior to undergoing any treatment or diagnostic investigations, which included acquiring their permission to use any findings for future studies without revealing their personal identity. G Power 3.1.9.4 software was used to determine the sample size. The sample size taken was 148 scans. This study has 1152 permanent lower anterior teeth acquired from 200 CBCT images, of which 96 were males and 104 were females, with ages ranging from 20 to 65 years. The data acquired were from records between January 2021 and January 2023.

Inclusion criteria: A CBCT image of the mandible should have a minimum of one lower incisor or canine that has a closed apex with no filling, post and core or calcifications. The teeth should not show root resorption or any periapical lesions. The CBCT image should be of adequate quality and without the presence of any motion or foreign objects.

In order to eliminate bias, the evaluation of the images was done by two observers. In cases of conflict of opinion regarding an image, a third observer was included for the interpretation of the images. Final decisions were regarded as diagnoses.

The AxeosTM Imaging System (Dentsply Sirona) was used to acquire the CBCT images. The unit used had a voxel size of 0.5 mm, exposure conditions : 10 mA and 90 KVp, an exposure time of 14.2 seconds, and a field of view (FOV) of 100×70×50mm. A 0.2 mm slice thickness in the axial, sagittal and coronal planes was then selected in order to obtain a more accurate detection of the anatomy and morphology of the root canal. In order to view the images in all three planes, the Galileos software (Dentsply Sirona) was used to study the images on a computer monitor (Dell) in a darkened room that maintained a consistent level of light.

Vertucci’s classification was used to classify the incisors and canines after CBCT examination of their root configuration: “Type I: a single canal is present from the chamber to the apex; Type II: two separate canals leave the pulp chamber and join to form one canal to the exit site; Type III: one canal from the pulp chamber divides into two within the root, which then merge to exit in one canal; Type IV: two separate canals exit from the pulp chamber to the apex; Type V: 1 canal leaves the pulp chamber and divides into two separate canals that have two separate apical foraminas; Type VI: Two canals leave the pulp chamber, merge in the body of the root, then divide before the apex to exit as two separate canals; Type VII: 1 canal leaves the pulp chamber, divides and then rejoins within the body of the root, and finally divides again into 2 separate canals short of the apex; Type VIII: three separate canals from the pulp chamber to the apex."(27) (Refer Fig 3-6)

Each lower central and lateral incisor canal was categorized according to Vertucci's classification, which was then tabulated. While scrolling along the axial plane of the image to assess and classify the canals, the images produced in the coronal and sagittal planes were also assessed to evaluate the root canal systems and accurate root numbers.

RESULTS

This study involved the examination of 1152 mandibular anterior teeth, which consisted of 378 central incisors, 384 lateral incisors, and 390 canines. Out of the 200 CBCTs assessed, 96 were

male and 104 were female (refer to Fig. 1 and Table 1). Calcified canals were excluded from the study.

A chi-square test was applied to determine the prevalence of each tooth. The prevalence of right canines with Type I configuration is 47%, Type III is 48%, and Type V is 2%. For the right lateral incisor, Type I canal configuration is observed in 19%, Type III in 65%, Type V in 1%, and Type VII in 11%. The right central incisor has a Type I canal configuration in 39% of cases, Type III in 45%, Type V in 1%, and Type VII in 11%.

In the left canine, Type I canal configuration is found in 58%, Type III in 38%, and Type V in 2%. For the left lateral incisor, Type I is observed in 31%, Type III in 53%, and Type V in 12%. In the left central incisor, Type I is present in 38%, Type III in 53%, Type V in 1%, and Type VII in 1%. These differences are statistically significant (p 0.05) (refer to Table 2 and Fig. 2).

Of the 1152 teeth evaluated, the majority of the central incisors (51.85%, 196/378), lateral incisors (61.45%, 236/384), and canines (44.10%, 172/390) demonstrated a type III canal configuration. Type I configuration was present in 53.84% of canines, 26.04% of lateral incisors, and 40.74% of central incisors. Type V configuration was observed in 2.05% of canines, 6.77% of lateral incisors, and 1.05% of central incisors. Type VII configuration was absent in canines but present in 5.72% of lateral incisors and 6.34% of central incisors.

To assess the gender predilection in each tooth, the Mann-Whitney U test was applied. Interestingly, the prevalence of Type III configuration was found to be higher in males in almost all teeth (tooth numbers 43, 42, 41, 31, and 32), whereas the prevalence of Type I was higher in females in tooth number 33, although not statistically significant. The prevalence of Type V configuration was found to be very low in all teeth, with only 1-2% of participants having this configuration (refer to Table 3).

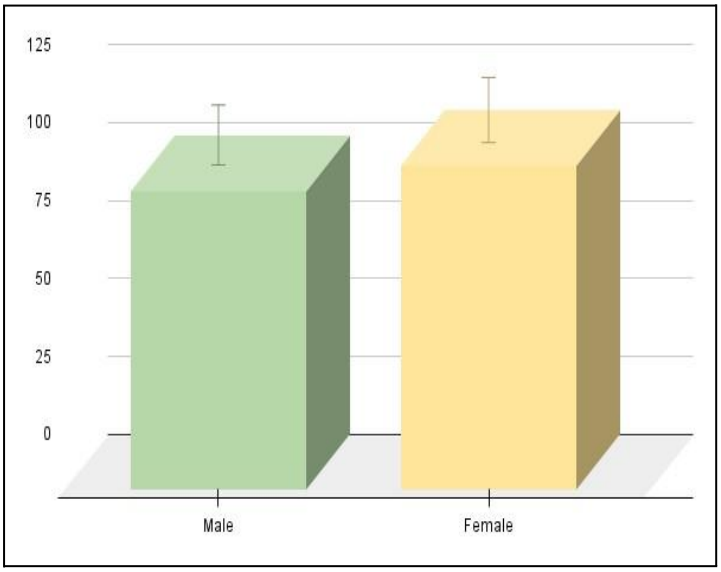

FIG 1: Gender distribution

TABLE 1: Gender Distribution

		Gender		
		Frequency	Percent	P Value
	Male	98	48.0	0.746
	Female	52	52.0	
	Total	200	100.0	

TABLE 2: Number and percentage of type I, type III, type V, and type VII Vertucci's Classification for Mandibular Right and Left Central, Lateral, and Canine

Tooth Number	Missing		Vertucci's Classification			Calcified	P Value
		Type I	Type III	Type V	Type VII		
43	6(3.0%)	94(47.0%)	96(48.0%)	4(2.0%)	0(0%)	0(0%)	0.00
42	4(2.0%)	38(19.0%)	130(65.0%)	2(1.0%)	22(11.0%)	4(2.0%)	0.00
41	6(3.0%)	78(39.0%)	90(45.0%)	2(1.0%)	22(11.0%)	2(1.0%)	0.00
31	10(5.0%)	76(38.0%)	106(53.0%)	2(1.0%)	2(1.0%)	4(2.0%)	0.00
32	6(3.0%)	62(31.0%)	106(53.0%)	24(12.0%)	0(0%)	2(1.0%)	0.00
33	2(1.0%)	116(58.0%)	76(38.0%)	4(2.0%)	0(0%)	2(1.0%)	0.00

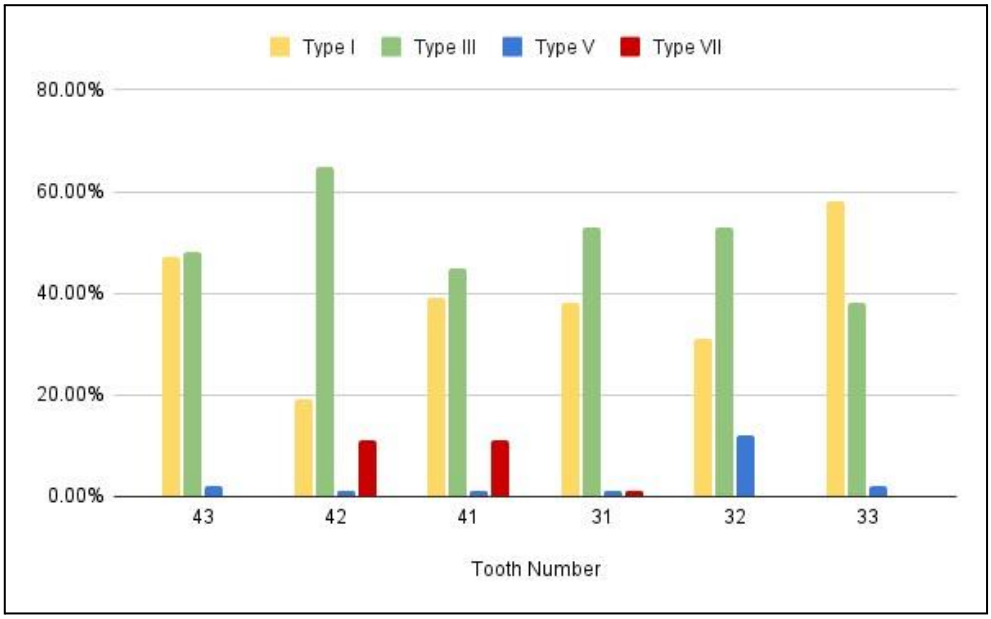

FIG 2: Canal Configurations in Mandibular Anterior Teeth Grouped by Gender

TABLE 3: Distribution of Vertucci's classification types (Type I, Type III, Type V, and Type VII) for mandibular right and left central incisors, lateral incisors, and canines based on gender

Tooth Number	Gender	Vertucci's Classification				
		Type I	Type III	Type V	Type VII	p-value
43	Male	17%	31%,	0%	0%	0.006
	Female	30%	17%	2%	0%	
	Total %	47%	48%	2%	0%	
42	Male	9%,	38%,	1%	0	0.003
	Female	10%	27%	0%	11%	
	Total %	19%	65%	1%	11%	
41	Male	12%,	35%,	0%	0%	0.000
	Female	27%	10%	1%	11%	
	Total %	39%%	45%	1%	11%	
31	Male	12%	33%,	0%	1%	0.035
	Female	26%	20%	1%	0%	
	Total %	38%	53%	1%	1%	

32	Male	19%,	27%,	1%	0%	0.008
	Female	12%	26%	11%	0%	
	Total %	31%	53%	12%	0%	
33	Male	25%,	23%,	0%	0%	0.156
	Female	33%	15%	2%	0%	
	Total %	58%	38%	2%	0%	

DISCUSSION

Mandibular anterior teeth have been thought of as the easiest teeth to treat endodontically, but high failure rates have been observed due to a lack of identification of a frequent presence of a second canal that cannot be appreciated in a 2D periapical radiograph. CBCT is a new modality that offers more advantages over other laboratory techniques of identification, which have been found to be invasive or require the use of extracted teeth. (12,15,28,29). Using CBCT, some researchers have explored the anatomy of the teeth and jaws, both quantitatively and qualitatively. (29–31) As compared to the gold standard of visual inspection by physical sectioning, CBCT has shown reliability in detecting variations in root canal anatomy. (32–34) The CBCT imaging approach can provide enough data to allow for the proper handling of complex endodontic conditions during clinical procedures as a complementary radiological evaluation to traditional imaging techniques (35). The root morphology of numerous samples from a specific population can also be analyzed cross-sectionally. In contrast to ex vivo approaches, it is much simpler to acquire background information regarding the teeth, such as the prevalence of various root canal configurations by sex, tooth position, and age. (36)

In this study, 200 South Indian subjects with a total of 1,152 mandibular incisors and canines were subjected to CBCT to assess the root canal systems. Vertucci's Type I, Type III, Type V and Type VII canal configurations were seen. The central incisors, lateral incisors, and right canines showed a higher prevalence of Type III canal configuration, while Type I was more common in the left canines. These findings are consistent with previously conducted studies (37,38). A study done by Zitong Lin et al, (13) in the Chinese population, Type III canal configuration was more prevalent. A higher frequency for the second canal (35%) in the mandibular lateral incisor (29%) compared to the central incisor was seen in the Mirhosseini et al. study. (39) In the Malaysian population, Vertucci Type I (45%) was the second most typical configuration for mandibular lateral incisors, after Type III (51%). (40) Similar to the findings of this study, 39.1% of teeth in an Israeli population had Type III canal configuration. (41)

In contrast, the study by Miyashita et al. (15)11] discovered that among the teeth that had two canals, Type II canals were the most prevalent, followed by Type III. Al-Qudah et al. [8(12) found similar findings on the classification of canal configurations: In a population from Jordan, Type II canals were found to be more frequent than Type III canals. According to Lalit et al. [32(42), there was a greater occurrence of singular canals in the mandibular incisors of individuals from the Northeast region of India. A study by Geduk et al, (43) suggests that all mandibular incisors have one root and mostly one canal. The variations in the outcomes of morphological studies may be due to differences in examination methods, sample sizes, ethnicities, and classifications.

Previous research investigating root canal anatomy differences between genders has revealed notable dissimilarities. In this study, comparable findings were obtained, with males exhibiting greater variations than females. (44,45) Iqbal et al. conducted a study that observed variations in root canal anatomy that are linked to gender.(46)

The most widely used system for categorizing root canal morphology is Vertucci's classification (27).Vertucci's taxonomy allows for the description of complex root canal configurations without requiring the memorization of Roman numerals. However, a recent study found significant flaws in this classification (44). The current classification system overlooks the number of roots in anterior and premolar teeth, which is a significant flaw. Categorizing teeth with double roots in the anterior and premolars as Type IV or Type V is not accurate, as the number of roots is crucial in determining appropriate

treatments such as root canal therapy and post-placement (47). Hence, this could be considered a limitation of the study.

CONCLUSION

Type III was the most commonly observed canal configuration in all teeth, except for the left mandibular canine, where Type I was predominant. Type III was typically followed by Type I in most teeth, but the left mandibular canine showed the opposite pattern, with Type I being followed by Type III. Additionally, males exhibited a higher prevalence of Type III canal configuration in mandibular anterior teeth compared to females.

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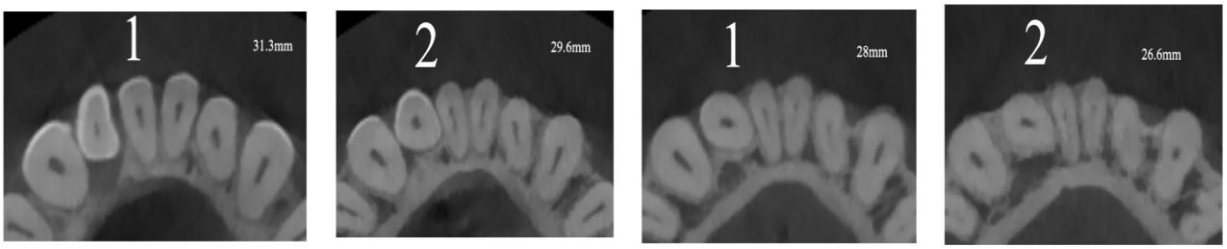

FIG 3: Type VII canal configuration seen in 31. Various axial sections showing 1-2-1-2 configuration.

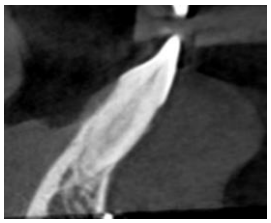

FIG 4: Type VII canal configuration in coronal section in 31.

FIG 5: Type I canal configuration

FIG 6: Type III canal configuration