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Root Canal Morphology of Mandibular Permanent Incisors - A Cone-Beam Computed Tomographic (CBCT) Study

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ABSTRACT

Background

Proper knowledge of root canal anatomy is most important for the success of root canal treatment. The objective of this study to find the numbers and morphological characteristics of root and root canals of mandibular central and lateral incisors using cone beam computed tomography (CBCT).

Methods

Retrospective CBCT data of 194 patients were retrieved between January 2022 to December 2024. In this study 52 patients were included, with 170 mandibular incisors were included in the study. The number of roots and root canals, and the canal configuration according to Vertucci's classification were analyzed. The effect of tooth type and gender on the occurrence of anatomical variations was evaluated.

Results

The occurrence of two root canals was found to be 27.6% in mandibular incisors with all tooth having single root. Male (18.82%) shows a high occurrence of two canals. Mandibular lateral incisors show a high (17.06%) occurrence of two canals. According to Vertucci's canal configuration, Type I (71.8%) has a higher occurrence, followed by Type II (15.9%), Type III (7.1%), Type V (2.9%), Type IV (1.8%), and Type VII (0.6%).

Conclusions

Type I was the most common type of canal configuration found in mandibular incisors followed by type II. Male shows almost double the occurrence of anatomical variations on mandibular incisors. Mandibular lateral incisors show a high occurrence of anatomical variations.

Keywords: central mandibular incisors; CBCT; lateral mandibular incisor; root morphology.

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INTRODUCTION

The knowledge of root canal morphology is essential for successful endodontic treatment.[1] Mandibular incisors, though seemingly simple in structure, often present with complex root canal configurations that challenge clinicians during endodontic procedure.[2] Before beginning endodontic treatment, the most accurate imaging techniques, such as conventional periapical radiography and cone-beam computed tomography (CBCT) imaging, should be used to efficiently assess the anatomic pattern of tooth structures.[3, 4] Conventional periapical radiography provides two-dimensional images in which the roots may overlap with the surrounding tissue.[5] CBCT through a single exposure of a cone-shaped beam of radiation around an object, provides three-dimensional images that reveal the internal architecture of the object by obtaining volume in a 360-degree rotation. Technically, CBCT is a reliable method for assessing and exploring the root canal anatomy.[6] The morphologic variations of mandibular anterior teeth with various canal configurations that can be found through this study will serve as a reference for the endodontic treatment of these teeth.

METHODS

This analytical cross-sectional study was conducted in the Department of Conservative Dentistry and Endodontics, College of Medical Sciences and Teaching Hospital, Bharatpur, Chitwan, Nepal on CBCT images of patients in the archives of Chitwan Dental Imaging Diagnostic Center (CDIDC), wherein all the CBCT images taken from January 2022 to January 2024 in CDIDC were examined for the study . The study was conducted after approval of ethical clearance from the institutional review committee of the hospital (Ref No. COMSTH-IRC/2024-030). The sample size was calculated using the formula: $n = Z^2 pq/e^2 = 160$, where; n= sample size, z = standard deviation set at 1.96 (95% confidence interval), p = prevalence of condition (prevalence of type I canal morphology of mandibular anterior =88.2%)[7], q= 100-p, e= permissible error=5%. This study was conducted among 160 cases. CBCT images other than mandibular central and lateral incisors, incomplete and unclear images of the target area, and previously treated canals, teeth with root resorption, and teeth with immature apices were excluded. 194 patients' CBCT images who visited CDIDC, Bharatpur, with an age above 18 years from January 2022 to December 2024 were retrieved. 170 mandibular anterior teeth were selected for the study from the 52 included patients' images using the convenience sampling technique. Gender and tooth type were recorded. Teeth were investigated for the number of roots and canals and canal configuration types according to Vertucci's classification: [5, 8] Type I: A single canal extends from the pulp chamber to the apex. Type II: Two separate canals leave the pulp chamber and then join to exit as one canal. Type III: One canal leaves the pulp chamber, divides into two within the root, and then joins to exit as one canal. Type IV: Two separate canals leave the pulp chamber an exit as two distinct canals. Type V: One canal leaves the pulp chamber and divides within the body of the root to exit as two separate canals. Type VI: Two separate canals leave the pulp chamber and join within the body of the root, and then redivide to exit as two distinct canals. Type VII: One canal leaves the pulp chamber, then divides and rejoins within the body of the root canal, and the redivides to exist as two separate canals. Type VIII: Three separate canals leave the pulp chamber and exit as three distinct canals. These CBCT images were examined by two endodontists separately in the Department of conservative dentistry and Endodontics, COMS-TH, Bharatpur. Consultations where required were undertaken with an Oral radiologist. For image assessment, Dentium rainbow viewer software was utilize having the parameters such as peak voltage 94 kVp, tube current 8mA, scan time 20sec, field of view limited (5x5) and stitched (16x18) and voxel size 100-300 µm, the slice thickness was 0.2 mm viewed from the coronal to apical region. The obtained images were viewed and analyzed in Rainbow TM image Viewer Version 1.0.0.0. The images were viewed on the same computer screen using the same image viewer, under ambient light. The observer used all the software features, such as zooming and changes in contrast and brightness. Data were entered into

MS-Excel and analyzed by SPSS software version 20 and statistical tests were done using frequencies, the chi-square test, and Fisher's exact test. P<0.05 was considered statistically significant.

RESULTS

After screening 194 patients' CBCT images, 52 patients' CBCT images with 170 mandibular incisors were selected who fulfilled the inclusion criteria, of which 28 (53.8%) were male and 24 (46.2%) were female. 81(47.6%) were mandibular central incisors and 89 (52.4%) were mandibular lateral incisors. All the mandibular incisors had a single root, of which 123(72.4%) recorded a single canal and 47(27.6%) recorded two canals. According to Vertucci's canal configuration, Type I (71.8%) has a higher occurrence, followed by Type II (15.9%), Type III (7.1%), Type V (2.9%), Type IV (1.8%), and Type VII (0.6%) (Table 1).

Type I canal configuration was dominant in both the incisors. Two canals were common in mandibular lateral incisors (17.06%) compared to central incisors (10.59%). Type II was present twice in lateral incisors but was not significant. Type IV was present only in the lateral incisor, and type VII was found in only one of the central incisors. There was no statistical significance in the number of canals or type of canal configuration in association with tooth type (Table 2).

This study has no difference in the distribution of mandibular incisors between males and females. Male shows significantly higher (18.82%) occurrence of two canals compared to females (8.82%). Type II canal configuration was found significantly higher in males, whereas Type III was found significantly higher in females. Types IV, V, and VII were present in rare of which Type IV, V was present only in males, and Type VII was present only in females (Table 3).

Table 1. Frequency and percentage distribution of root/canal morphology in mandibular anterior teeth by gender and Vertucci classification.

Variables	Frequency (%)
Gender	
Male	28 (53.8)
Female	24 (46.2)
Tooth involved	
Mandibular central incisor	81 (47.6)
Mandibular lateral incisor	89 (52.4)
Number of roots	
Single	170 (100)
Number of root canals	
Single	123 (72.4)
Two canals	47 (27.6)
Canal configuration (Vertucci's type)	
Type I	122 (71.8)
Type II	27 (15.9)
Type III	12 (7.1)
Type IV	3 (1.8)
Type V	5 (2.9)
Type VII	1 (0.6)

Table 2. Association of number of root canals and canal configuration according to Vertucci's type with tooth type.

Tooth type	Manibular CI n (%)	Manibular LI n (%)	Chi-square	p-value
Number of canals				
1 canal	63 (37.06)	60 (35.29)	0.131	0.719
2 canals	18 (10.59)	29 (17.06)	3.706	0.054
Canal configuration				
Type I	63 (37.06)	60 (35.29)	0.131	0.718
Type II	10 ((5.88)	17 (10)	2.778	0.096
Type III	5 (2.94)	7 (4.12)	0.423	0.515
Type IV	0 (0)	3 (1.76)	3.015	0.083
Type V	2 (1.18)	2 (1.18)	0.00	1
Type VII	1 (0.58)	0 (0)	1.015	0.314

Table 3. Distribution of tooth type, number of canals, and canal configuration (Vertucci's classification) of mandibular anteriors in terms of gender.

Variables	Gender		Chi-square value	p-value
	Male n (%)	Female n (%)		
Tooth type				
Mandibular central incisor	43 (25.3)	38 (22.35)	0.001	0.971
Manibular lateral incisor	47 (27.65)	42 (24.76)	0.329	0.566
Number of canals				
Single canal	58 (34.12)	65 (38.24)	0.563	0.453
Two canals	32 (18.82)	15 (8.82)	7.224	0.007
Canal configuration				
Type I	58 (34.12)	65 (38.23)	0.563	0.453
Type II	22(12.94%)	5 (2.94)	12.857	<0.001
Type III	3(1.76)	9 (5.29)	3.968	0.046
Type IV	2(1.18)	0 (0)	2.015	0.156
Type V	5 (2.94%)	0 (0)	5.074	0.024
Type VII	0 (0)	1 (0.58)	1.015	0.314

DISCUSSION

Mandibular anterior teeth have been thought of as the easiest teeth to treat endodontically, but due to anatomical variations like second canal, apical delta, intercanal septum, and bifurcations, it is one of the challenging during root canal treatment.[8-10] An inappropriate diagnosis of the anatomical configuration can lead to a series of complications and the failure of the endodontic treatment.[8, 11] CBCT provides a technique for performing a more precise investigation of root canal systems and facilitates a detailed investigation of both the external and the internal anatomy of teeth.[2, 12-14] Using this approach, tooth anatomy can be simultaneously or separately observed from different angles that can reveal the anatomy in sagittal, coronal and axial sections reconstructing 3D images, and the characteristics of a tooth can be both qualitatively and quantitatively assessed.[2, 10] CBCT is a sophisticated diagnostic imaging technique that doesn't present geometrical distortion or anatomical noise; as seen in intra oral periapical x-ray; providing accurate measurements of the information acquired.[6] This makes CBCT a useful tool for endodontic assessment because it permits an in-depth analysis of the anatomy before treatment. As compared to the gold standard of visual inspection by physical sectioning, CBCT has shown reliability in detecting variations in root canal anatomy.[6, 10] The CBCT imaging approach can provide enough data to allow for the proper handling of complex endodontic conditions during clinical procedures, allowing a feasible method and reproducible clinical scenario that is better than a periapical radiograph.[6]

This study evaluated 170 mandibular incisors using CBCT imaging, of which 81 were mandibular central incisors and 89 were mandibular lateral incisors. All the involved teeth exhibit a single root, which is similar to other studies.[12, 15-20] Other Studies have found less than 1% of two-rooted mandibular lateral incisors.[9, 21, 22] Mandibular incisors 27.6% in this study show 2 canals which is similar to other studies.[1, 2, 20] Some studies show less prevalence of two canals in mandibular incisors compared to our study.[12, 17, 22, 23] whereas other studies show higher prevalence of 2 canals.[10, 11, 15, 16, 18, 19, 21] Lateral incisors has high occurrence (17.06%) of two canals compared to central incisor (10.59%) similar to other studies.[10, 17, 18, 21]. In contrast to this study, others have found central incisors with a high prevalence of two canals.[9, 15, 16] Male (18.82%) shows significantly high occurrence of two canals compared to females (8.82%), which suggests that males have a greater likelihood of complex root canal anatomy similar to other studies.[2, 5, 10, 15, 16, 18, 23] In contrast to our study, other studies have shown females with a high prevalence of 2 canals mandibular incisors.[22, 24] The results of this study show that Vertucci type I (71.8%) has a high percentage of prevalence, followed by type II (15.9%), type III (7.1%), type IV (1.8%), type V (2.9%), and type VII (0.6%). Higher percentage of Vertucci type I canal configuration present in the study was similar to other studies.[9-19, 24] Among double root canals, type II shows highest percentage of occurrence similar to other studies.[19, 25] Most of the studies show type III had high percentage of occurrence in double root canals mandibular incisors.[9, 10, 12, 14-18, 21, 24] There was a statistically significant association between canal configuration and gender. Males were more likely to have type II canal configuration, whereas females were more likely to have type III canal configuration. Variations in canal morphology were found to be significantly higher in males.

The study performed by Amal et al found no significant association between gender and canal configuration, but type V shows a significant association with gender, which is more predominant in males.[21] In another study, they found a statistically significant association between gender and canal configuration, where females tend to have more Type I canal configuration, whereas males tend to have more Type III canal configuration.[16] Another study found that type I, type III, and type VII canal configurations were found significantly higher in males.[10] Another study shows a statistically significant difference between the Vertucci classifications by gender. The incidence of Type III in males was higher than in females, while the incidence of Type I in females

was significantly higher than in males.[18] There was no statistically significant association between tooth types and canal configuration. This study found an equal distribution of canal configuration between central and lateral incisors. Whereas Type VII was present only in the Central incisor and Type IV was present only in the Lateral incisor, which was found similar to the Polish study, where Type VII was present only in the central incisor and Type IV was present only in the lateral incisor.[15] A study conducted in Chile and Belgium patient type I and III were more prevalent in lateral incisors, with no statistically significant difference.[9] A study conducted in Turkey found no statistical significance in canal configuration and tooth type, though more canal variations were present in mandibular central incisors.[18] Another study of the Saudi population shows no statistically significant difference between the mandibular central and lateral incisors among the different types of canal configurations, except that type V was more common in mandibular lateral incisors than in mandibular central incisors, with a statistically significant difference.[21] Whereas in another study conducted in the Saudi population, for two canals found, type III was most frequently present in central incisors, but no canal configuration type II, type IV were found, and only one type V was present in the lateral incisor.[16] A Study conducted in India shows more anatomical variations present in lateral incisors, where type III and type V were found in higher percentages in lateral incisors.[10] A study performed in the Polish population shows an almost equal distribution of canal configuration in central and lateral incisors.[15] These variations in various studies may be due to differences in examination methods, sample sizes, ethnicities, evaluation methods, and the reliability of the examiners.

CONCLUSIONS

Type I was the most common type of canal configuration found in mandibular incisors, whereas type II was most common among two canals in mandibular incisors. Male shows almost double the occurrence of anatomical variations on mandibular incisors. Lateral incisors show a high occurrence of anatomical variations compared to mandibular central incisors.

Clinical implications: Thorough exploration during root canal treatment of mandibular incisors with magnifying tools or CBCT imaging in suspected cases is most important to have better results after root canal treatment of mandibular incisors.

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