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Radiographic assessment of root canal morphology of mandibular central incisors using new classification system

A cross-sectional study

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Abstract

Lack of basic knowledge about the external and internal anatomies of the root canal system and common variations in teeth may lead to various procedural errors or treatment failure. In this study, the root canal configurations of mandibular incisors and the symmetry of the contralateral incisors of Saudi Arabian subpopulations were analyzed and determined using cone beam computed tomography (CBCT). A retrospective evaluation of 700 patients was conducted, and 1260 fully developed permanent mandibular central incisors were assessed. The number of root canals was determined, and the internal root canal anatomies were categorized based on Ahmed et al.'s criteria. The CBCT images were independently evaluated by 2 trained dentists and an endodontist. The data were assessed using the chi-square and one-way analysis of variance tests. All the mandibular central incisors included in the study were single-rooted. According to Ahmed et al's classification system, the most common classification (82.6%) was ^{1}ManA^{1} (Vertucci type I), followed by ^{1}ManA$^{1\text{-}2\text{-}1}$ (Vertucci type III; 13%). Second canals were more frequently recorded in the male participants than in the female participants. The root canal configuration between contralateral incisors was largely symmetrical. Most of the mandibular incisors in the examined Saudi Arabian population had a single canal. Nevertheless, a substantial number of patients had a complex root morphology. Hence, CBCT can be utilized as a potential supplementary tool during root canal treatment.

Abbreviations: 3D = 3-dimensional, C = Canal system, CBCT = cone beam computed tomography, F = Foramen [foramina] F, kV = kilovolt, mA = milliampere, NiTi = nickel-titanium, O = Orifice, s = seconds, SPSS = Statistical Package for the Social Sciences.

Keywords: canal configuration, cone beam computed tomography, mandibular central incisors, new classification system, root canal morphology

1. Introduction

Failure of endodontic treatment is frequently a source of concern for both clinicians and patients. The outcome of root canal treatment is subject to efficient cleaning, disinfection, and filling of the root canals of the teeth. Lack of basic knowledge about the external and internal anatomies of the root canal system and common variations in teeth may lead to various procedural errors or treatment failure. Hence, awareness of the complex root canal morphology is crucial to achieving good-quality root canal treatment.

The introduction of new materials and techniques has significantly increased effective treatment outcomes; anatomical knowledge is crucial to assessing and choosing the appropriate material and tools. Missing untreated root canals account for 12.2% and 17.4%, respectively, of the cases of periapical lesions in the central and lateral mandibular incisors.[1] Von Arx[2] reported that isthmuses or untreated root canals are the main etiological causes of endodontic therapy failure. Although the permanent mandibular anterior teeth often have a single root and a single canal, root canal variations,

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Data related to this study will be made available by the first or corresponding author on demand for academic and clinical purposes via e-mail.

The institutional review board at the College of Dentistry of King Khalid University approved the study protocol (IRB/KKUCOD/ETH/2020-21/017).

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such as an additional canal, a lateral canal, or apical deltas, have been documented by researchers.

Root canal variations along the length of the root, with a long oval cross-section, were found in 25% of the studied sample. Vertucci,[3] in their assessment of 300 extracted teeth, found that 27.5% of the mandibular teeth had 2 root canals. Meanwhile, Al-Qudah and Awawdeh,[4] in their study on the Jordanian population, found that 26.2% of the mandibular incisors had 2 root canals. Ezoddini et al[5] reported 55.9%. However, Miyashita et al.[6] found only a 15% incidence of 2 root canals in the mandibular incisors in their study.

Various techniques are employed to evaluate root canal morphology. These include clinical and in-vitro methods, such as dye injections,[7] decalcification,[8] ex-vivo radiography, in-vitro macroscopic evaluation, and scanning electron microscopy observation of pulp floor sectioning or grinding. Although conventional periapical radiographs are routinely used in clinical practice, their inherent limitations, such as distortions, bone or dental structure overlapping, and 2-dimensional images, make them less reliable. Cone beam computed tomography (CBCT) has been introduced as a diagnostic tool for dental clinical practice. It provides a 3-dimensional (3D) image of the teeth and the surrounding structures at 3 orthogonal planes: axial, coronal, and sagittal. The combination of views at different planes eliminates the superimposed anatomical structures. Hence, root canal morphology, including number, convergence/divergence, and curvature, can be accurately visualized. Additionally, the patients are exposed to less radiation compared to conventional computed tomography.

Verma et al[9] initially proposed the classification of root canals into types I–VIII. Considering the complexity of the root canal anatomy, the root canal classification was subsequently extended by other researchers, such as Martins et al[10] The present study adopted Ahmed et al's[11] classification system to overcome the inadequacies of the preceding classification systems by addressing the number of roots in every tooth type. The said classification system can describe root canal configurations without referring to specific Roman numerals, which is a challenge when applying the Vertucci classification system to teeth with complex canal systems.

As observed in previous studies, root canal morphology varies significantly by race and sex. Thus, it is important to be aware of the incidence of root canal morphology variations in the population to serve it better. In addition, as the variations are genetically determined, it is recommended that the patient's racial origin be traced. Researchers had recommended taking into consideration both race and sex during pretreatment evaluation. Adequate knowledge of the root canal morphology variations among racial groups is essential to identify the locations and subsequent management of teeth requiring root canal treatment.[12–15]

A review of the literature disclosed the paucity of research to assess mandibular anterior root morphology symmetry using CBCT. In the Saudi Arabian population, very few studies have been conducted to evaluate root canal morphology using CBCT. Thus, the present study aimed to assess the root canal morphology variations in the mandibular incisors of Saudi Arabian subpopulations and to evaluate the root canal morphology symmetry between the left and right mandibular incisors using CBCT. The hypothesis formulated was that there will be no variation in the mandibular incisors and the root canal morphology.

2. Materials and Methods

The institutional review board at the College of Dentistry of King Khalid University approved the study protocol (IRB/KKUCOD/ETH/2020-21/017).

2.1. Research design and sample selection

The cross-sectional research design adopted in the present study was descriptive and retrospective and enabled prevalence estimation in nature. Such a research design was selected to estimate the prevalence of lower incisors' root morphology in the Saudi Arabian subpopulations. The study included the retrospective CBCT images of the patients who visited the clinics in the College of Dentistry of King Khalid University within the period from July 2017 to April 2021. Seven hundred patients, 314 (44.9%) of whom were male and 386 (55.1%) female, were included in the study. The patients' ages ranged from 18 to 60 years, with a mean age of 41.7 years. The images were selected based on the following criteria[16]: complete root formation, no previous root canal treatment, absence of direct or indirect coronal restorations, and no root resorption or periapical lesions.

The CBCT images were obtained from KAVO OP 3D Pro (KaVo Dental, Charlotte, NC, USA), and the parameters were set at 59 kV, 5 mA, 5–12 s exposure time, and 0.85 mm voxel size. All the CBCT images were processed and reconstructed using the On demand 3DTM imaging software (Cybermed Inc., Unit K Tustin, CA). Two trained dentists independently evaluated all the images. Kappa statistical analysis was performed to measure the assessment agreement, with k = 0.52. The assistance of a qualified endodontist was sought for decisive evaluation when there was a lack of consensus.

The following parameters were assessed: number of roots in the mandibular central incisors, number of root canals in the mandibular central incisors, and root canal configuration (using Ahmed et al's[15] classification system).

Statistical analysis was performed using the SPSS 19 software (IBM Corporation, Armonk, NY), with the chi-square and one-way analysis of variance tests. The level of statistical significance was set at <.05.

3. Results

Of the 1,260 teeth that were examined, 632 (50.2%) were left mandibular central incisors and 628 (49.8%) were right mandibular central incisors.

3.1. Frequency distribution of numbers of roots in the left and right mandibular central incisors by sex

All the male and female cases included in the present study had one root each in the left and right mandibular central incisors.

3.2. Distribution of root canal configurations in the left mandibular central incisors by sex: root canal configurations according to the new system (orifice[s] O, canal system C, and foramen [foramina] F)

As shown in Table 1, among the 273 male cases studied, 219 (80.2%) had a (1-1-1) root canal configuration (see Fig. 1), 37 (13.6%) had (1-2-1) (see Fig. 2), 6 (2.2%) had (1-1-2), 10 (3.7%) had (1-2-2), and 1 (0.4%) had (2-2-1). Of the 359 female cases studied, 303 (84.4%) had a (1-1-1) root canal configuration, 45 (12.5%) had (1-2-1), 9 (2.5%) had (1-2-2), and 2 (0.6%) had (2-2-1). The root canal configuration distribution in the left mandibular central incisors did not significantly differ between the male and female groups ($P > .05$).

3.3. Distribution of root canal configurations in the right mandibular central incisors by sex: root canal configurations according to the new system (orifice[s] O, canal system C, and foramen [foramina] F)

As shown in Table 2, of the 270 male cases studied, 208 (77.0%) had a (1-1-1) root canal configuration, 3 (1.1%) had (1-1-2), 44 (16.3%) had (1-2-1), 13 (4.8%) had (1-2-2), 1 (0.4%) had

Table 1

Frequency distribution of canal configuration in left mandibular central incisor teeth according to gender.

	Canal configuration [orifice(s), canal system and foramen (foramina)]														
	O-C-F [1-1-1]		O-C-F [1-1-2]		O-C-F [1-2-1]		O-C-F [1-2-2]		O-C-F [2-1-1]		O-C-F [2-2-1]		Total		*P* value
Sex	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	
Male	219	80.2	6	2.2	37	13.6	10	3.7	0	0.0	1	0.4	273	100.0	.057[NS]
Female	303	84.4	0	0.0	45	12.5	9	2.5	0	0.0	2	0.6	359	100.0	
Total	**522**	**82.6**	**6**	**0.9**	**82**	**13.0**	**19**	**3.0**	**0**	**0.0**	**3**	**0.5**	**632**	**100.0**	

P value by Chi-square test. *P* value<.05 is considered to be statistically significant.
NS = Statistically non-significant.
O-C-F – orifice - canal system - foramen (foramina).

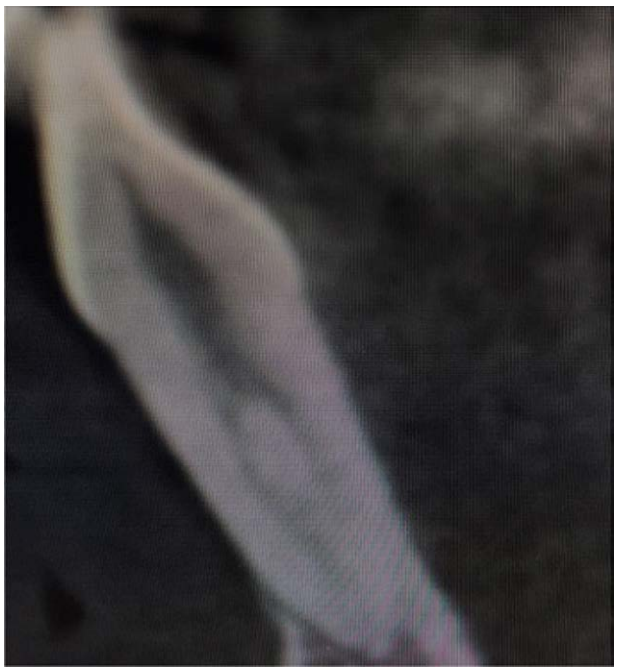

Figure 1. Sagittal cone beam computed tomography slice of a central incisor showing type (1-2-1).

(2-1-1), and 1 (0.4%) had (2-2-1). Of the 358 female cases studied, 304 (84.9%) had a (1-1-1) root canal configuration, 45 (12.6%) had (1-1-2), 7 (2.0%) had (1-2-2), and 2 (0.6%) had (2-2-1). The distribution of root canal configurations in the right mandibular central incisors significantly differed between the male and female groups ($P < .05$).

4. Discussion

Divergent root canal morphology is a common occurrence, making effective cleaning, shaping, and filling challenging for endodontists. Hence, a comprehensive understanding of the expected root canal morphology variations is necessary for successful endodontic treatment. CBCT provides an accurate root canal morphology description through 3D scans with a combination of axial, sagittal, and coronal planes. Sousa et al[17] reported that the diagnostic accuracy of CBCT is 0.89, while that of periapical radiographs is 0.55. The corresponding values for specificity were 0.93 and 0.98, while those for sensitivity were 0.18 and 0.79. Previous studies discovered the higher reliability of CBCT in detecting roots and root canal systems compared to sectioning of the teeth.

Figure 2. Axial cone beam computed tomography slice at the middle root showing two canals.

Vertucci[3] categorized root canal configurations into 8 types. Increasing anatomical complexity in root canal morphology was observed with the advent of CBCT and endodontic microscopy in clinical practice. The existing system's inadequacies in categorizing each root canal morphology variation are becoming more evident. The limitations of the Vertucci classification system, such as in categorizing teeth with analogous root canal configurations but with different numbers of roots as singular types. Moreover, the apical extent of the pulp chamber and the location of the canal orifice are not considered in the classification. Some researchers expressed the opinion that some root canal configurations were non-classifiable when utilizing the Vertucci system. Vertucci[3] reported that the old classification system did not apply to 13% of the samples. In the present study, the new classification system by Ahmed et al.[15] was utilized because it offers comprehensive information (e.g., tooth number, root number, root canal configuration) in a single code precisely depicting the anatomy of the tooth.

The results of the present study showed that the single root canal [1-1-1], which is equivalent to Vertucci type I, was the most prevalent root canal configuration among the participants. This finding is consistent with that of Basha,[9] who reported a 95% incidence of type I Vertucci configuration among the female participants in his study and a 76% incidence among the male participants. These concur with our finding of the predominance of single root canals in the female samples rather than in the male samples. Verma et al.[13] also observed that most of the mandibular incisors (66.5%) in their study among the Indian population had a single root with a single canal. Nevertheless, there were second canals in the right and left central incisors in 33.5% and 30% of the study participants, respectively, compared to only 18.5% and 17.4% in the corresponding teeth in the present study. Notably, our results run counter to those of Sert and Bayirli,[11] who reported that a second canal was detected in 68% of the mandibular central incisors of the indigenous Turkish population. Karobari et al[18] reported more root canal configuration variations in the mandibular incisors of the Malay racial group than in those of the Chinese and Indian racial groups, confirming the influence of race on root canal configurations. These study results also coincide with our observation of the higher prevalence of root canal configuration variations in the mandibular incisors of males.

Table 2

Frequency distribution of canal configuration in right mandibular central incisor teeth according to gender.

	Canal configuration [orifice(s), canal system and foramen (foramina)]														
	O-C-F [1-1-1]		O-C-F [1-1-2]		O-C-F [1-2-1]		O-C-F [1-2-2]		O-C-F [2-1-1]		O-C-F [2-2-1]		Total		*P* value
Sex	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	
Male	208	77.0	3	1.1	44	16.3	13	4.8	1	0.4	1	0.4	270	100.0	.034*
Female	304	84.9	0	0.0	45	12.6	7	2.0	0	0.0	2	0.6	358	100.0	
Total	**512**	**81.5**	**3**	**0.5**	**89**	**14.2**	**20**	**3.2**	**1**	**0.2**	**3**	**0.5**	**628**	**100.0**	

*P value <.05.

P value by Chi-square test. P value <.05 is statistically significant.

O-C-F – orifice - canal system - foramen (foramina).

Our study results are consistent with the observation of the higher prevalence of second canals in male patients than in female patients in earlier studies by Altunsoy et al[7] and Liu et al[19] In the present study, 21.4% of the male patients and 15.35% of the female patients had second canals. Altunsoy et al.[7] observed second canals in 18.9% of the male participants in their study and in 11.8% of the female participants. Meanwhile, Liu et al[19] recorded second canals in 14.6% of the male participants in their study and in 11.9% of the female participants. However, the findings of Verma et al[13] and Kayaoglu et al[1] contradict these findings, showing the predominance of second canals in the mandibular incisors of the female study participants. Verma et al[13] noted that 20.4% of the female participants in their study and 15.2% of the male participants had a second canal.

Knowledge of the existence of root canal anatomical symmetry is of great value during clinical practice. It will assist the clinician while treating 2 opposite teeth of the same patient. The root canal morphologies of the left and right mandibular central incisors of the female patients were symmetrical, but those of the contralateral mandibular incisors were marginally diverse. A similar finding of the higher symmetry of the root canal morphologies of the female participants' mandibular incisors compared to those of their male counterparts was reported by Sroczyk-Jaszczyńska et al[20]

Mashyakhy and Gambarini[21] reported that both the male and female participants in their study from the Saudi Arabian population at Jazan Province had only one root, but there was a higher prevalence of 2 roots in the males (32.7%) than in the females (20.6%). Ghabbani et al[22] found multiple root canals in 49.4% of Saudi nationals compared to 18.2% of non-Saudi ethnic groups. Type I Vertucci configuration was most frequently recorded in 47.3% of the mandibular central incisors. Meanwhile, Al-Fouzan et al,[23] utilizing staining and clearing techniques, observed that about one-third of the Riyadh population had 2 canals in their mandibular incisors. Mohamed et al[24] reported that a single root with 2 root canals was the most common root canal configuration in the mandibular incisors of a Saudi subpopulation in the Qassim region.

As mentioned earlier, awareness of the prevalent root canal morphology in the local population is of great value in clinical practice because root canal morphology variations hinder effective endodontic treatment. Hence, the results of the present study will assist dentists in determining the root canal morphologies in the mandibular central incisors of the surveyed Saudi Arabian subpopulations.

Because of the complex morphology of the root canal system, many technologies have been developed to increase the success of endodontic treatment. Some examples are improving the nickel-titanium (NiTi) rotary and reciprocating the instrument, using ultrasonic equipment for effective disinfection, and using different obturation techniques, such as continuous wave and hydraulic obturation (single cone with hydraulic silicate cements).[24,25]

As for the root canal anatomy, an oval-shaped root canal will make adequate shaping and cleaning complex because the instrument will not be able to touch the recesses and fins on the lingual and buccal aspects of the canal. This irregular morphology, which does not match the round instrumentation system, may leave bacteria inside the root canal, and the level of bacteria in the root canal will determine whether the periradicular inflammation will be sustained.[26] The root canal may also be packed with dentin chips, which will interfere with the quality of the obturation.[27] When infected root canals are missed, the remaining bacteria may cause or maintain periapical diseases, compromising the endodontic treatment and decreasing the expected treatment outcome.[28–30]

The present study had some limitations. First, the participants who were evaluated in the study were from a southern province of Saudi Arabia. Hence, the study results are not generalizable to the entire Saudi population. Second, even though root canal morphology evaluation with CBCT has many advantages, it cannot be routinely recommended for all patients because it exposes patients to higher radiation levels compared to conventional radiographs.

5. Conclusions

Within the limitations of the present study, the results indicate that the mandibular central incisors predominantly showed one root canal from the orifice to the foramen. Second canals were more common in men than in women. Contralateral mandibular central incisors showed a symmetrical root canal morphology.

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