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ORIGINAL ARTICLE

Cone-beam computed tomographic evaluation of root canal morphology of mandibular anterior teeth in a Saudi subpopulation, retrospective *In-Vivo* study

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KEYWORDS

Cone beam computed tomography;
CBCT;
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Mandibular canine;
Root canal configuration

Abstract *Background:* There is variability in the results of dental morphological studies between different ethnic populations. This study aimed to investigate the root canal morphology of mandibular anterior teeth in a Saudi subpopulation in the Riyadh region.

Methods: We examined a total of 1,769 cone-beam computed tomography (CBCT) images of the mandibular anterior teeth, including the central incisors (n = 587), lateral incisors (n = 590), and canines (n = 592). The number and configuration of the root canals were determined. Fisher's exact and Pearson's chi-square tests were used to assess the differences between sexes and age groups, with a level of statistical significance was set at $p < 0.05$.

Results: Overall, Type I canal was the most frequent configuration among the mandibular anterior teeth (76.1%). However, the prevalence of Type III canal configuration in the central and lateral incisors was 36.5% and 31%, respectively. Additionally, the mandibular canines were mainly Type I canals (98.4%). The prevalence of canal configuration was predominantly Type I (95.7%), followed by Type III (2.7%), Type IV (0.4%), and Type V (1.2%). There was a statistically significant difference in the canal configurations between men and women ($p = 0.02$). Females more often had Type I root canals (60.6%), while Type III was more frequent in males (57.2%). However, there were no statistically significant differences between the age groups in canal configuration.

Conclusion: The mandibular anterior teeth of the Saudi subpopulation had mainly one root canal. However, almost one-third of the central and lateral incisors had two canals. CBCT is a

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useful tool that can be used, if available, to investigate root canal morphology before root canal treatment.

1. Introduction

Majority of failed endodontic cases are associated with interradicular microbial infections resulting from the failure to eliminate all pulp tissue and microorganisms from the entire root canal system (Cantatore et al., 2006; Vertucci, 2005). Thus, a thorough understanding and complete awareness of root canal morphology and its anatomical variations are essential to achieve successful root canal treatment.

Generally, mandibular incisors and canines have one root and one canal. However, previous classic studies on morphology of mandibular anterior teeth have documented the presence of two canal systems located in the buccal and lingual directions, with different canal configurations (Benjamin and Dowson, 1974; Green, 1955; Hess and Zürcher, 1925). If a second canal is present, the failure to locate, debride, and seal it during endodontic treatment might affect the outcome. Therefore, one of the main reasons for endodontic treatment failure in mandibular incisors is the mismanagement of the second canal, usually the lingual canal (Benjamin and Dowson, 1974). However, the prevalence of the two canals in mandibular incisors and canines varies widely as revealed by numerous studies in different populations (Al-Fouzan et al., 2012; Al-Qudah and Awawdeh, 2006; Boruah and Bhuyan, 2011; Martins et al., 2020; Sert et al., 2004; Vertucci, 1984).

For almost a century, many morphological studies have been conducted using different clinical and laboratory techniques to explore internal root canal morphology (Green, 1955; Hess and Zürcher, 1925). These include sectioning of extracted teeth, clearing techniques, conventional radiography, and cone-beam computed tomography (CBCT). CBCT is a noninvasive technique that provides three-dimensional images via a single exposure of a cone-shaped beam of radiation around an object, obtaining volume in a 360-degree rotation to reveal the internal architecture of that object. Technically, CBCT has been shown to be a reliable method for assessing and exploring the root canal anatomy (Matherne et al., 2008; Michetti et al., 2010). In recent years, it has been extensively used to investigate and evaluate root canal morphology in various populations (Altunsoy et al., 2014; Han et al., 2014; Verma et al., 2017).

Based on several morphological studies, the root canal morphology is known to be affected by genetic and racial conditions, and a variability is seen across different ethnic groups and populations (Martins et al., 2020; Sperber, 1990). Accordingly, further research is warranted to fully explore the differences in root canal morphology among different populations. Limited studies have investigated the root canal morphology of mandibular anterior teeth in different regions of the Saudi population using CBCT. Therefore, this study aimed to explore the root canal morphology of mandibular incisors and canines among Saudi subpopulations in the Riyadh region using CBCT. Additionally, the null hypothesis to be tested was that there is no difference between sex and age regarding the proportion of second root canal in both mandibular incisors and canines.

2. Materials and methods

The study was structured according to specific preferred reporting items for cross-sectional studies on root and root canal anatomy using CBCT that been proposed by Martins et al., (2020a). In order to improve the quality and increase the validity of this study, all items have been addressed (as shown in Table 1) are followed.

2.1. Data acquisition

We recruited all participants who had undergone CBCT for different dental purposes (orthodontics, endodontics, surgery, and implant treatment planning) at the University Dental Hospital (DUH) and King Saud University in Riyadh, Saudi Arabia between 2018 and 2020. By primarily scanning all the cases (n = 1,320) during a four-month period (January–April 2021), we selected 300 cases that met the inclusion criteria. A total of 1,769 mandibular anterior teeth, 587 central incisors, 590 lateral incisors, and 592 canines were included. The study was approved by the local Institutional Review Board (Research project No. E-20–5003) and the Review Committee of the College of Dentistry Research Center (CDRC), with

Table 1 Specific Preferred Reporting Items for Cross-sectional Studies on Root and Root Canal Anatomy Using Cone-beam Computed Tomographic (CBCT) (Martins et al., 2020a).

Section and items
1. Title
Introduction
2. Keywords
3. Aim
Methods
4. Participants (in vivo assessment)
5. CBCT
6. Morphology concept and assessed teeth (variables)
7. Assessment
8. Observers
9. Potential sources of bias
10. Final simple size
11. Reliability
12. Statistical analysis
13. Ethics Committee
Results
14. Primary outcomes
15. Other analysis
16. Visual documentation support.
17. Discussion
18. Outcomes interpretation
19. Strength and limitations
20. Generalizability
21. Future research

approval number (No. IR 0380) and conducted in accordance with the Declaration of Helsinki of the World Medical Association.

2.2. Inclusion and exclusion criteria

We included any fully matured mandibular incisors and canines on the right and left sides, if both were available. Teeth with root canal fillings, posts, open apexes, periapical lesions, root resorption, or unclear CBCT images were excluded from the study to eliminate any potential sources of bias.

2.3. Radiographic evaluation and techniques

The CBCT images were taken with a Planmeca Promax 3D Max Digital Imaging Device (Planmeca, Helsinki, Finland) with the following specifications: 84 kVp, 12.0 mA and 160 μm voxel size; the exposure time was 12 s. Tomography sections of 0.2 mm thick in the axial, coronal, and sagittal planes were displayed using Planmeca Romexis® 3.6 viewer software (Planmeca, Helsinki, Finland). Adjustable contrast and brightness of the viewer software were used to obtain optimal image visualization. All CBCT images were examined independently by two examiners (general dentists who have been well trained in CBCT) in the sagittal, coronal, and axial planes. Cases in which there was any disagreement between the two examiners were reevaluated independently by a third examiner (experienced endodontist), and then a final decision was made. A series of CBCT images were examined carefully by scrolling up and down from the pulp chamber to the apex to determine the number of roots, number of canals, and canal configurations according to the Vertucci classification (Vertucci, 1984). Moreover, differences between sexes and age groups were recorded.

To evaluate inter- and intra-examiner reliability, 30 cases were randomly collected and examined independently by the examiners on two occasions, with a one-week interval between each evaluation. An agreement was calculated using the Cohen Kappa coefficient value (k), ranging from 0.0 to 1.0 (with 1.0 indicating a perfect agreement).

2.4. Statistical analysis

Statistical analysis was performed using SPSS software (version 25.0, Inc., Chicago, IL, USA, IBM Corp, 2017). Fisher's exact and Pearson Chi-square tests were used to assess the differences between the gender and age groups. The level of statistical significance was set at $p < 0.05$.

3. Results:

For the inter-examiner reliability, results of Cohen Kappa coefficient value indicated a substantial level of agreement was achieved ($k = 0.80$), and almost a perfect agreement was reached for the intra-examiner reliability ($k = 0.95$ and 1) for first and second examiners, respectively.

A total of 1,769 mandibular anterior teeth (587 central incisors, 590 lateral incisors, and 592 canines) were evaluated. These teeth were examined using CBCT in 300 participants, including 145 men (48%) and 155 women (52%). The age of the participants ranged from 12 to 71 years, with a mean age of 30.47 years (median = 41.5 years).

Overall, the Type I canal was the most frequent configuration among all mandibular teeth (76%). All mandibular central and lateral incisors had a single root (100%), with one canal Type I (66%) or two canals Type III (34%). The prevalence of Type III canal configuration in the central and lateral incisors was 36.5% and 31%, respectively (Fig. 1). Additionally, mandibular canines had a single root (98.4%). The prevalence of canal configuration in the mandibular canines was predominantly Type I (95.7%). The frequency and percentage of root canals and canal configurations are presented in Table 2.

Regarding sex, among the lower mandibular teeth, females tended to have more Type I than Type III (60.6% vs. 39.4%), and males tended to show more Type III than Type I (57.2% vs. 42.8%, Table 3). There was a statistically significant difference between men and women with respect to the type of canal configuration ($p < 0.05$, $p = 0.002$). Conversely, there was no association between the number of root canals among the different age groups, as shown in Table 4 ($p > 0.05$, $p = 0.393$,).

4. Discussion:

This study was conducted to assess the root canal morphology of mandibular incisors and canines in a Saudi subpopulation in the Riyadh region. A total of 300 patients (145 men and 155 women) with 1,769 mandibular anterior teeth who underwent CBCT scanning for different purposes were included. The results revealed that all mandibular incisors had a single root, and two-thirds of the participants (66%) had a Type I canal configuration (one canal with one apical foramen). The findings are comparable to those of many other studies that have shown that all mandibular incisors have a single root, and that the majority of their samples had a Type I canal system (Al-Fouzan et al., 2012; Al-Qudah and Awawdeh, 2006; Altunsoy et al., 2014; M Mashyakhy, 2019; Verma et al., 2017).

The presence of two canals in the central and lateral incisors in participants of our study was 36.5% and 31%, respectively. These results are similar to the range reported in earlier studies on different populations which documented that nearly one-third of mandibular incisors exhibited two canal systems (Al-Qudah and Awawdeh, 2006; Boruah and Bhuyan, 2011; Mashyakhy, 2019). However, some other studies have reported a higher percentage of the two canal systems in mandibular incisors. Sert et al., (2004) found that 68% of the mandibular incisors in the Turkish population had two canals. In addition, another studies that included Saudi population, one in the Al-Qassim region (Mohamed et al., 2021), reported that 55.6% of mandibular incisors had two canals, while the other study in the Al-Madinah region by Ghabbani et al., (2020) found that 49.4% of mandibular incisors had two canals (Table 5). This discrepancy in results could be attributed to differences in the ethnic backgrounds of the participants, sample sizes, evaluation methods, and reliability of the observers.

As regards the canal configuration, several reports (Boruah and Bhuyan, 2011; Popović et al., 2018; Verma et al., 2017) have documented that if the mandibular incisors had two canals, the Type III configuration was the most common (this is when one canal is divided into two and then joined as one at

Fig. 1 **(a & b):** CBCT section of mandibular lateral incisor with type III canal configuration: (a) sagittal view, (b) axial view. **(c & d):** CBCT section of mandibular canine with type V canal configuration and two roots: (c) sagittal view, (d) axial view.

Table 2 Frequency and percentage of the number of the root canal and canal configuration (according to Vertucci classification) of the mandibular anterior teeth by tooth type and gender.

	Mandibular Central Incisor			**Mandibular Lateral Incisor**			**Mandibular Canine**		
	Male n (%)	Female n (%)	Total n (%)	Male n (%)	Female n (%)	Total n (%)	Male n (%)	Female n (%)	Total n (%)
Number of canal									
One canal	155 (55.5)	218 (70.8)	373 (63.5)	175 (61.8)	232 (75.5)	407 (69)	271 (95.8)	296 (95.8)	567 (95.7)
Two canals	124 (44.4)	90 (29.2)	214 (36.5)	108 (38.2)	75 (24.5)	183 (31)	12 (4.2)	13 (4.2)	25 (4.3)
Total	279 (100)	308 (100)	587 (100)	283 (100)	307 (100)	590 (100)	283 (100)	309 (100)	592 (100)
Canal configuration									
Type I	155 (55.5)	218 (70.8)	373 (63.5)	175 (61.8)	232 (75.5)	407 (69)	271 (95.8)	296 (95.8)	567 (95.7)
Type II	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Type III	124 (44.4)	90 (29.2)	214 (36.5)	107 (37.8)	75 (24.5)	182 (30.8)	7 (2.5)	9 (2.9)	16 (2.7)
Type IV	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.3)	1 (0.3)	2 (0.4)
Type V	0 (0)	0 (0)	0 (0)	1 (0.4)	0 (0)	1 (0.2)	4 (1.4)	3 (1%)	7 (1.2)
Total	279 (100)	308 (100)	587 (100)	283 (100)	307 (100)	590 (100)	283 (100)	309 (100)	592 (100)

Table 3 Comparison between male and female participants in frequency and percentage of the number of root canals in mandibular anterior teeth.

		Number of canals		Total
		One canal	Two canals	
Male	n	62	83	145
	(%)	(42.8)	(57.2)	(100.0)
Female	n	94	61	155
	(%)	(60.6)	(39.4)	(100.0)
Total	n	156	144	300
	(%)	52.0%	(48.0)	(100.0)

Table 4 Comparison between age groups of subjects in frequency and percentage of the number of root canals in mandibular anterior teeth.

Age group		Number of canals		Total
		One canal	Two canals	
(10–29)	n	82	74	156
	(%)	(52.6)	(47.4)	(100.0)
(30 – 49)	n	37	39	76
	(%)	(48.7)	(51.3)	(100.0)
(50 +)	n	12	10	22
	(%)	(54.5)	(45.5)	(100.0)
Total	n	131	123	254
	(%)	(51.6)	(48.4)	(100.0)

the apex), followed by Type II (two canals joined as one at apex), then Types IV and V canals that existed in two separate foramina (Fig. 1). However, in our study, all mandibular incisors with two canals were found to have a Type III canal configuration. Moreover, in a study of a Chinese subpopulation (Lin et al., 2014) that investigated 1,412 mandibular incisors, it was found that lateral incisors exhibited two canals significantly more frequently than central incisors (25.5% vs. 10.9%). However, our results show that both the central and lateral incisors were comparable in the presence of a two-canal system.

With regard to the gender differences, the present study reported that the presence of one canal (Type I) was more frequent in females than in males (60.6% vs. 42.8%), while two canals (Type III) were more prevalent in males than females (57.2% vs. 39.4%). These findings are in agreement with those of previous studies conducted among different populations in China (Lin et al., 2014), Saudi (Ghabbani et al., 2020; M Mashyakhy, 2019) and Turkey (Altunsoy et al., 2014) divulging that the prevalence of two canals for mandibular anterior teeth in men was significantly higher than that in women. In addition, a recent *meta*-analysis revealed that sex and patient geographic origins are possible confounding factors that can influence the prevalence of a second canal in the mandibular anterior teeth (Martins et al., 2020).

In mandibular canines, most studies have reported higher percentages of single roots, with predominantly Type I canal configuration (Al-Dahman et al., 2019; Altunsoy et al., 2014; Han et al., 2014; Mohammed Mashyakhy, 2019). Similarly, the findings of the present study showed that the majority of mandibular canines (98.4%) had single roots, mainly canal Type I (95.7%), followed by Type III (2.7%), Type IV (0.4%), and Type V (1.2%). In addition, our results also revealed that a small percentage (1.6%) of the mandibular canines had double roots. These findings are comparable with other studies undertaken with the Saudi subpopulation; one study (Mohammed Mashyakhy, 2019) reported that 11 teeth out of 410 mandibular canines had two roots (2.7%), while another one (Al-Dahman et al., 2019) noted that only one tooth out of 454 mandibular canines (0.2%) was double-rooted. Nevertheless, a study on the Serbian population (Popović et al., 2018) showed that the incidence of mandibular canines with two canals can be as high as 7.1%. Moreover, when we compared mandibular incisors with canines, there was a higher prevalence of two canals in incisors than in canines (33.7% vs. 4.3%). However, canines have more possibility of two canals being separated at the apex (Types IV and V), while all of the incisors that had two canals were found to be joined into one apical foramen (Type III).

As the present as well as previous studies have illustrated the morphology of root canals in mandibular incisors and canines and the possibility of the presence of second canal, clinicians should always assume the presence of a second canal and accordingly access an opening. Inadequate access cavity preparation on mandibular incisors and canines and incomplete removal of the lingual shelf of dentin over the second canal are the most common causes of mistreatment of the lingual canal. Therefore, pre-assessment of the case by carefully interpreting the preoperative radiographs is highly important, and it has been recently recommended by the European Society of Endodontology to have CBCT for assessment of complex root canal anatomy prior to endodontic management or

Table 5 comparison of root canal configuration (according to Vertucci classification) of the mandibular incisors and canines between previous studies at different regions of Saudi subpopulation and the present study:

Study/year	Region	Method	Tooth type	Sample size	Type I (%)	Type II (%)	Type III (%)	Type IV (%)	Type V (%)
Present study	Riyadh	CBCT	Central incisor	587	63.5	0	36.5	0	0
			Lateral incisor	590	69	0	30.8	0	0.2
			Canine	592	95.7	0	2.7	0.4	1.2
(Mohamed et al., 2021)	Qassim	CBCT	Central incisor	188	41	10.1	45.7	1.1	2.1
			Lateral incisor	188	48	5.8	44.1	0	2.1
(Ghabbani et al., 2020)	AlMadinah	CBCT	Central incisor	812	49.4	0	43.3	0.2	7.1
			Lateral incisor	812	51.4	0	41.5	0.2	6.9
(M Mashyakhy, 2019)	Jazan	CBCT	Central incisor	410	73.7	0	26.3	0	0
(Mohammed Mashyakhy, 2019)			Lateral incisor	412	69.2	0	29.8	0	1
			Canine	410	90.7	0	6.1	0	3.2
(Al-Fouzan et al., 2012)	Riyadh	Clearing/ extracted teeth	Central incisor	40	70	0	30	0	0
			Lateral incisor	40	70	0	30	0	0
(Al-Dahman et al., 2019)	Riyadh	CBCT	Canine	454	95.4	2.6	1.8	0.2	0

before nonsurgical re-treatment in cases of possible untreated canals (Patel et al., 2019).

Our data were obtained from a dental center in Riyadh; thus, the findings cannot be generalized to the entire population. Further studies from multiple centers with larger sample sizes and systematic reviews of existing studies on the Saudi population, if available, are highly recommended.

5. Conclusion

Although the majority of mandibular anterior teeth in the Saudi subpopulation in the Riyadh region exhibited a single root with one canal, almost one-third of the central and lateral incisors had two canals. Therefore, it is essential for clinicians to consider the presence of a second canal when attempting to access the cavity in the mandibular incisors and attempt to locate it by careful examination. In addition, it is evident that CBCT is a useful diagnostic tool for the detection of root canals. Therefore, clinicians should consider using CBCT in those cases wherein more information is needed to achieve successful treatment outcomes.

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CRediT authorship contribution statement

Muath Alshayban: Methodology, Writing – original draft. **Turki Abughosh:** Investigation. **Waleed Almalki:** Investigation. **Mishary Alrasheed:** Investigation.

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Ethical approval registration

The study was ethically approved by the local institutional review board (IRB) (Research project No. E-20-5003) at King Saud University, and by Review Committee of College of Dentistry Research Center (CDRC) (No. IR 0380). The study was conducted in accordance with the World Medical Association Declaration of Helsinki.

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