Original Article

Quantitative statistical evaluation of maxillary and mandibular incisor root canal morphology in Saudi patients

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Abstract

Introduction: Clinical practice demands understanding the complexity of the root canal system to achieve desired treatment goals. The statistically detailed morphology of the tooth and root canal morphology is very important to know. Therefore, the present study aims to investigate the statistical analysis of root canal morphology and morphological variations of maxillary and mandibular incisor teeth using cone-beam computed tomography (CBCT) in Saudi patients attending King Saud University Dental Hospital.

Materials and Methods: CBCT images of 480 patients were selected. Number of roots and root canal configuration were identified and categorized according to Vertucci's classification. Tooth length, distance from cementoenamel junction (CEJ) to the area of canal division, and width of the canal at the area of division were also evaluated. Bilateral symmetry and association between gender and age with the different variables were investigated. Data were analyzed using Chi-square, multiple linear regression, and McNemar's tests.

Results: A total of 3412 teeth were evaluated. All maxillary teeth had one root with Type I canal configuration. For mandibular teeth, all exhibited one root with the majority having Type I canal configuration in central (71.2%) and lateral (75%) incisor teeth. There was a statistically significant association between number of canals and age in mandibular incisor teeth observed only in females ($P < 0.001$), while no association was observed between canal configuration and gender ($P = 0.900$ and $P = 0.721$, respectively). Multiple regression analyses showed that age and gender significantly explain the difference of the variance in tooth length ($P < 0.001$). Moreover, bilateral symmetry was observed in 98.1% of mandibular central and 97.6% of lateral incisor teeth with no statistically significant association ($P = 1$ and $P = 0.058$, respectively).

Conclusion: All maxillary and most mandibular incisor teeth present with one root and Type I canal configuration. In general, males have longer teeth than females, with a significant decrease in length with

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each year increase in age. Mandibular lateral incisor teeth exhibited the highest mean distance from CEJ to point of canal separation and highest mean width in the area of canal division.

Keywords: Cone-beam computed tomography, mandibular incisors, maxillary incisors, root canal morphology, statistical evaluation

INTRODUCTION

The success of root canal therapy is attributed to the proper shaping, cleaning, and filling of the root canal system. It requires a thorough understanding of the external and internal anatomy of the root canal system and its morphological variations.[1,2] These variations play an essential role in endodontic therapy. The failure to locate and treat all root canals will lead to the persistence of microorganisms and necrotic tissues inside the canals and impact the treatment outcomes.[3]

Different variations of root canal system morphology have been investigated and classified by several investigators,[4-7] and the most widely used is Vertucci's classification.[5] Maxillary and mandibular central and lateral incisors typically present with a single root and single root canal.[5,8] However, morphological variations exist and are correlated to various racial and genetic factors.[8,9]

The reported number of roots in maxillary central and lateral incisors was one root (100%) with Type I canal configuration (100%).[5,8,9] Most of the mandibular central and lateral incisors teeth were reported to have one root and Type I canal configuration, while the prevalence of one root with two root canals has been reported to range between 25% and 30% in both mandibular central and lateral incisor teeth.[5,8,10]

Different methods are available to study the root canal system, including the clinical evaluation during root canal treatment, retrospective assessment of patients' records, conventional radiography, digital radiography, cone-beam computed radiography (CBCT),[11,12] canal staining and tooth clearing,[5,10] tooth sectioning,[4] microscopic examination, and using three-dimensional (3D) methods such as micro-computed tomography (μ-CT).[13-15]

A few studies that investigated the root canal morphology of maxillary incisor teeth using CBCT in Saudi Arabia were conducted in Jazan City,[9] Al-Madinah Al-Munawara,[16] Qassim[17] and in Riyadh.[18] In addition, one study in Riyadh evaluated the root canal morphology using the tooth-clearing method.[10]

To the researchers' knowledge, no study has so far evaluated statistically the detailed morphology of the tooth and root canal morphology of maxillary and mandibular incisor teeth using CBCT in Saudi patients. The present study aims to investigate this in Saudi patients attending King Saud University Dental Hospital.

MATERIALS AND METHODS

Setting and design

The study project was approved by the Institutional Review Board (IRB) of King Saud University, Kingdom of Saudi Arabia, under the registration number: E-20-5626. The study was conducted in accordance with the World Medical Association Declaration of Helsinki.

This cross-sectional retrospective study was conducted on the CBCT images of Saudi patients seeking routine dental treatment who were referred to the Radiology Department of the King Saud University Dental Hospital between 2019 and 2021.

The manuscript was written according to Preferred Reporting Items for Laboratory Studies in Endodontology 2021 guidelines [Figure 1].

Data collection

Since the study used multiway frequency analysis, it was difficult to calculate the sample power because it depended on the various variables (age, gender, number of roots, canal configuration, tooth length, bifurcation distance, and width of the canal at the area of division) that were assessed in the study.[19] A minimum total sample was 240, which would be doubled to 480 for a reasonable chance of finding 3rd order effects. While for the continuous variables (age and bifurcation distance), using the expected correlation coefficient as small ($r = 0.2$), $\alpha = 0.05$, $\beta = 0.2$, and two-tailed test, so the minimum sample size would be 193 participants. Moreover, using 480 participants, there was a >99% probability ($\beta < 0.01$) of detecting a statistically significant effect for a correlation of 0.2 and $\alpha = 0.05$.

The inclusion criteria were as follows: the presence of at least one maxillary or mandibular central or lateral incisor tooth with fully developed roots in clear CBCT images of

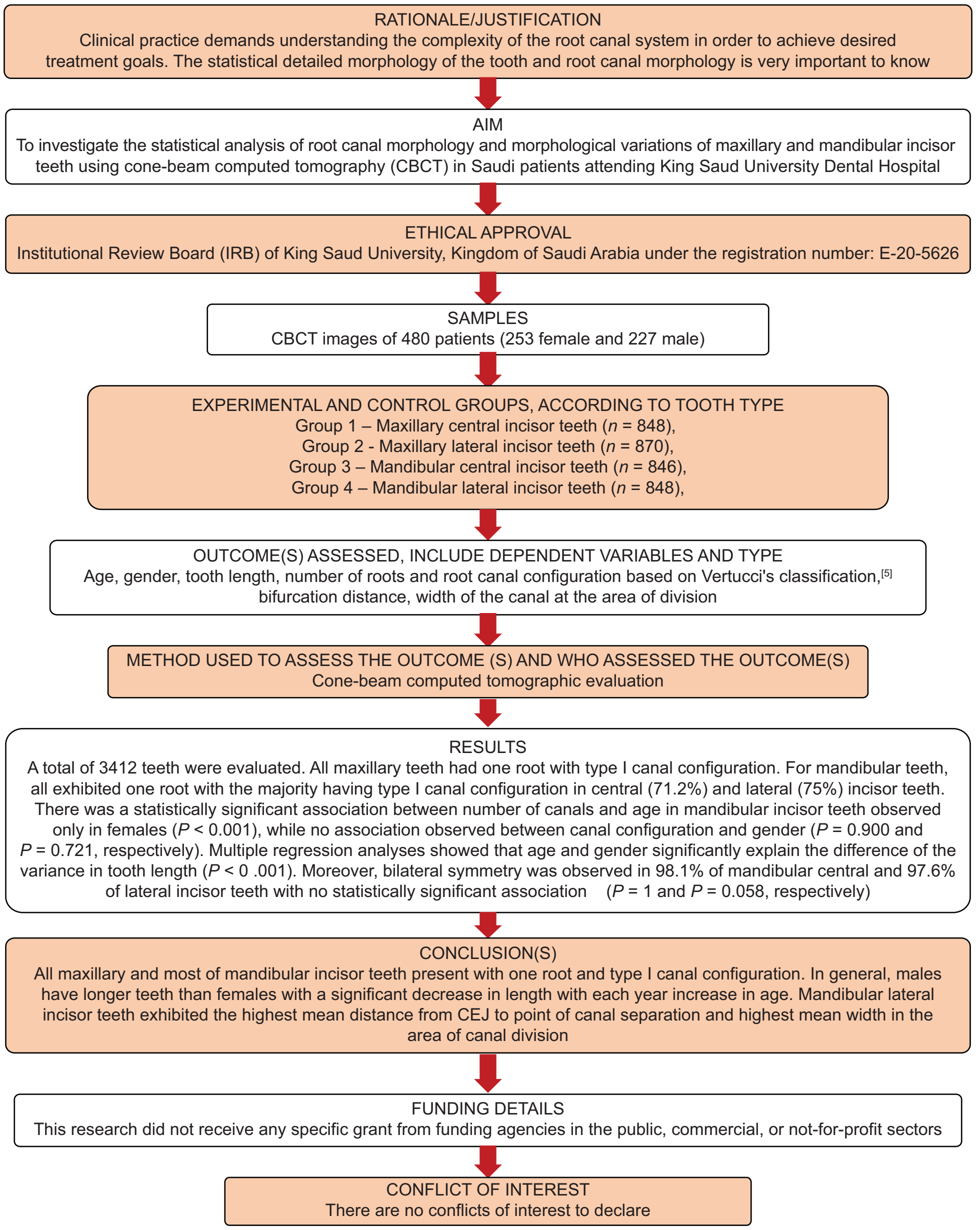

Figure 1: Preferred Reporting Items for Laboratory studies in Endodontology 2021 flowchart. CBCT: Cone-beam computed radiography

Saudi patients no <13 years of age, teeth with no previous endodontic therapy, absence of posts or crowns, periapical lesions, and any physiological or pathological process such as dental caries or resorption, and teeth opposed by natural teeth.

The exclusion criteria were: missing maxillary and/or mandibular central and/or lateral incisor tooth, CBCT images of patients under 13 years of age, CBCT images of non-Saudi patients, distorted CBCT images, previous endodontically initiated or treated teeth, presence of posts or crowns, periapical lesions, and any physiological or pathological process, teeth with immature apex, presence of active/passive orthodontic treatment.

The CBCT images were evaluated by two endodontists, each with at least 3 years of clinical experience, for morphological variations in the axial, sagittal, and coronal planes using the Planmeca Romexis Viewer software (PLANMECA, Roselle, IL, USA). In case of any disagreement, a third evaluator (oral radiologist) was consulted to reach the final consensus. The images were collected from a CBCT machine: Planmeca ProMax 3D (PLANMECA, Helsinki, Finland) with a voxel size of ≤200 μm. The exposure time was <15 s and the sample included CBCT images with either small or large fields of view. The CBCT cross-sections were set at 0.2 mm thick and were viewed from the coronal to apical regions on the HP Z420 workstation (HP, Palo

Alto, CA, USA) with a 30" Barco MDCC-6130 color LCD monitor (Beneluxpark, Kortrijk, Belgium) with a resolution of 3280 × 2048 pixels in a dark room. The contrast and brightness of the images were adjusted to ensure optimal visualization with the software.

The CBCT image samples were carefully selected and subjected to exclusion criteria until reaching 480 samples starting from January 1st, 2019, to May 6th, 2021. The total final samples were evaluated in terms of tooth length; measured by calculating crown and root length separately by drawing a horizontal line indicating the cementoenamel junction (CEJ) and then measuring the crown length from the most superior point on the incisal edge to the CEJ line, and root length from the CEJ line to the most inferior point on the root in the sagittal view of the CBCT image [Figure 2]. The number of roots and root canal configuration was evaluated based on Vertucci's classification.[5] The age and gender of the patients were also recorded.

Figure 2: Example used to illustrate evaluation procedure: The green line is drawn down the length of the tooth from crown to root apex. Blue line, a line perpendicular to the green line indicating the cementoenamel junction (CEJ). Red line, line drawn to measure the crown length from the most superior point on the incisal edge to the CEJ line (here 10.58 mm), and root length from the CEJ line to the most inferior point on the root (here 13.33 mm)

Moreover, in samples having two root canals, additional evaluation criteria included bifurcation distance, recorded from the CEJ to the canal terminus in the sagittal view of the CBCT image by adjusting the starting point at CEJ level (Point A) and the endpoint at the furcation area (Point B) then calculating the distance between the two points; and width of the canal at the area of division, by adjusting two points on the inner buccal wall (Point A) and the inner lingual wall (Point B) of the main canal at the area of the division on the axial view of the CBCT image, then calculating the distance between the two points [Figure 3].

Data analysis and management

To ensure the reliability of the research results, inter- and intra-examiner reliabilities were measured by identifying the root canal anatomy of maxillary and mandibular incisor teeth of 30 randomly selected CBCT images according to the evaluation criteria. For intra-examiner reliability, the same images were evaluated after 1 week. Both inter- and intra-examiner reliability were calculated using the Kappa test for categorical variables and interclass correlation coefficient (ICC) for continuous quantitative variables. The Kappa test and ICC were used to calculate the inter-and intra-examiner reliabilities for categorical and continuous quantitative variables, respectively.

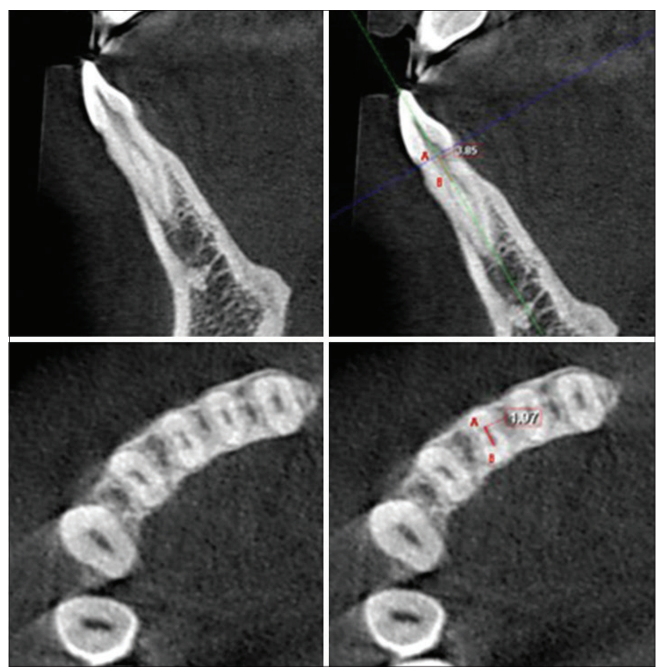

Figure 3: Example with two root canals, to illustrate measurement evaluation procedure. As in the previous figure, the green line is drawn down the length of the tooth from crown to root apex. Blue line, a line perpendicular to the green line indicating the cementoenamel junction (CEJ). Red line: (Above right) line drawn to measure the distance between CEJ and furcation area (A – B, here 3.85 mm), (below): Line drawn to measure the width of the canal at area of division (A – B, here 1.97 mm)

The Chi-square test was used for testing categorical data. The Chi-square (test of association) was used in this study to determine if the difference between observed data and expected data was due to chance. Multiple linear regression was used, with tooth length as the dependent variable and age and gender as predictors. The McNemar test is a nonparametric test used in this study to determine if there are differences on a dichotomous dependent variable between two related groups.

All analyses were done using statistical software Jamovi version 2.3 (The jamovi project [2022]. jamovi. [version 2.3] [Computer Software]). Retrieved from https://www.jamovi.org. Statistical significance was set at 5%.

RESULTS

For interexaminer reliability, the kappa test was 1 (excellent) for the number of roots and 0.841 (excellent) for canal configuration. For intraexaminer reliability, ICC was 1 for the first examiner and 0.963 for the second examiner in regard to the total length measurements. The ICC demonstrated that the procedure was standardized for the evaluations and measurements performed by the two observers.

A total of 480 CBCT images were evaluated (253 females and 227 males) with a mean age of 39 years. The total final number of teeth evaluated was as follows: 848 maxillary central incisor teeth, 870 maxillary lateral incisor teeth, 846 mandibular central incisor teeth, and 848 mandibular lateral incisor teeth. The maxillary central and lateral incisor teeth of both genders were presented with one root and one canal (100%) in all CBCT images evaluated. In both teeth, Type I canal configuration was the most prevalent observation (100%). For this reason, the statistical difference could not be computed.

For mandibular teeth, central and lateral incisors presented with one root (100%) in all CBCT images evaluated. In both teeth, Type I canal configuration was the most prevalent observation (71.2% and 75%, respectively), followed by Type III (28.4% and 25%, respectively). Furthermore, Type V canal configuration was observed in mandibular central incisor teeth in 0.4%. In mandibular central incisor teeth, Type V canal configuration merged with Type III for statistical analysis. There was no statistically significant association in mandibular central and lateral incisor teeth between canal configuration and gender (χ^2 [1] = 0.0158, P = 0.900 and χ^2 [1] = 0.127, P = 0.721, respectively).

There was a statistically significant association between number of canals and age in central and lateral incisor teeth, but only in females (χ^2 [4] = 38.21, $P < 0.001$ and χ^2 [4] = 43.93, $P < 0.001$, respectively). In general, males have longer teeth than females in all studied groups. The mean tooth length for maxillary central incisor was 23.0 mm in males and 22.4 mm in females, while for lateral incisor teeth, the mean tooth length was 22.2 mm in males and 21.5 mm in females. For mandibular central incisor teeth, the mean tooth length was 20.2 mm in males and 19.8 mm in females. Moreover, the mean tooth length was 21.3 mm in males and 20.9 mm in females in mandibular lateral incisor teeth. The total lengths for maxillary and mandibular central and lateral incisor teeth are presented in Figures 4 and 5.

Multiple regression analyses examined the relationship between tooth length and gender and age. In maxillary central and lateral incisor teeth, multiple regression showed that age and gender significantly explain the variance in tooth length (R^2 = 0.127, $P < 0.001$ and R^2 = 0.0955, $P < 0.001$, respectively). The results showed that males have longer teeth than females by 0.6523 mm for central and 0.6967 mm for lateral incisor teeth ($P < 0.001$), and with each year increase in age, the tooth length decreased by 0.0384 mm for central and 0.0247 mm for lateral incisor teeth ($P < 0.001$).

For mandibular central and lateral incisor teeth, multiple regression showed that age and gender significantly explain the variance in tooth length (R^2 = 0.0973, $P < 0.001$ and R^2 = 0.0510, $P < 0.001$, respectively). The results showed that males have longer teeth than females by 0.3934 mm for central and 0.4286 mm for lateral incisor teeth ($P < 0.001$), and with each year increase in age, the tooth length decreased by 0.0324 mm for central and 0.0193 mm for lateral incisor teeth ($P < 0.001$). The mean distance from CEJ to the area of canal division of mandibular central and lateral incisor teeth was longer in females than in males in both tooth groups [3.37 mm and 3.46 mm, respectively; Table 1].

Multiple regression analyses examined the relationship between the distance from CEJ to the area of canal division and gender and age. In mandibular central incisor teeth, multiple regression was marginally not statistically significant for age and gender (F [2,243] = 2.89, P = 0.058).

Table 1: Group descriptives of mandibular incisor teeth

Group	*n*	Mean	Median	SD	SE
Distance 1 (central incisor)					
Female	126	3.37	3.30	0.553	0.0493
Male	120	3.26	3.33	0.713	0.0651
Distance 1 (lateral incisor)					
Female	107	3.46	3.39	0.684	0.0661
Male	105	3.24	3.28	0.650	0.0634

SD: Standard deviation, SE: Standard error

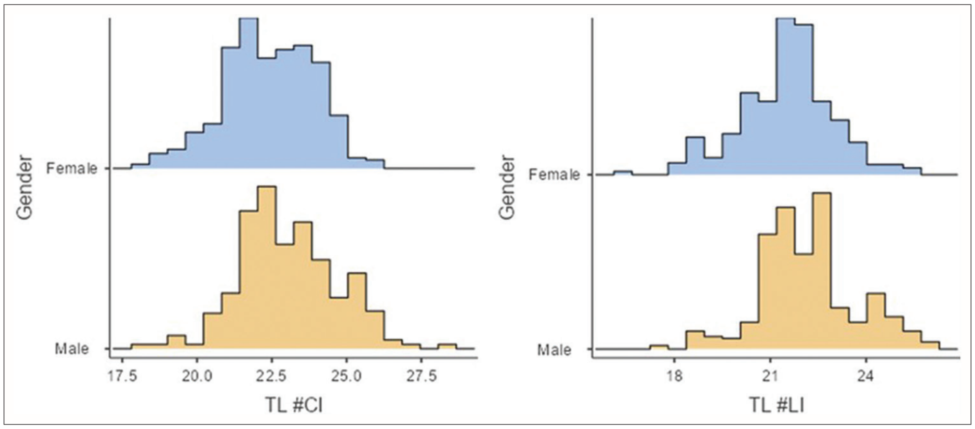

Figure 4: Histogram plots of maxillary central incisor (left) and lateral incisor (right) tooth length in relation to gender variable. TL: Tooth length, CI: Central incisor, LI: Lateral incisor

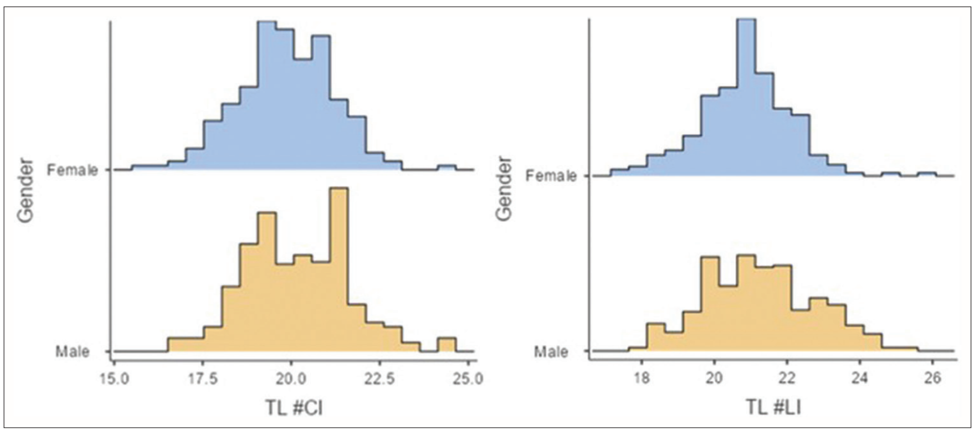

Figure 5: Histogram plots of mandibular central incisor (left) and lateral incisor (right) tooth length in relation to gender variable. TL: Tooth length, CI: Central incisor, LI: Lateral incisor

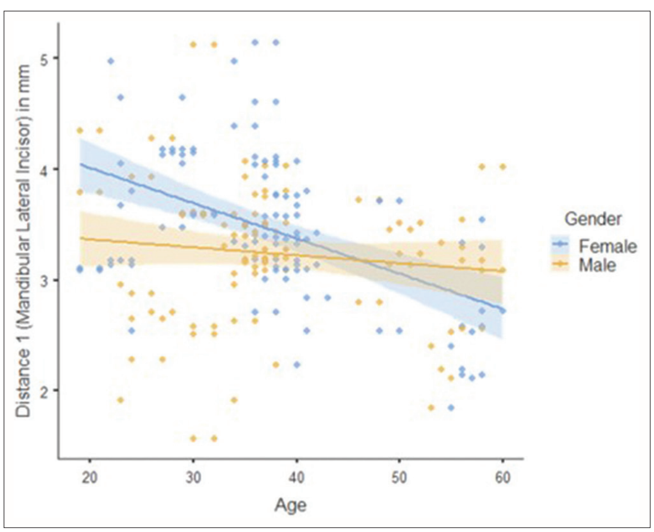

Figure 6: Scatterplot of distance from cementoenamel junction to the area of canal division (distance 1) of mandibular lateral incisor teeth in relation to gender and age variables

The results showed that males have a shorter distance from CEJ to area of canal division than females by 0.10064 mm ($P = 0.214$), and with each year increase in age, the distance decreased by 0.00743 mm ($P = 0.048$).

Table 2: Model coefficients - distance 1 (mandibular lateral incisor)

Predictor	Estimate	SE	*t*	*P*	Standard estimate
Intercept[a]	4.6531	0.23394	19.89	<0.001	
Age	−0.0319	0.00602	−5.29	<0.001	−0.487
Gender					
Male - female	−1.1428	0.32791	−3.49	<0.001	−0.312
Age×gender					
Age × (male - female)	0.0247	0.00838	2.95	0.004	0.378

[a]Represents reference level. SE: Standard error

In mandibular lateral incisor teeth, multiple regression showed that age and gender significantly explain the 14.8% of the variance in distance from CEJ to area of canal division (F [3,208] =12.0, $P < 0.001$). The results showed that males have a shorter distance from CEJ to area of canal division than females by 1.1428 mm ($P < 0.001$), and with each year increase in age, the distance decreased by 0.0319 mm ($P < 0.001$). Moreover, a statistically significant interaction between age and gender was observed [$P = 0.004$, Table 2 and Figure 6].

The mean width of the canal at the area of division of mandibular central and lateral incisor teeth was wider in males than in females in both tooth groups [2.35 mm and 2.46 mm, respectively; Table 3].

Multiple regression analyses examined the relationship between the width of canal at area of division and gender and age. In mandibular central incisor teeth, multiple regression showed that gender significantly explained the 7.15% of the variance in the width of canal at area of division (F [3,242] = 6.21, $P < 0.001$). The results showed that males have narrower diameter of canal at area of division than females by 0.71579 mm ($P = 0.004$), and with each year increase in age, the width decreased by 0.00271 mm ($P = 0.562$). The interaction between age and gender was statistically significant [$P = 0.001$, Table 4]. In mandibular lateral incisor teeth, multiple regression showed that gender significantly explains the 7.42% of the variance in width of canal at area of division (F [3,208] =5.56, $P = 0.001$). The results showed that males have a narrower diameter of canal at area of division than females by 0.69512 mm ($P = 0.004$), and with each year increase in age, the distance decreased by 0.00154 mm ($P = 0.725$). The interaction between age and gender was statistically significant [$P = 0.002$, Table 5].

Table 3: Group descriptives of mandibular incisor teeth

Group	*n*	Mean	Median	SD	SE
Distance 2 (central incisor)					
Female	126	2.29	2.30	0.500	0.0445
Male	120	2.35	2.21	0.585	0.0534
Distance 2 (lateral incisor)					
Female	107	2.45	2.39	0.436	0.0422
Male	105	2.46	2.32	0.502	0.0490

SD: Standard deviation, SE: Standard error

Table 4: Model coefficients - distance 2 (mandibular central incisor)

Predictor	Estimate	SE	*t*	*P*	Standard estimate
Intercept[a]	2.39098	0.18015	13.272	<0.001	
Age	−0.00271	0.00467	−0.581	0.562	−0.0540
Gender					
Male - female	−0.71579	0.24559	−2.915	0.004	0.0878
Age × gender					
Age × (male - female)	0.02020	0.00626	3.228	0.001	0.4029

[a]Represents reference level

Table 5: Model coefficients - distance 2 (mandibular lateral incisor)

Predictor	Estimate	SE	*t*	*P*	Standard estimate
Intercept[a]	2.50521	0.16950	14.780	<0.001	
Age	−0.00154	0.00436	−0.352	0.725	−0.0338
Gender					
Male - female	−0.69512	0.23759	−2.926	0.004	0.0225
Age × gender					
Age × (male - female)	0.01870	0.00607	3.078	0.002	0.4110

[a]Represents reference level. SE: Standard error

Symmetrical number of roots and canal configuration were seen in 100% in patients where both right and left maxillary central and lateral incisors were present. In 421 patients, where the right and left mandibular central incisors were present, 98.1% of teeth showed a symmetrical number of roots and canal configurations, while 1.9% showed symmetrical number of roots but different canal configurations with no statistically significant difference using a paired test ($P = 1$). For mandibular lateral incisors, right and left teeth were present in 421 patients in which 97.6% showed symmetrical number of roots and canal configurations while 2.4% showed symmetrical number of roots, but different canal configurations with no statistically significant difference ($P = 0.058$).

DISCUSSION

Although the general morphology of permanent dentition is similar across human races, they still vary in multiple aspects, such as root canal classifications and the root length.[7] Our understanding of root canal morphology has undergone frequent updates as far back as 1870, according to the literature. Research was done to better understand morphological variety, develop treatment methods, and increase treatment success rates.[20]

The most frequent reason for endodontic failure was noted to be an unanticipated extra or missing canal.[21] As a result, clinicians must possess the necessary knowledge and abilities to manage various morphological differences.[22] For this reason, different methods have been utilized to study root canal morphology. In this study, the CBCT technique used provided a 3D observation of the root canal system.[23] This technique was a noninvasive and accurate method that conveniently and swiftly unveiled microstructures. Therefore, an increasing amount of research has relied on this advanced technology to observe dental internal structures such as tooth canals.[12,17] Despite its advantages, the presence of gutta-percha or metallic restorations (such as amalgam restorations, metal posts and/or crowns, and implants) in CBCT image can result in significant radiographic artifact, enough to obscure details of root canal anatomy and relevant pathosis such as root resorption and root fractures.[24]

Although there are several canal classification systems, Vertucci's classification is the most frequently used. It was used in the current study for easy comparison with the results of other investigations. One root with Type I Vertucci's canal configuration was observed in maxillary central and lateral incisors in the current study. These results were similar to the results of other national and international studies.[5,8,9,25,26]

Types I, III, and V of Vertucci's canal configurations were observed in the current study in mandibular central incisor teeth, while Types I and III were observed in mandibular lateral incisor teeth. The prevalence of having one apical foramen in mandibular central and lateral incisor teeth was high (99.6% and 100%, respectively), which is consistent with the results of other studies.[5,10,16,18,25,27]

The incidence of two root canals in mandibular incisor teeth differs from previous studies. The current study found them in 28.8% of mandibular central incisor teeth and in 25% of lateral incisor teeth. Mohamed *et al*.[17] reported that 45.7% of mandibular central incisor teeth had two canals of Type III, and 44.1% in mandibular lateral incisor teeth, which are higher than found by the current study. Ghabbani *et al*.[16] found that 43.2% of the examined mandibular central incisors and 41.5% of the lateral incisors of the Saudi Arabian subpopulation in Al-Madinah Al-Munawara city have a second canal of Type III and Alshayban *et al*.[18] found that 36.5% of mandibular central incisors and 31% of the lateral incisors of the Saudi Arabian subpopulation in Riyadh have a second canal of Type III, which is also higher than the results of the present study (28.8% for central and 25% for lateral incisor teeth).

The discrepancies were very large, Chi-square analysis gave $P < 0.001$ for comparisons between all the studies which suggests that sampling variability cannot explain the differences. Moreover, statistical analyses were done for comparison of the results of the two studies. Sert and Bayirli reported 68%, whereas Lin *et al.* found that only 10.9% of mandibular central incisor teeth have a second root canal.[28,29] By contrast, these differences could be explained and attributed to the genetic and racial differences of the participants, and/or differences in the experience and methodologies of the examiners.[10,16]

Clinically, several methods could facilitate the detection of the presence of an extra canal starting with at least two preoperative radiographs, with the second one angulated from 15° to 20°, either mesial or distal from the long horizontal axis of the root. A sudden narrowing of the main canal on the radiograph usually indicates that more than one root canal should be suspected.[30] In addition, if the pulp chamber space appears to deviate from its typical configuration and tends to be more oval or triangular in shape, then maybe another canal exists.[31] In mandibular incisor teeth where two canals are present, the access cavity should be extended linguistically to prevent missing the second canal, and also endodontic instruments and materials can be handled easily and properly in such a complex root canal system.

In the present study, the symmetrical number of roots and canal configurations of maxillary central and lateral incisors were seen in 100%, 98.1% of mandibular central incisors, and 97.6% of mandibular lateral incisors. Ghabbani *et al*.[16] reported diversity in only (1.2%) of mandibular incisors, and Alobaid *et al*.[32] marginally diverse, while Zhengyan *et al*.[33] reported no significant variation between tooth sides. These findings suggest that the root canal anatomy of anterior teeth may predict a similar configuration for the corresponding contralateral side.

In terms of gender, no statistically significant difference was found between mandibular central and lateral incisor teeth in terms of number of root canals. The presence of two root canals was higher in females than in males. These findings were like those reported by Geduk *et al*.[34] and Verma *et al*.[35] but in disagreement with Mashyakhy,[27] Lin *et al*.,[29] and Martins *et al*.[36]

One of the most important factors affecting the root canal morphology is age. Calcifications of canals increase with age and may result in the disappearance of the root canals.[37] The results of this study demonstrated that age is an influencing factor on the root canal morphology and canal calcification. Moreover, age was correlated with a decrease in the tooth length of maxillary and mandibular central and lateral incisor teeth. In maxillary teeth, the decrease was 0.0384 mm and 0.0247 mm per year for central and lateral incisors, respectively. In mandibular teeth, it was 0.0324 mm for central and 0.0193 mm per year for lateral incisor teeth. Different studies reported age as a dominant factor for occlusal tooth wear, which had a negative impact on crown length and certainly will affect the tooth length.[38-40]

Tooth size varies between males and females, and this is attributed to gender-related differences in the odontogenic timing, enamel thickness, and body size; in this instance, the tooth size is also influenced by hormonal variations.[41-43] In the preoperative assessment of root canal morphology, gender has been consistently reported as an important factor to be considered. In this study, all teeth length measurements were higher in males than in females, with statistically significant difference ($P < 0.001$). The results were similar to the report of Kulkarni *et al*.[44]

No previous studies have been published that examine the distance from CEJ to the point of separation of the canals and width of the canal at the area of division in mandibular central and lateral incisor teeth with two root canals. Therefore, it is not possible to compare the findings of the present investigation with others. There was a statistically significant interaction between gender and age for the distance from CEJ to the area of canal division in mandibular lateral incisor teeth. Older females had a larger difference from younger females compared to male age groups, which could be attributed to the fact that females' teeth are more durable and less prone to wear compared to males where greater masticatory forces are generated and will cause calcification of the root canal which also explain that males have shorter distance from CEJ to the area of canal division than females.[45]

For the width of the canal at the area of division, there were statistically significant interactions between gender and age in both central and lateral teeth groups. In both teeth, older males had a larger difference from younger males compared to female age groups. This could be attributed to increased calcification with aging, the canals narrowing in diameter, and thus, the measurement of width will be increased.[46]

King Saud University Dental Hospital is considered to be one of the largest government dental institutes providing free dental services to a large slice of the Saudi population from different regions. The data in this study were acquired in a single center, which may limit the generalization of the results to a wider population. In addition, the preexisting CBCT images were accessed regardless of the voxel size used to avoid exposing a large number of patients to unnecessary radiation doses and to achieve larger sample size. Further studies with large samples representative of other regions in Saudi Arabia and fixed voxel size are recommended. In addition, Ahmed's new method of classifying root canal morphology[7] may need to be used to compare it with Vertucci's classification to further advance future research in this field.

CONCLUSION

Within the limitations of this study, it can be concluded that all maxillary incisor teeth present with one root and Type I canal configuration, and most mandibular incisor teeth had one root, with Type I being the predominant canal configuration. However, more than one root canal with different canal configurations was also observed, and this was more frequently in females. In general, males have longer teeth than females in all studied groups. As expected, they decrease in length with each passing year of age. Mandibular lateral incisor teeth exhibited the highest mean distance from CEJ to the point of separation of the canal, and the highest mean width in the area of division of the canal. Statistically significant interactions were observed between gender and age in both mandibular central and lateral incisor teeth groups. The reported measurements in this study promote a more quantitative approach to endodontic access cavity preparation for mandibular incisor teeth with two root canals.

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Conflicts of interest

There are no conflicts of interest.

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