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Research Article

Root and Canal Morphology of Permanent Maxillary and Mandibular Canines in a Sample of Yemeni Population Using Cone Beam Computed Tomography

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Abstract

Aims and Objective: This study aimed to investigate the external and internal morphological characteristics, including crown shape, root curvature, canal diameter, and root canal configuration, of maxillary and mandibular canine teeth in a Yemeni population using cone-beam computed tomography (CBCT).

Materials and Methods: A total of 400 CBCT images (200 maxillary, 200 mandibular) were analyzed from 400 Yemeni subjects (average age 34).

Results: All maxillary canines had a single root, while 4% of mandibular canines had two roots (slightly higher in females, but not significantly). Maxillary canines were markedly larger in males ($p = 0.001$). Most maxillary canines (98.5%) had a single root canal, while 16.5% of mandibular canines had two (significantly higher in males). Using the Vertucci classification, root canal configuration analysis showed that maxillary canines were predominantly Type I, while mandibular canines displayed more variation.

Conclusion: This study provides insights into the morphological characteristics of Yemeni canine teeth. Gender is a significant factor in canine dimensions, with males having larger teeth.

Keywords: cone-beam computed tomography; maxillary canine; mandibular canine; root morphology; yemeni population

Introduction

Successful endodontic treatments require a comprehensive understanding of root canal system (RCS) morphology. Lack of familiarity with anatomical variations can lead to incomplete cleaning, shaping, and filling, resulting in treatment failure. [1]

Canine teeth play a crucial role in dental occlusion, mastication, and esthetics. Understanding their external and internal morphology is essential for various clinical procedures, including root canal treatment, tooth extraction, and prosthetic rehabilitation. Anatomical variations in the number of roots and root canal morphology can significantly impact

the complexity and success of endodontic and surgical interventions. [4, 5]

Previous studies have investigated the external and internal morphology of canine teeth in different populations using various imaging techniques. These studies have reported variations in the number of roots, root canal configurations, and anatomical dimensions across different ethnic and geographic groups. [6, 7]

Cone-beam computed tomography (CBCT) has become an invaluable tool in dental research and clinical practice. It provides high-resolution three-dimensional (3D) images, allowing for detailed analysis of tooth morphology. [8, 9]

To the best of our knowledge, no studies have investigated the external and internal morphological characteristics of maxillary and mandibular canine teeth in a Yemeni population using CBCT imaging. This study aimed to analyze the morphology, including the number and type of roots, as well as the anatomical dimensions of maxillary and mandibular canine teeth in a sample of the Yemeni population using CBCT.

Materials and Methods

Study Design and Sample Selection

This cross-sectional study utilized CBCT images of Yemeni subjects. A total of 400 CBCT images were analyzed, with 200 each for maxillary and mandibular canines. The study population consisted of 400 Yemeni individuals aged 18-50, with an equal distribution of males and females for each jaw.

Inclusion criteria:

• Yemeni individuals aged 18-50 years

• Complete set of permanent dentition

• No previous dental treatments or abnormalities in canine teeth

• High-quality CBCT images without artifacts or distortions

Exclusion criteria:

• Pathological conditions or developmental anomalies in canine teeth

• Poor image quality or significant artifacts in CBCT images

The study was approved by the Institutional Review Board, and informed consent was obtained from all participants.

CBCT Image Acquisition and Analysis

All CBCT images were acquired using a standardized protocol with a Planmeca ProMax 3D Mid machine. Scans were performed with an 8x8 cm field of view, a 0.2 mm voxel size, and a 12-second exposure time.

Two experienced oral and maxillofacial radiologists analyzed the CBCT images using Planmeca Romexis software. The number and type of roots, as well as the anatomical dimensions (crown length, root length, and total length) of the maxillary and mandibular canine teeth, were assessed and recorded.

Statistical Analysis

Data were analyzed using SPSS software. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were calculated. The Chi-square test was used to compare the number of roots between genders, and the independent t-test was used to compare anatomical dimensions between male and female subjects. A p-value of less than 0.05 was considered statistically significant.

Results

Root Anatomy of Maxillary and Mandibular Canines

Root Number:

• Maxillary canines: All maxillary canines examined had a single root.

• Mandibular canines: 96% were single rooted, while 4% had two roots. There was a slightly higher incidence of two-rooted mandibular canines in females compared to males, but this difference was not statistically significant ($p > 0.05$). (Table 1)

Anatomical Dimensions:

• Maxillary canines:

The average anatomical length of the maxillary canine crown was 8.3 mm, and the root was 16.8 mm.

The total average length was 25.1 mm.

Male patients had significantly longer maxillary canines than female patients ($p = 0.001$). (Table 2)

Mandibular canines:

Single-rooted mandibular canines had an average root length of 15.5 mm, crown length of 7.8 mm, and total length of 23.3 mm. (Table 3)

oTwo-rooted mandibular canines had an average root length of 12.5 mm per root, crown length of 9.4 mm, and total length of 21.9 mm. (Table 3)

Male individuals had significantly larger mandibular canines than female individuals ($p = 0.001$). (Table 4)

Root Canals:

• Maxillary canines: 98.5% had a single root canal, while 1.5% had two. There was no significant difference between males and females. (Table 5)

• Mandibular canines: 83.5% had a single root canal, while 16.5% had two. Males had a significantly higher prevalence of two-canal mandibular canines compared to females ($p = 0.04$). (Table 5)

Root Canal Configurations:

• Maxillary canines: The most common configuration was Type I (98.5%), followed by Type III (1%) and Type VII (0.5%). No significant differences were observed between males and females. (Table 6)

• Mandibular canines: The most common configuration was Type I (83.5%), followed by Type III (11%). Significant differences were found between genders, with Type I and Type V being more prevalent in females and Type III being more common in males. (Table 6)

Bilateral Symmetry:

• Maxillary canines: There was 100% bilateral symmetry for the number of roots, 99% for the number of root canals, and 99% for canal configurations. (Table 7)

• Mandibular canines: There was 98% bilateral symmetry for the number of roots, 97% for the number of root canals, and 95% for canal configurations. (Table 7)

Overall, maxillary canines consistently exhibited a single root and a single root canal, while mandibular canines showed more variation in root and canal anatomy.

Root canal	Male (100)		Female (100)		Total		CI 95%	
	N	%	N	%	N	%	Max	Man
One root	97	48.5%	95	47.5%	192	96.0%	2.5	0.1
Two roots	3	1.5%	5	2.5%	8	4.0%		
OR	0.6							
*χ^2 = 0.5 p = 0.5								

Table 1. Number of roots in the mandibular canines.

Gender	Root length		Crown length		Total length	
	N	Mean ±SD	N	Mean ±SD	N	Mean ±SD
Male	100	17.7±1.8	100	8.4±1.0	200	26.2±1.9
Female	100	15.8±2.1	100	8.1±0.7	200	23.9±2.2
(male+ female)	200	16.8	200	8.3	200	25.1
P Value	0.001		0.006		0.001	

Table 2: The cumulative mean tooth length of maxillary canine (root & crown) of the female and male.

variable	Average length	Root	Crown	Total (root + crown)
One root	N=192	15.5	7.8	23.3
Two roots	N=8	L+B=12.5	9.4	21.9

*L: lingual root / *B: buccal root

Table 3: The average length of mandibular canines with one and two roots.

Variable	Male		Female		P
	N	Mean ±SD	N	Mean ±SD	
Root length	97	16.2±1.6	95	14.8±2.2	0.001
Root length (L)*	3	11.8±2.3	5	13.3±0.4	0.4
Root length (B)*	3	11.8±2.3	5	13.2±0.4	0.4
Crown length	100	7.9±0.9	100	7.7±0.9	0.1
Total length	97	24.0±1.9	95	22.5±2.5	0.001
Total length of teeth has two roots	3	21.6±2.5	5	22.5±0.7	0.6

*L: lingual root / *B: buccal root

Table 4. The cumulative mean tooth length of the mandibular canine (root& crown) of the female and male.

Variable	Root canal	Male (100)		Female (100)		Total (200)		CI 95%		P value
		N	%	N	%	N	%	Max	Man	0.6
Maxillary canines	One canal	98	49.0%	99	49.5%	197	98.5%	22.6	0.2	
	Two canals	2	1.0%	1	0.5%	3	1.5%			
Mandibular canines	One canal	78	39.0%	89	44.5%	167	83.5%	5.0	1.04	0.04
	Two canals	22	11.0%	11	5.5%	33	16.5%			

Table 5. Distribution of number of canals in permanent maxillary and mandibular canines.

Variable	Gender	Type I		Type II		Type III		Type V		Type VII		P value
		N	%	N	%	N	%	N	%	N	%	0.6
Maxillary canines	Male (100)	98	49.0%	…	…	1	0.5%	…	…	1	0.5%	
	Female (100)	99	49.5%	…	…	1	0.5%	…	…	0	0.0%	
	Total	197	98.5%	…	…	2	1.0%	…	…	1	0.5%	
Mandibular canines	Male (100)	78	39%	2	1.0%	17	8.5%	3	1.5%	…	…	0.04
	Female (100)	89	44.5%	1	0.5%	5	2.5%	5	2.5%	…	…	
	Total	167	83.5%	3	1.5%	22	11.0%	8	4%	…	…	

Table 6. Distribution of root canal configuration in permanent maxillary and mandibular canines.

Variable	Maxillary canines			Mandibular canines		
	Right (n=100)	Left (n=100)	Number of symmetrical teeth	Right (n=100)	Left (n=100)	Number of symmetrical teeth
One root	100	100	200	97	95	190
Two roots	----------	----------	------	3	5	6
Total	100	100	200	100	100	196
Total symmetry n (%)			100%			98%
One root canal	98	99	196	85	82	164
Two root canals	2	1	2	15	18	30
Total	100	100	198	100	100	194
Total symmetry n (%)			99%			97%
Vertucci type I	98	99	196	85	82	164
Vertucci type II	…	…	…	1	2	2
Vertucci type III	1	1`	2	9	12	18
Vertucci type V	……..	……	…….	3	5	6
Vertucci type VII	1	…….	0	…	…	…
Total	100	100	198	100	100	190
Total symmetry n (%)			99%			95%

Table 7. Bilateral symmetry of maxillary and mandibular canines.

Discussion

A comprehensive understanding of root canal morphology is paramount for the successful outcome of endodontic treatment. However, dentists must be vigilant in identifying less common root canal variations to ensure proper treatment. The failure to locate and treat all root canals can lead to negative treatment outcomes [10].

Since the late 19th century, various techniques have been employed to study dental root canal anatomy, including replication [11], histopathological analysis [12], radiography [13], microscopy [14], and micro-computed tomography (micro-CT) [15]. While these methods have provided valuable insights, they often involve invasive procedures that can alter the true morphology.

To overcome the limitations of previous techniques, cone-beam computed tomography (CBCT) has emerged as a non-invasive, three-dimensional imaging modality for evaluating external and internal dental anatomy. CBCT offers accurate, isotropic imaging that allows for precise visualization and measurement of anatomical features, unlike traditional medical CT scans [16]. The increasing use of CBCT in clinical practice has facilitated a better understanding of normal and atypical root canal morphology, which is crucial for improving the success of endodontic treatments [17].

The primary objective of this study was to investigate the morphology and canal anatomy of the roots of maxillary and mandibular permanent canines in a sample of the Yemeni population using an in vivo CBCT method.

This study found a 4% incidence of double roots in lower canines, which is consistent with the 4.7% rate reported in an Iranian population [18]. However, this rate is higher than those reported in several other populations, such as Iraqi (2.17%), Saudi (0.2%, 2.88%, and 1.6%), Moscow (0.2%), Turkish (3.1% and 3.4%), Brazilian (1.7%), Chinese (0.7%), South Asian Indian (0%), Chongqing (0.8%), Malaysian (1.21%), Iranian (1.3% and 1.6%), and Syrian (2.15%) [19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 7, 31]. In contrast, the rate is lower than the 12.08% reported in the Iranian population [32] and the 5.2% reported in the Pakistani population [33], as well as the 5.8% found in a Serbian population [34]. The variations in the incidence of double roots in lower canines across different populations could be attributed to genetic, racial, and geographical factors.

Regarding the maxillary canines, the present study did not find any instances of two-rooted maxillary canines, which is consistent with several previous studies conducted in various populations worldwide, including the USA by Green, UK, Mexico, Brazil, Vertucci in the USA, South Africa, Moscow, Turkey, and Iran [36, 37, 38, 13, 39, 23, 25, 22].

The present study found that gender had no significant effect on the distribution of root numbers in the maxillary and mandibular canines among the Yemeni population. This finding is consistent with studies conducted on Saudi Arabian populations [40, 20, 21]. Similar results were also reported in a Malaysian subpopulation [30]. In contrast, studies on Iranian and Turkish populations have reported statistically significant differences in the number of roots between gender [7, 25]. The variations in gender-based differences across different populations suggest that root canal morphology of canines may be influenced by genetic, racial, and geographical factors.

The prevalence of two canals in mandibular canines in this study was found to be 16.5%, which is higher than the values reported in several previous studies. Pineda and Kuttler [13] found a prevalence of 13.5%, Pecora et al. [26] reported 7.8%, Han et al. [41] found 6.3%, Kayaoğlu et al. [24] reported 6.1%, Mağat found 9.4% [42], Okumus and Kanyılmaz reported 7.2% [43], Büyükbayram et al. found 15.8% [44], Soleymani et al. found 11.6% [7], Almohaimede et al. reported 9.94% [21], and Mashyakhy found 9.3% [40]. However, the prevalence found in the present study was lower than that reported by Rahimi et al. (20.48%) [33], Vertucci (22%) [39], Aminsobhani et al. (28.2%) [18], Sert et al. (24%) [12], Naseri (18.4%) [31], and Amardeep et al. (20.4%) [45].

Regarding the maxillary canines, the present study found that 98.5% had a single canal, and only 1.5% had two canals. These findings are consistent with the results reported by Mashyakhy in a Saudi population (99% with one canal, 1% with two canals) [40] and Almohaimede et al. in a Saudi population (98.1% had one canal, 1.9% had two canals) [21]. However, these results differ from those in Malaysian and Iranian populations, where 100% of the maxillary canines had a single canal [30, 46]. The study by Naseri et al. in an Iranian population reported a higher frequency of two root canals in maxillary canines (34.9%), which is

significantly different from the present findings [31]. This variation could be attributed to ethnic and genetic differences.

In this study, the prevalence of two canals in both maxillary and mandibular canine teeth was higher in males than females. This finding is consistent with the observations made by Sert and Bayirli [12], Altunsoy et al. [6], and Soleymani et al. [7], who also reported a higher incidence of two-canal canines in male subjects. In contrast, Kayaoğlu et al. [24] reported that canines with two canals were more often found in females than in males. This discrepancy in findings across different studies may be attributed to variations in study populations, sample sizes, and the diagnostic techniques employed.

The average anatomical length of the maxillary canine crown was 8.3 mm in this study, which is not consistent with previous reports, which have stated the average maxillary canine crown length to be 10 mm [47] and 9.61 mm [45]. The average root length of the maxillary canine in the current study was 16.8 mm, which is in closer agreement with the previously reported averages of 17 mm [47] and 16.82 mm [45].

The total average length of the maxillary canine (crown and root) in the present study was 25.1 mm, which is shorter than the internationalaverage records of 26.5 mm [48] and 27.31 mm [49]. This discrepancy may be attributed to potential population-specific variations in tooth dimensions.

Regarding the mandibular canine, the average crown length in the present study was 7.8 mm, which is shorter than the 11 mm reported by Ash and Nelson [47]. The average root length of the mandibular canine was 15.5 mm, and the root was significantly longer in males than in females. These findings are consistent with the studies by Versiani et al. [50], Amardeep et al. [45], Soleymani et al. [7], and Doumani et al. [32], who also observed gender-related differences in mandibular canine root lengths.

The present study also revealed that the average tooth length of the evaluated maxillary and mandibular canines among Yemeni males was significantly longer than that in females. This observation is in line with the findings reported by Kulkarni et al. [51].

Based on Vertucci's classification, 83.5% of the mandibular canines were found to have a Type I canal configuration, followed by Type III (11%), Type V (4%), and Type II (1.5%). Our results agree with those reported in a previous investigation in a Saudi subpopulation by Mashyakhy [40] and Almohaimede et al. [21], in a Turkish population [25], and in an Iranian population [31], where most canal configurations were Type I followed by Type III and Type V. However, another study in a Saudi subpopulation by Al Dahman et al. [20] and Vertucci's study [39] found that the second most commonly occurring canal pattern was Type II followed by Type III. In another study in a Saudi population [22], it was recorded that Type I canal configuration was found in most mandibular canines (95.8%), followed by Type III (1.9%) and Type II (1.1%). Type IV canal pattern in mandibular canines was not observed in this study, whereas several studies showed this configuration pattern in lower canines [39, 13, 12, 26].

Conclusion

This study, conducted through CBCT imaging of a Yemeni population, offers significant insights into the external and internal morphological characteristics of maxillary and mandibular canine teeth. Our findings reveal that gender plays a substantial role in determining the anatomical dimensions of both maxillary and mandibular canines, with males exhibiting larger canine dimensions than females.

Regarding root canal anatomy, the maxillary canine was predominantly found to have a single root canal, with a low prevalence of two-canal configurations. In contrast, the mandibular canine exhibited a higher occurrence of two-canal configurations, especially in male individuals.

An analysis based on Vertucci's classification revealed that the majority of maxillary canines had a Type I root canal configuration, with no significant gender-related differences. However, the distribution of root canal types in mandibular canines differed significantly between males and females.

These results hold important clinical implications for various dental procedures and contribute to a deeper understanding of dental anatomy within the Yemeni population.

This study provides valuable insights into the external and internal morphological characteristics of maxillary and mandibular canine teeth in a Yemeni population using CBCT imaging. The findings suggest that gender is an influential factor in the anatomical dimensions of both maxillary and mandibular canine teeth, with male subjects exhibiting larger canine dimensions compared to their female counterparts The theory of maxillary canines had a single root canal, with a low prevalence of two-canal anatomy. In contrast, the mandibular canines exhibited a higher occurrence of two-canal configurations, particularly in male individuals.

The analysis of root canal configurations based on Vertucci's classification revealed that the majority of maxillary canines had a Type I configuration, with no significant gender-related differences. However, the distribution of root canal types in mandibular canines differed significantly between males and females. These results have important clinical implications for various dental procedures and contribute to the understanding of dental anatomy in the Yemeni population.

Limitations and future research

Limitations:

- **Sample size:** A larger sample is needed for broader generalizability.
- **Age range:** Expanding the age range can explore age-related variations.
- **Other factors:** Systemic diseases, medications, and dental trauma should be considered.
- **CBCT limitations:** Image resolution can be inadequate for small or calcified canals.

Future research:

- **Comparative studies:** Compare with other populations for global variations.
- **Developmental aspects:** Investigate root canal development over time.
- **Correlation with dental problems:** Explore the relationship between morphology and dental issues.
- **Advanced imaging:** Use micro-CT for higher-resolution images.
- **Clinical implications:** Study the impact of morphology on endodontic treatment outcomes.

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Author's contributions:

- **Manar Abdulsalam Ali Al-kinani:** Primary investigator, data analysis, manuscript writing
- **Other authors:** Data collection, analysis, interpretation, manuscript review
- **Supervisor:** Professor Abdulwahab Al-kholani study conception, guidance, oversight, manuscript review

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