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ReviewArticle

Length Variation in Maxillary Central and Lateral Incisors: A CBCT Study on a sample of Yemeni Population

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Abstract

Background and Aim: To measure the crown and root lengths of maxillary central and lateral incisors in a sample of the Yemeni population, compare these measurements between genders, and evaluate the clinical relevance of any observed variations.
Materials and Methods: Cone-beam computed tomography (CBCT) images from 100 individuals (50 males and 50 females), representing a total of 400 maxillary anterior teeth, were analyzed. Only teeth without pathology, restorations, or previous endodontic treatment were included. Crown and root lengths were measured using [Ez3D-i software], following a standardized protocol based on clearly defined anatomical reference points. Measurements were performed by two calibrated examiners to ensure consistency and reliability.
Results: All examined teeth had single roots. Both crown and root lengths showed variation within and between groups (central vs. lateral and male vs. female). Lateral incisors exhibited slightly longer roots than central incisors, while males tended to have greater crown and root dimensions, though not all differences were statistically significant.
Conclusion: This CBCT-based study highlights considerable variability in the crown and root dimensions of maxillary incisors within a Yemeni population. These findings underscore the importance of individualized assessment for accurate endodontic, restorative, and prosthetic planning. Future studies with larger and more diverse samples are recommended to validate these results.
Key Words: CBCT, maxillary incisors, root length, anatomical variation, Yemeni population

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Introduction

Anatomical precision forms the foundation of all successful dental procedures. Accurate knowledge of tooth morphology, particularly crown and root dimensions, is essential for achieving predictable and long-lasting treatment outcomes. Within clinical dentistry, this precision plays a vital role across multiple disciplines. In endodontics, determining the correct working length ensures complete cleaning, shaping, and obturation of the root canal system, reducing the risk of procedural errors such as perforation or incomplete debridement (Ng et al., 2011; Vertucci, 2005). In restorative dentistry, understanding crown length is key to designing well-fitting crowns, bridges, and veneers that maintain both function and esthetics (Scheid et al., 2016). Similarly, in implantology, accurate assessment of root and alveolar bone dimensions guides implant length selection and placement, minimizing the risk of complications involving

adjacent anatomical structures (Al-Amery et al., 2015).

Although standard reference values for crown and root lengths are well-documented in dental literature (Nelson, 2014; Ingle and Beveridge, 1985), considerable inter-individual and inter-population variability exists (Versiani et al., 2016; Vertucci, 1984). Such anatomical variation highlights the limitations of relying solely on generalized averages and emphasizes the need for individualized assessment in clinical decision-making (Rotstein and Ingle, 2019; Torabinejad and Walton, 2009). Factors contributing to these differences include genetic background, environmental influences, and developmental processes (Sert and Bayirli, 2004; Walker, 1987). Moreover, methodological inconsistencies—such as variations in imaging modalities and measurement protocols—can further affect reported dimensions (Martins et al., 2017; Scarfe et al., 2009).

To date, limited research has focused on tooth morphometry within the Yemeni population, particularly regarding maxillary central and lateral incisors. The use of cone-beam computed tomography (CBCT) provides a powerful tool for addressing this gap, offering high-resolution, three-dimensional visualization that enables precise, reproducible measurement of dental anatomy (Mallya and Lam, 2019; Patel et al., 2016).

Therefore, the present study aims to: (1) measure the crown and root lengths of maxillary central and lateral incisors using CBCT; (2) evaluate variations according to tooth type and gender; and (3) discuss the potential clinical implications of these findings within the context of endodontic, restorative, and implant procedures.

Materials and Methods

Study Design and Sample Selection

This cross-sectional study analyzed cone-beam computed tomography (CBCT) images of maxillary central and lateral incisors from a Yemeni population. The dataset included 400 teeth (200 male and 200 female) from 100 individuals aged 18–50 years. Participants were selected through a retrospective convenience sampling method from the CBCT database of Al-Waleed Digital Radiology Center, where scans had originally been obtained for diagnostic or treatment planning purposes.

Inclusion criteria required teeth to be fully developed and free from caries, restorations, periapical lesions, previous endodontic or orthodontic treatment, fractures, or any pathology that could compromise measurement accuracy. Exclusion criteria included scans with motion artifacts or incomplete anatomical visualization. Ethical approval was obtained from the Sanaa University, and informed consent was obtained from all participants prior to data use.

CBCT Image Acquisition

All CBCT images were acquired using a PaX-Flex3D (PHT-60CFO) scanner (VATECH Global, Korea) under the following parameters: 60 kVp, 4 mA, 9–15 s exposure time, voxel size 0.2 mm, and a medium field of view (FOV) of 16 × 10 cm. A standardized head position and exposure protocol were used for all subjects to minimize variability and motion artifacts.

Image Calibration and Display Conditions

Images were analyzed using Ez3D-i software (VATECH Global, Korea) in a dimly lit room on a diagnostic-grade monitor (1920 × 1080 resolution, 27-inch) that was hardware-calibrated according to DICOM GSDF (Grayscale Standard Display Function) standards. Calibration was verified monthly using the software's internal quality assurance tools to ensure consistent brightness, contrast, and grayscale accuracy throughout the study period.

Measurement Protocol

Each tooth was evaluated in the axial, coronal, and sagittal planes to ensure correct orientation before measurement. The following parameters were recorded manually using the built-in linear measurement tool in Ez3D-i software, based on standardized anatomical landmarks:

- **Overall Tooth Length (OTL):** distance from the incisal edge to the root apex.
- **Root Length (RL):** distance from the cementoenamel junction (CEJ) to the root apex.
- **Crown Length (CL):** distance from the incisal edge to the CEJ. (Figure 1)

All measurements were taken manually by a

calibrated examiner using the digital caliper tool, with precision to 0.01 mm. Each measurement was repeated twice at a one-week interval to evaluate intra-observer consistency.

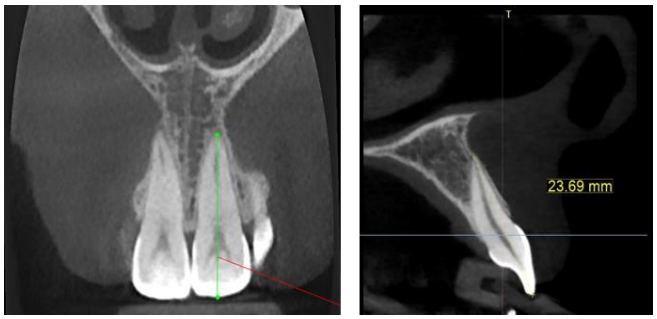

Figure 1. Coronal view (left), sagittal view (right), providing a comprehensive assessment for overall length of teeth.

To assess inter-observer reliability, a second trained examiner independently repeated 20% of the measurements following the same protocol. Intra- and inter-examiner reliability were assessed using intra-class correlation coefficients (ICCs), where values above 0.90 were considered indicative of excellent agreement.

Statistical Analysis: Data were entered and analyzed using SPSS software (Version 27.0; IBM Corp., Armonk, NY, USA). Descriptive statistics, including means, standard deviations (SD), and ranges, were calculated for the crown, root, and overall tooth lengths of maxillary central and lateral incisors according to gender.

A Chi-square test was initially considered for canal configuration comparisons; however, as all teeth in the current sample exhibited a single root and single canal configuration, this analysis was not applicable and therefore excluded from final testing.

The level of significance (α) was set at $p < 0.05$ for all statistical tests.

A power analysis was conducted prior to data collection using G*Power software (version 3.1) to determine the minimum required sample size for detecting a medium effect size (Cohen's d = 0.5) at a power of 0.80 and α = 0.05. The analysis indicated a minimum of 84 teeth per group, confirming that the study's final sample size (400 teeth) provided adequate statistical power.

Results

A.Overall length

Table 1 provides a detailed analysis of the overall length of maxillary anterior teeth in a sample of 400 individuals (N=400), broken down by tooth position (left or right), location (central or lateral incisors), and gender (female or male). While the mean overall tooth length generally falls within a narrow range (21.2–23.4 mm), the table reveals several interesting observations:

i. Slight Trend: There appears to be a slight trend towards longer central incisors compared to lateral incisors, with mean lengths of 23.4 mm and 23.3 mm, respectively.

ii. Minimal Gender Impact: The mean overall length of teeth does not show a significant difference between genders, suggesting that gender may not be a major factor influencing overall tooth length.

iii. Variability: The standard deviation (SD) values highlight the variability in tooth length within each group, with the highest variability observed in central incisors, particularly in female samples.

iv. Individual Range: The maximum and minimum values provide a broader perspective on the overall length range of maxillary anterior teeth, demonstrating a considerable spread, particularly in central incisors.

Table 2 provides a detailed summary of the overall length of maxillary central incisors for a sample of 200 subjects, analyzed separately for the left and right positions.

The analysis of the overall length of maxillary central incisors revealed that the mean length was 22.9 mm for both the left and right sides, indicating no significant difference between the two positions. Both positions exhibited a standard deviation of 1.9 mm, suggesting a moderate level of variability around the mean. The maximum length recorded was 28.3 mm for the left incisors and 26.7 mm for the right incisors, while the minimum lengths were 17.1 mm and 16.9 mm, respectively. The range, representing the total spread of the data, was 11.2 mm for the left and 9.8 mm for the right incisors.

Table 3 presents a comprehensive summary of the overall length of maxillary lateral incisors for a

Table1. Mean Overall Length of Maxillary Anterior Teeth (N = 400) by Position, Tooth, and Gender

N=400		Position							
		Left				Right			
		Central Female	Central Male	Lateral Female	Lateral Male	Central Female	Central Male	Lateral Female	Lateral Male
Overall length in mm	Mean	22.5	23.3	21.2	22.5	22.5	23.4	21.3	22.7
	SD	2.2	1.5	1.7	1.9	2.1	1.6	1.7	1.8
	Maximum	28.3	27.7	25.8	25.7	26.0	26.7	24.6	26.5
	Minimum	17.1	20.6	16.8	17.5	16.9	20.2	17.0	19.4

Table 2. Overall length in mm for maxillary central incisors

N=200		Position	
		Left	Right
Overall length in mm	Mean	22.9	22.9
	Standard Deviation	1.9	1.9
	Maximum	28.3	26.7
	Minimum	17.1	16.9
	Range	11.2	9.8

Table 3. Overall length in mm for maxillary lateral incisors

N=200		Position	
		Left	Right
Overall length in mm	Mean	21.9	22.0
	Standard Deviation	1.9	1.9
	Maximum	25.8	26.5
	Minimum	16.8	17.0
	Range	9.0	9.5

sample of 200 subjects, with separate analyses for the left and right positions.

B.The length of the root

Table 4 presents a detailed analysis of the mean length of roots in maxillary anterior teeth (N=400), taking into account tooth position (left or right), location (central or lateral incisor), and participant gender (female or male). The data reveals several interesting patterns:

i. Central vs. Lateral: The mean root length for lateral incisors is generally longer than that of central incisors, with average lengths ranging from 16.0-16.1 mm for lateral incisors and 15.6-15.7 mm for central incisors.

ii. Gender Comparison: While there is a slight trend for male participants to have slightly longer roots, overall, there is no statistically significant difference in root length between genders.

Table 4. Mean Length of Root for Maxillary Anterior Teeth (N = 400) by Position, tooth, and Gender

N=400		Position							
		Left				Right			
		Central female	Central male	Lateral female	Lateral male	Central female	Central male	Lateral female	Lateral male
Length of the root in mm	Mean	14.9	15.6	14.7	16.0	14.8	15.7	14.7	16.1
	SD	2.1	1.5	1.9	1.6	1.9	1.5	1.7	1.7
	Maximum	20.0	19.5	18.7	19.3	17.7	18.4	18.4	19.9
	Minimum	9.7	12.3	10.0	11.3	10.0	11.8	10.9	13.0

iii. Variability: The standard deviation (SD) values indicate that the variability in root length is relatively consistent across the different conditions, with values generally ranging from 1.5-2.1.

iv. Individual Range: The maximum and minimum values highlight the overall range of root lengths observed, revealing a broader spread in some conditions, particularly for central incisors.

Table 5 presents the descriptive statistics for the length of the root (in mm) of maxillary central incisors. A total of 200 teeth were measured (N=200). The data reveals that the mean root length of the left maxillary central incisors (15.3 mm) was slightly larger than that of the right maxillary central incisors (15.2 mm). While both sides exhibited similar standard deviations (1.9 mm vs. 1.8 mm) and a relatively small range (10.3 mm vs. 8.4 mm), the slight difference in mean values is worth noting.

Table 6 details the descriptive statistics for the root length (in mm) of maxillary lateral incisors. A sample of 200 teeth (N=200) reveals nearly identical mean root lengths for both left and right lateral incisors (15.4 mm). Moreover, the standard deviations (1.9 mm vs. 1.8 mm) and ranges (9.3 mm vs. 9.0 mm) are very similar between sides, indicating a consistent and comparable distribution of root lengths in maxillary lateral incisors regardless of position.

C.The length of crown

Table 7 presents the mean length of the crown for maxillary anterior teeth in a sample of 400 individuals, categorized by position (left or right), tooth type (central or lateral), and gender (female or male). The table shows that the mean crown length of maxillary anterior teeth varies significantly depending on the position, tooth type, and gender of the individual.

The table also shows that the mean crown length of male teeth is generally larger than that of female teeth. For example, the mean crown length of central male teeth is 7.8 mm on the left side and 7.7 mm on the right side, while the mean crown length of central female teeth is 7.5 mm on the left side and 7.7 mm on the right side.

Standard Deviation (SD): The standard deviation values provide a measure of the spread or dispersion of the crown length measurements within each group. A larger SD indicates greater variability in crown lengths within that group. For example, comparing the SD values for central female teeth (left: 1.0 mm, right: 1.0 mm) to the SD values for lateral male teeth (left: 0.7 mm, right: 0.9 mm), we can infer that there's more variation in the crown lengths of central female teeth than lateral male teeth.

Maximum and Minimum Values: These values provide the extreme observed crown lengths within each group. They offer context to the overall range of crown lengths observed.

Table 8 presents the descriptive statistics for maxillary central incisor crown length (in mm) categorized by gender. With a sample size of 200 teeth (N=200), the data suggests a potential gender-based difference. While the mean crown length is slightly larger in males (7.8 mm) compared to females (7.6 mm), a notable difference lies in the variability. Male crown length exhibits a larger standard deviation (1.2 mm) and a wider range (7.7 mm) than females (1.0 mm and 4.8 mm respectively), indicating greater size variation in maxillary central incisor crowns among males.

Table 5. Length of root in mm for maxillary central incisors

N=200		Position	
		Left	Right
Length of the root in mm	Mean	15.3	15.2
	Standard Deviation	1.9	1.8
	Maximum	20.0	18.4
	Minimum	9.7	10.0
	Range	10.3	8.4

Table 6. Length of root in mm for maxillary lateral incisors

N=200		Position	
		Left	Right
length of the root in mm	Mean	15.4	15.4
	Standard Deviation	1.9	1.8
	Maximum	19.3	19.9
	Minimum	10.0	10.9
	Range	9.3	9.0

Table 7. Mean Length of Crown for Maxillary Anterior Teeth (N = 400) by Position, tooth, and Gender

N=400		Position							
		Left				Right			
		Central Female	Central Male	Lateral Female	Lateral Male	Central Female	Central Male	Lateral Female	Lateral Male
Length of the crown in mm	Mean	7.5	7.8	6.5	6.4	7.7	7.7	6.6	6.7
	SD	1.0	1.2	1.0	.7	1.0	1.1	.8	.9
	Maximum	10.6	11.9	9.6	8.0	9.9	10.9	8.9	9.9
	Minimum	5.9	4.2	5.1	4.5	5.8	5.7	5.2	5.0

Table 8. Length of crown in mm for maxillary central incisors for both male and female

N=200		Gender	
		Female	Male
Length of the crown in mm	Mean	7.6	7.8
	Standard Deviation	1.0	1.2
	Maximum	10.6	11.9
	Minimum	5.8	4.2
	Range	4.8	7.7

Table 9 displays the descriptive statistics for maxillary lateral incisor crown length (in mm) categorized by gender. Based on a sample of 200 teeth (N=200), the data reveals very similar mean crown lengths for females (6.5 mm) and males (6.6 mm). Interestingly, while the standard deviations are comparable (0.9 mm for females and 0.8 mm for males), the range of crown lengths is slightly wider for males (5.4 mm) compared to females (4.5 mm), suggesting slightly greater size variation among males.

Table 9. Length of crown in mm for maxillary lateral incisors for both male and female

N=200		Gender	
		Female	Male
Length of the crown in mm	Mean	6.5	6.6
	Standard Deviation	0.9	0.8
	Maximum	9.6	9.9
	Minimum	5.1	4.5
	Range	4.5	5.4

Discussion

Maxillary central and lateral incisors in a Yemeni population using CBCT imaging. These findings contribute to the limited body of morphometric data available for Middle Eastern populations and offer clinically relevant insights for restorative, endodontic, and implant procedures.

Interpretation of Findings

The mean overall tooth lengths obtained in this study (21.2–23.4 mm) fall within the range reported in previous research on various ethnic groups (Ahmed et al., 2017; Versiani et al., 2016). The finding that maxillary central incisors tend to be slightly longer than lateral incisors corroborates several population-based morphometric studies (Walker, 1987; Martins et al., 2017). However, minor differences in magnitude compared with reports from Asian and European populations suggest that genetic and environmental factors, such as diet, craniofacial growth patterns, and occlusal stress, may influence crown and root development.

Interestingly, the present data revealed that lateral incisors exhibited proportionally longer roots compared with central incisors—an observation consistent with Vertucci (1984) but not with more recent CBCT-based reports from Turkish and Indian populations (Sert and Bayirli, 2004; Joshi et al., 2021), where central incisors demonstrated greater root length. These discrepancies may reflect population-specific morphological variation, sample size differences, or differences in voxel resolution among imaging systems.

Gender-related differences were observed, with males showing slightly greater mean values for both crown and root lengths. Although not all differences reached statistical significance ($p > 0.05$ in some parameters), the trend aligns with previously reported sexual dimorphism in dental dimensions (Martins and Versiani, 2019). Such dimorphism is often attributed to hormonal influences and variations in overall craniofacial size.

Statistical and Methodological Considerations

While the study achieved an adequate sample size based on power analysis, several methodological limitations must be acknowledged. First, the use of a convenience sample may limit the generalizability of the findings to the broader Yemeni population. Second, CBCT voxel size (0.2 mm)—although clinically acceptable—introduces a small degree of measurement uncertainty, particularly near the cementoenamel junction. Third, while intra- and inter-examiner reliability values (ICCs > 0.90) indicate excellent consistency, potential observer bias cannot be entirely excluded.

Furthermore, although gender differences and

intertooth variations were analyzed statistically, some comparisons approached but did not reach conventional levels of significance ($p < 0.05$). This suggests that the magnitude of anatomical variation, while clinically relevant, may not always be statistically distinct between subgroups. Future studies incorporating larger and more diverse samples could help clarify these trends.

Broader Clinical and Scientific Implications

Beyond their direct relevance to endodontic and restorative procedures, these morphometric findings hold potential applications in forensic odontology and anthropological research, where tooth dimensions are used to infer ancestry, gender, and population affinity. The establishment of population-specific reference values can also enhance dental education and clinical training, enabling practitioners to anticipate anatomical differences when treating Yemeni and other Middle Eastern patients.

Limitations and Future Directions

This study is limited by its cross-sectional design and reliance on retrospective imaging data. The absence of skeletal and facial morphology correlations limits the ability to explore broader craniofacial relationships. Future investigations should:

1. Include other ethnic and regional groups within Yemen to assess intrapopulation variation.
2. Examine associations between incisor dimensions, facial types, and skeletal classes.
3. Evaluate the clinical outcomes of endodontic and restorative procedures performed using individualized morphometric data.
4. Utilize higher-resolution CBCT protocols or 3D surface scanning for improved precision.

Conclusion

This study provides population-specific reference data for the crown and root dimensions of maxillary central and lateral incisors in Yemeni adults, contributing to the limited morphometric database available for Middle Eastern populations. The findings demonstrated that maxillary central incisors were generally longer overall, while lateral incisors exhibited proportionally longer roots relative to crown length. Although males showed slightly greater mean values across most parameters, gender differences were not statistically significant. These results emphasize that dental morphology exhibits measurable variation even within closely related populations, reinforcing the need for individualized radiographic assessment rather than reliance on generalized averages.

Clinically, these data enhance the precision of endodontic length determination, prosthetic crown design, and implant planning by providing a localized anatomical reference. From a research perspective, the study highlights the value of using CBCT for high-resolution morphometric evaluation and sets the groundwork for broader comparative studies across ethnic and regional groups. Future investigations should include larger, multi-regional Yemeni cohorts and explore correlations between incisor morphology, skeletal patterns, and clinical outcomes to strengthen the applicability of these findings in both dental and anthropological contexts.

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