ORIGINAL RESEARCH

Root-crown Ratio of Maxillary and Mandibular Anterior Permanent Teeth in Yemeni Adults using CBCT

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Abstract

Aim: To assess the root–crown ratio (RCR) of maxillary and mandibular anterior permanent teeth from cone-beam computed tomography (CBCT) acquired from a sample of Yemeni adults.

Materials and methods: This was a retrospective radiographic observational cross-sectional study. The study included 233 CBCTs. Root length, crown length, and RCR of all anterior teeth were measured using Ez-3Di software. Factors considered for correlation included gender differences, skeletal classifications (class I, II, and III), overjet (OJ), and overbite (OB). The data were entered and analyzed using the Statistical Package for the Social Sciences software. Significance was set at a value of $p < 0.05$.

Results: Mean RCR of maxillary and mandibular anterior teeth ranged between 1.2 and 1.3 for central incisors, 1.3 and 1.4 for lateral incisors, and 1.5 and 1.6 for canines. The length of roots and crowns was generally greater in males, except for the mean crown length of the left mandibular central incisor. Class III participants exhibited the longest root length for maxillary and mandibular canines, 15.75 and 14.7 mm, respectively, compared with class I and II participants. Participants with increased OJ (>4 mm) showed the lowest root and crown lengths in all canines and lateral incisors while displaying the highest root length in all central incisors. However, no statistically significant variances were observed in root length and the RCR ($p > 0.05$). Those with a deep bite had the longest roots for maxillary lateral and central incisors and the shortest roots for maxillary canines. In contrast, participants with an open bite displayed the opposite measurements.

Conclusions: Gender differences in RCR were insignificant except for the mandibular right central incisor. No significant differences were observed among the three skeletal classes in all study parameters. Furthermore, RCR variations based on OJ and OB were not statistically significant, except for the mandibular left lateral incisor in relation to OB.

Clinical significance: Understanding RCR variations supports clinicians in treatment planning, especially in anchorage selection, force application, and predicting treatment outcomes. This knowledge is important for minimizing potential complications and improving treatment effectiveness in various orthodontic cases.

Keywords: Anterior teeth, Cone-beam computed tomography, Crown length, Crown root ratio, Root length, Yemen.

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Introduction

Human teeth are composed of two distinct anatomical structures, namely the crown and root. The point of convergence between these two segments is referred to as cemento-enamel junction (CEJ). In a state of healthy gingiva, the roots of teeth are fully encased within alveolar bone and enveloped by soft tissue.[1] The root–crown ratio (RCR) is defined as the value between the root and the crown. It is determined by dividing the length of the root by the length of the crown.[2] In the literature, the RCR is classified into anatomical and clinical RCR. The anatomical RCR utilizes the CEJ as a point of reference. In contrast, clinical RCR is determined by the alveolar bone level.[3] Insufficient RCR can lead to tooth mobility, which can compromise the stability of orthodontic appliances and impact the success of orthodontic treatment (OT). Therefore, it is essential to assess the RCR accurately and plan treatment accordingly.[2]

The RCR holds pivotal importance as a diagnostic parameter in OT, influencing treatment decisions and aiding in the evaluation of permanent teeth health. Anterior teeth with unfavorable RCR influence the prognosis of OT; variation in the mean RCR can be attributed to ethnicity, tooth development, individual variation, and measurement methods.[4] Most studies examining normal RCR depend on periapical (PA), orthopantomograms (OPGs) radiographs, or extracted teeth.[5] However, each method has issues of accuracy as PA can be influenced or distorted by the angle

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between the tooth and the film; OPGs are susceptible to vertical magnification, while assessment of RCR on extracted teeth also has challenges in obtaining intact teeth, leading to limitations in sample size.

Various papers validated the accuracy and reliability of using cone-beam computed tomography (CBCT) to assess RCR compared with traditional radiographs.[6,7] The CBCT has been proven to offer clinically significant information and cutting-edge three-dimensional (3D) research data. Recent scientific evidence supports its role not only in diagnosis but also in enhancing treatment plans and outcomes. The CBCT allows visualization of root structure and surrounding bone in 3D, improving the understanding of tooth anatomy.[8] Maintaining adequate anchorage is essential for successful treatment results. The RCR is involved in assessing the anchorage capability of teeth. A decreased or unfavorable RCR, commonly linked to shorter dental roots, can affect a tooth's capacity to function as a reliable anchor in OT.[9] Till date, there is a lack of information about the RCR of anterior permanent teeth among Yemeni adults. Therefore, the study aimed to assess the RCR of maxillary and mandibular anterior permanent teeth from CBCT acquired from a sample of Yemeni adults. The current study addressed this gap by conducting a comprehensive assessment of the RCR of anterior permanent teeth in a sample of Yemeni adults utilizing CBCT technology.

Materials and Methods

This is a retrospective cross-sectional study. The study was carried out at the Faculty of Dentistry, Sana'a University, Yemen, from January to September 2023. Ethical approval from the Medical Ethics Committee of the Faculty of Dentistry at Sana'a University was obtained prior to the commencement of the study (Ref No.: 171/2023). Moreover, in order to maintain patients' privacy, only their gender and age were recorded. Participants aged 16–40 years with fully developed roots were included to ensure age-specific relevance. All collected information was managed confidentially. A total of 233 CBCT images of adult patients were recruited from an imaging center in Sana'a city. The inclusion criteria were fully developed roots, no existing OT, and no craniofacial deformities. The exclusion criteria included missing one or more permanent anterior teeth, any restoration that altered the incisal edges, external resorption, severe attrition, hypercementosis, and dilacerations.

Data Collection and Processing

The CBCT scans were conducted with subjects positioned upright using the following parameters: scanning time of 15.0 seconds, field of view measuring 15 × 15 cm, tube voltage ranging from 50 to 99 kV, tube current varying from 4 to 16 mA, and voxel size set between 0.2 and 0.3. The scans were performed using the PaX-i3D Green (model name: PHT-60 CFO; Vatech Co., Hwaseong, Korea) imaging device. The resulting data was exported in DICOM multifile format and analyzed using 3D image analysis software (Ez3D-i 2009; Ewoosoft, Co., Ltd., Hwaseong, Korea). Processing of the CBCT images was conducted on a 64-bit Windows 10 system. Visualization of all images occurred on a DELL Precision 7720 UHD Graphics 17-inch screen with a resolution of 1,920 × 1,080 pixels in a dimly lit environment. To ensure optimal visualization, adjustments to contrast, sharpness, and brightness were made using the software's image processing tools.

Construction of the Multiplanar Windows

Initially, the tooth to be measured was identified on the 3D plane. Subsequently, the axial plane was used to mark the center of the pulp chamber. The coronal plane was then adjusted to align with the tooth's long axis from the tip to the root apex. Finally, the sagittal plane was aligned to pass through the tooth tip and root apex (Fig. 1).

Points Identification and Measuring of the Parameters

Points and parameters, such as A point, nasion, B point, overjet (OJ), overbite (OB), crown length, and root length, were identified on the software program according to their definitions found in the literature.[7,10–13] Definitions of points and parameters are provided in Table 1. Measurements of skeletal class I, II, and III malocclusions are illustrated in Figure 2.

The OJ refers to the horizontal distance of the most prominent maxillary incisal edge to the labial surface of the mandibular central incisor. It was measured in sagittal view when the teeth were in occlusion by placing the ruler tool over the labial surface of the lower central incisor so that the ruler was perpendicular to the labial surface. The normal OJ was considered from 2 to 4 mm, in which >4 mm is increased OJ while <2 mm is decreased OJ.[13] The OB was measured in sagittal view when the teeth in occlusion by placing the ruler tool between the incisal edges of the lower and upper central incisors; the vertical distance between the lower central incisor and the most intruded upper central incisor was recorded. The normal OB is 2–4 mm, in which >4 is increased OB or deep bite while <2 is decreased OB. When the OB is less than 0 mm, it is called open bite.[13] Figure 3A shows the measurement of OJ and OB. The study sample comprised 82 participants with class I, 91 with class II, and 60 with class III malocclusion.

The measurements of root and crown lengths, denoted in millimeters (mm), were consistently initiated from the upper right canine to the upper left canine. The lower anterior teeth were measured in the same order as the upper teeth. The length of the root was measured by placing the ruler tool along the axis of the tooth, from the apex to the center of the reference line between buccal and palatal CEJ. The levels of CEJ and root apex were assessed using both sagittal and coronal images. The length of crown was measured from the center of the reference line (CEJ) to the incisal edges of incisors and to cusp tips of canines (Fig. 3B). Curved roots were measured by using multilength tool rather than ruler tool to obtain the exact length of these roots (Fig. 3C).

Reliability of Measurements

Following the initial assessment, 2 weeks later, a second analysis was conducted blindly by the same examiner, using 20% of the sample, to assess the intraobserver reliability. The intraobserver agreement was then established by employing intraclass correlation coefficient (ICC) test, which revealed perfect agreement with a value of 0.919 ($p < 0.001$) with 95% confidence interval of 0.865–0.958 for all measurements (Table 2).

Statistical Analysis

The data was inputted and analyzed utilizing the Statistical Package for the Social Sciences (SPSS) software for Windows, Version 28.0 (IBM Corp., Armonk, NY). Statistical significance was determined by confidence intervals, with a p-value < 0.05 considered significant. Normality of data distribution was assessed using the Shapiro–Wilk test. Descriptive statistics, including numbers,

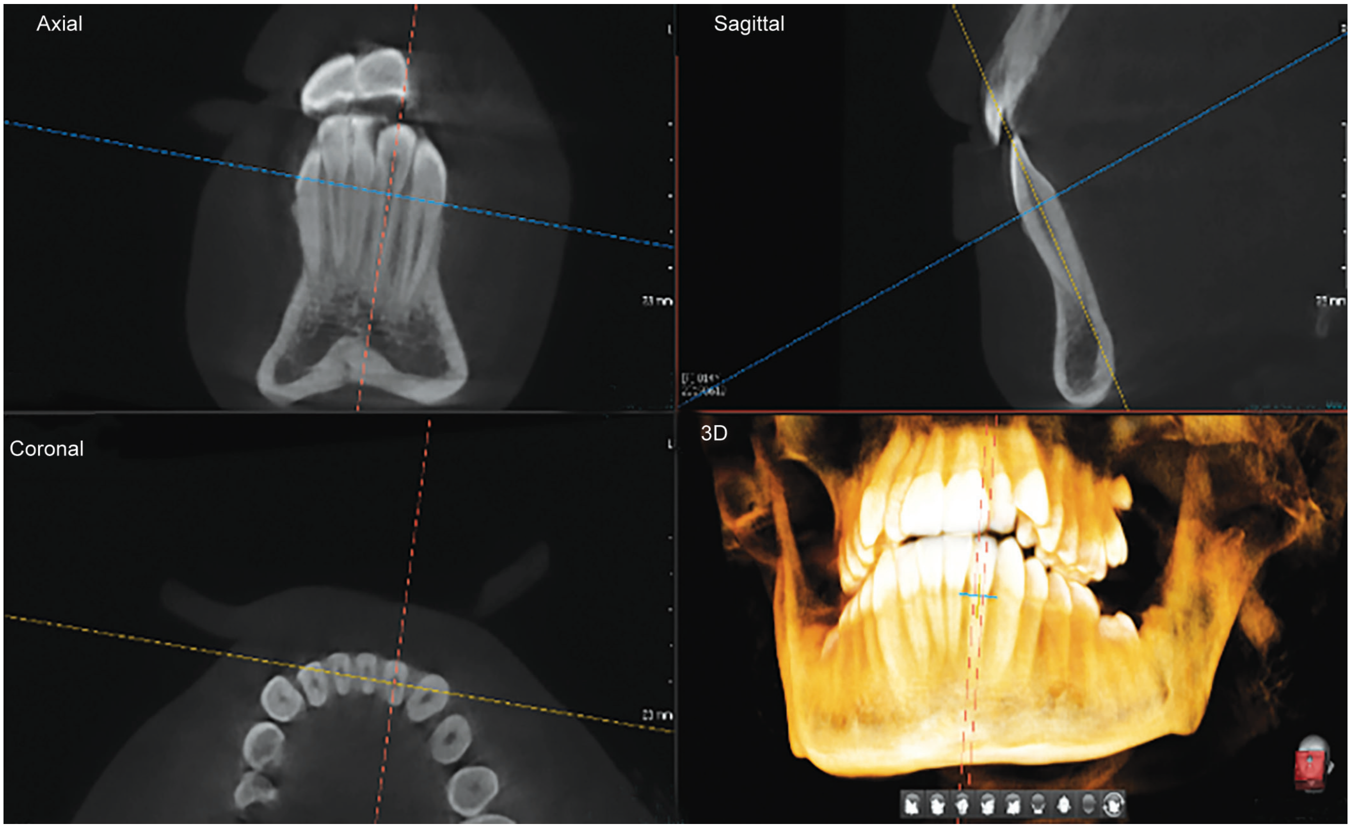


Fig. 1: Construction of multiplanar windows of the CBCT-based length measurements

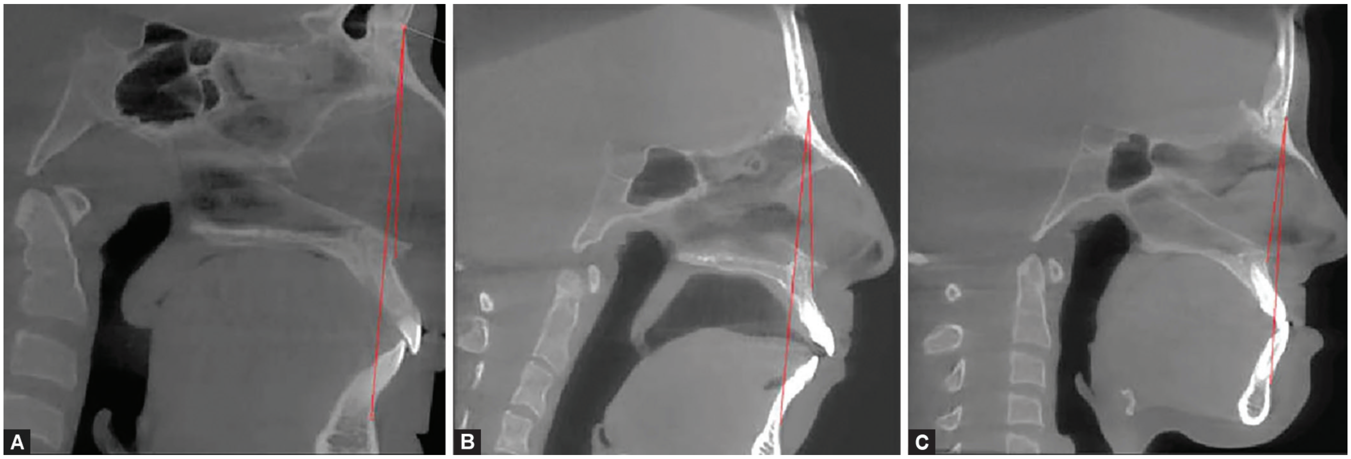
Table 1: Definition of the points and parameters used in the study

Point or measurement	*Abbreviation*	*Definition*
Point A (subspinale)	A	Refers to most concave point of anterior maxilla, between the anterior nasal spine and the prosthion[1]
Nasion	N	Refers to the most anterior point on the frontonasal suture in the midsagittal plane[1]
Point B (supramentale)	B	Refers to most concave point of mandibular symphysis, between the infradentale and the pogonion[1]
A point-nasion-B point	ANB	Refers to a cephalometric measurement that describes the relationship between the maxilla and the mandible when viewed anteroposteriorly. ANB angle from 2° to 4° indicates skeletal class I malocclusion; more than 4° indicates skeletal class II malocclusion; and less than 2° indicates skeletal class III malocclusion[1]
Skeletal class I malocclusion	Class I	This is a normal skeletal relationship between the maxillary and mandibular jaws, also known as a balanced bite, with straight appearance in profile when viewed anteroposteriorly. However, there may be crowding, misalignment of the teeth, crossbite, or other positional or rotational aberrations[2,3]
Skeletal class II malocclusion	Class II	An abnormal skeletal relationship between the maxillary and mandibular jaws, in which the maxillary jaw project more forward than the mandibular jaw, which results in a convex appearance in profile with a receding chin and lower lip[2,3]
Skeletal class III malocclusion	Class III	An abnormal skeletal relationship between the maxillary and mandibular jaws, in which the mandibular jaw projecting further forward than the maxillary jaw, which results in a concave appearance in profile, and the chin is quite prominent[2,3]
Overjet	OJ	Overjet is a term used in orthodontics to describe the horizontal distance between the maxillary and mandibular central incisors when the jaws are closed The OJ is determined by measuring the distance between the labial surfaces of the most prominent incisor and the mandibular incisor. This measurement ranges from 2 to 4 mm on average; it is referred to as increased OJ when it is greater than 4 mm and reduced OJ when it is less than 2 mm. If this measurement is negative, it is called reverse OJ[4]

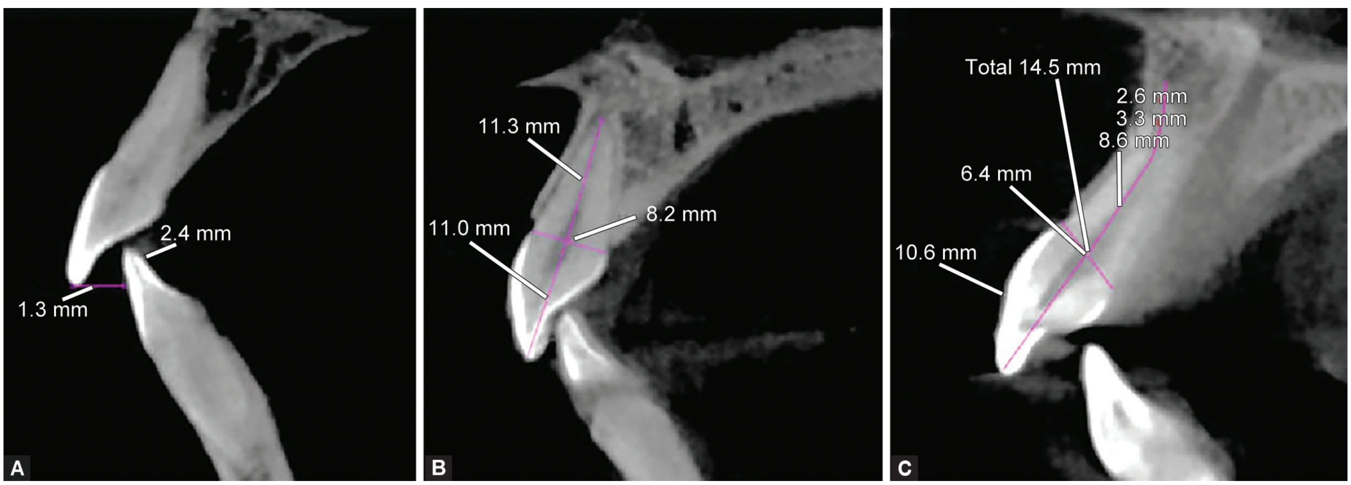
(Contd...)

Table 1: *(Contd...)*

Point or measurement	*Abbreviation*	*Definition*
Overbite	OB	Overbite is a term used in orthodontics to describe the vertical overlap of the maxillary central incisors over the mandibular central incisors This measurement ranges from 2 to 4 mm on average; more than 4 mm is called increased OB (deep bite), and less than 2 mm is called reduced OB. If this measurement is negative, it is called open bite[4]



Figs 2A to C: Skeletal classification in CBCT images: (A) Class I; (B) Class II; (C) Class III



Figs 3A to C: CBCT-derived measurements of (A) OJ and OB; (B) Root and crown lengths using the ruler tool; and (C) Curved root length using the multilength tool on Ez3D-i software

percentages (%), means, and standard deviations (SD), were employed for demographic details. Gender-based comparisons of CBCT measurements were conducted using independent *t*-tests. Analysis of variance (ANOVA) tests were employed to identify significant differences in measurements based on skeletal classification, OJ, and OB.

Results

Demographic details are given in Table 3. The CBCT radiographs of 233 subjects ($n = 110$ males (47.2%) and $n = 123$ females (52.8%)) were included in this study. The average age of the participants was 21.30 ± 6.94 years, ranging from 16 to 40 years. For maxillary and mandibular teeth, mean values of crown and root lengths were significantly ($p < 0.05$) greater for males compared with females. The RCR of right and left mandibular central incisors revealed significance differences ($p < 0.05$) (Table 4).

In the maxillary right side, class III participants showed the highest canine root length, while class II participants had the lowest mean root length, although RCR remained consistent across the three classes. For lateral incisors and central incisors, different classes exhibited variations in root and crown lengths, but RCR was relatively uniform. The mandibular right side demonstrated distinct patterns for canine, lateral incisor, and central incisor characteristics among the three skeletal classes. While in the left side, class III participants displayed the highest canine root length, while class I participants exhibited the highest lateral incisor root and crown lengths (Table 5).

Table 2: ICC test for agreement

Parameter	ICC	95% Confidence interval Lower	Upper	p
All	0.919	0.865	0.958	0.000
ANB	0.961	0.912	0.983	0.000
Overjet	0.961	0.911	0.983	0.000
Overbite	0.977	0.947	0.990	0.000
Maxillary right side				
Canine (R)	0.999	0.999	1.000	0.000
Canine (C)	0.999	0.999	1.000	0.000
Lateral incisor (R)	0.999	0.998	1.000	0.000
Lateral incisor (C)	0.998	0.995	0.999	0.000
Central incisor (R)	0.999	0.999	1.000	0.000
Central incisor (C)	0.999	0.997	0.999	0.000
Maxillary left side				
Central incisor (R)	0.999	0.997	0.999	0.000
Central incisor (C)	0.998	0.996	0.999	0.000
Lateral incisor (R)	0.999	0.999	1.000	0.000
Lateral incisor (C)	0.995	0.989	0.998	0.000
Canine (R)	0.999	0.998	1.000	0.000
Canine (C)	0.999	0.998	1.000	0.000
Mandibular right side				
Canine (R)	0.999	0.998	1.000	0.000
Canine (C)	0.999	0.997	0.999	0.000
Lateral incisor (R)	0.998	0.996	0.999	0.000
Lateral incisor (C)	0.999	0.997	0.999	0.000
Central incisor (R)	0.999	0.998	1.000	0.000
Central incisor (C)	0.998	0.995	0.999	0.000
Mandibular left side				
Central incisor (R)	0.998	0.995	0.999	0.000
Central incisor (C)	0.993	0.984	0.997	0.000
Lateral incisor (R)	0.999	0.997	0.999	0.000
Lateral incisor (C)	0.990	0.978	0.996	0.000
Canine (R)	0.999	0.997	0.999	0.000
Canine (C)	0.999	0.997	0.999	0.000

C, crown length; R, root length

In the maxillary right side, normal OJ showed the highest canine root (15.7 ± 1.7 mm) and crown length (10.2 ± 1.0 mm), while increased OJ had the lowest values (15.4 ± 1.9 mm and 9.7 ± 1.0 mm). In the mandibular right side, increased OJ had the lowest canine root and crown lengths, while decreased OJ had the highest values. The differences in RCR were not significant ($p > 0.05$) by OJ (Table 6). In the maxillary right and left side, open bite participants exhibited the highest canine root and the lowest crown length.

Deep bite participants had the lowest root (15.6 ± 1.4 mm) and the highest crown lengths. In the mandibular right side, deep bite participants had the highest canine root and crown lengths (14.7 ± 1.2 mm and 10.4 ± 1.0 mm). Normal and open bite participants had similar values for right and left side. The RCR was consistent in normal, open bite, and deep bite for the right and left side. In mandibular left side, deep bite participants had the highest canine root and crown length (14.7 ± 1.5 mm and 10.4 ± 1.0 mm) (Table 7).

Table 3: Characteristics of the study sample

Variables	Frequency	Percentage (%)
Gender		
Male	110	47.2
Female	123	52.8
Skeletal classification		
Class I	82	35.2
Class II	91	39.1
Class III	60	25.8
Overjet		
Normal	108	46.4
Increased	43	18.5
Decreased	82	35.2
Overbite		
Normal bite	106	45.5
Increased bite (deep bite)	42	18.0
Reduced bite	85	36.5
Age (years)	Mean ± SD	(Min–Max)
	21.30 ± 6.94	(16–40)

Table 4: Differences in crown length, root length, and RCR by gender in maxillary and mandibular anterior teeth

	Maxillary teeth			Mandibular teeth		
Parameter	Male	Female	p	Male	Female	p
Right side						
Canine (R)	16.2 ± 1.6	15.2 ± 1.8	0.001	14.9 ± 1.5	14.3 ± 1.4	0.003
Canine (C)	10.5 ± 1.0	9.8 ± 0.9	0.001	10.5 ± 1.0	9.9 ± 0.8	0.001
Canine (RCR)	1.6 ± 0.2	1.6 ± 0.2	0.872	1.4 ± 0.2	1.5 ± 0.2	0.254
Lateral incisor (R)	12.8 ± 1.3	12.3 ± 1.1	0.001	13.3 ± 1.4	12.7 ± 1.2	0.001
Lateral incisor (C)	9.7 ± 0.9	9.5 ± 0.9	0.05	9.3 ± 0.7	9.2 ± 0.7	0.130
Lateral incisor (RCR)	1.3 ± 0.2	1.3 ± 0.2	0.128	1.4 ± 0.2	1.4 ± 0.2	0.024
Central incisor (R)	12.9 ± 1.1	12.2 ± 1.4	0.001	12.1 ± 1.2	11.5 ± 1.2	0.001
Central incisor (C)	11.0 ± 0.9	10.7 ± 0.9	0.003	9.1 ± 0.9	9.1 ± 0.8	0.892
Central incisor (RCR)	1.2 ± 0.1	1.2 ± 0.2	0.320	1.3 ± 0.2	1.3 ± 0.2	0.005
Left side						
Central incisor (R)	12.9 ± 1.2	12.0 ± 1.4	0.001	12.1 ± 1.2	11.6 ± 1.3	0.003
Central incisor (C)	11.0 ± 0.9	10.6 ± 0.8	0.005	9.0 ± 0.8	9.1 ± 1.0	0.64

(Contd...)

Table 4: *(Contd...)*

	Maxillary teeth			Mandibular teeth		
Parameter	*Male*	*Female*	*p*	*Male*	*Female*	*p*
Central incisor (RCR)	1.2 ± 0.1	1.1 ± 0.2	0.018	1.4 ± 0.2	1.3 ± 0.2	0.010
Lateral incisor (R)	12.7 ± 1.3	12.1 ± 1.2	0.001	13.2 ± 1.2	12.8 ± 1.3	0.010
Lateral incisor (C)	9.7 ± 0.9	9.5 ± 0.9	0.092	9.3 ± 0.8	9.1 ± 0.7	0.06
Lateral incisor (RCR)	1.3 ± 0.1	1.3 ± 0.2	0.120	1.4 ± 0.2	1.4 ± 0.2	0.36
Canine (R)	16.0 ± 1.9	15.0 ± 1.8	0.001	15.0 ± 1.5	14.3 ± 1.3	0.001
Canine (C)	10.5 ± 1.0	9.9 ± 0.9	0.001	10.3 ± 0.9	9.7 ± 0.8	0.001
Canine (RCR)	1.5 ± 0.2	1.5 ± 0.2	0.904	1.5 ± 0.2	1.5 ± 0.2	0.17

C, crown length; R, root length. $p < 0.05$ indicates statistically significant difference

Table 5: Differences in crown length, root length, and RCR by skeletal classification in maxillary and mandibular anterior teeth

	Maxillary teeth				Mandibular teeth			
Parameter	*Class I*	*Class II*	*Class III*	*p*	*Class I*	*Class II*	*Class III*	*p*
Right side								
Canine (R)	15.6 ± 1.8	15.5 ± 1.7	15.9 ± 1.9	0.413	14.6 ± 1.6	14.6 ± 1.4	14.7 ± 1.5	0.881
Canine (C)	10.2 ± 1.0	10.0 ± 1.0	10.1 ± 1.0	0.665	10.3 ± 1.0	10.0 ± 0.9	10.2 ± 0.9	0.286
Canine (RCR)	1.5 ± 0.2	1.6 ± 0.2	1.6 ± 0.2	0.471	1.4 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	0.522
Lateral incisor (R)	12.6 ± 1.2	12.5 ± 1.1	12.5 ± 1.3	0.679	13.0 ± 1.3	12.8 ± 1.4	13.2 ± 1.5	0.421
Lateral incisor (C)	9.6 ± 0.9	9.6 ± 1.0	9.5 ± 0.8	0.861	9.2 ± 0.9	9.2 ± 0.7	9.4 ± 0.6	0.369
Lateral incisor (RCR)	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.993	1.4 ± 0.2	1.4 ± 0.2	1.4 ± 0.2	0.961
Central incisor (R)	12.5 ± 1.3	12.5 ± 1.2	12.5 ± 1.4	0.956	11.9 ± 1.2	11.9 ± 1.4	11.8 ± 1.1	0.452
Central incisor (C)	10.8 ± 0.9	10.8 ± 0.9	10.8 ± 0.9	0.985	9.0 ± 0.9	9.0 ± 0.8	9.2 ± 0.8	0.224
Central incisor (RCR)	1.2 ± 0.2	1.2 ± 0.1	1.2 ± 0.2	0.971	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.206
Left side								
Canine (R)	15.6 ± 1.8	15.3 ± 1.9	15.6 ± 2.1	0.808	14.6 ± 1.6	14.6 ± 1.4	14.7 ± 1.4	0.767
Canine (C)	10.3 ± 0.9	10.2 ± 1.0	10.1 ± 1.0	0.810	10.0 ± 0.9	10.0 ± 0.9	10.0 ± 0.9	0.058
Canine (RCR)	1.5 ± 0.2	1.5 ± 0.2	1.6 ± 0.2	0.754	1.5 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	0.195
Lateral incisor (R)	12.5 ± 1.4	12.3 ± 1.2	12.4 ± 1.3	0.577	13.1 ± 1.1	12.8 ± 1.4	12.9 ± 1.3	0.260
Lateral incisor (C)	9.6 ± 0.9	9.6 ± 0.9	9.6 ± 0.9	0.954	9.2 ± 0.8	9.2 ± 0.7	9.3 ± 0.6	0.423
Lateral incisor (RCR)	1.3 ± 0.2	1.3 ± 0.1	1.3 ± 0.2	0.407	1.4 ± 0.2	1.4 ± 0.2	1.4 ± 0.2	0.327
Central incisor (R)	12.5 ± 1.4	12.4 ± 1.3	12.5 ± 2.1	0.671	11.8 ± 1.2	11.9 ± 1.4	11.7 ± 1.2	0.947
Central incisor (C)	10.8 ± 0.9	10.8 ± 0.9	10.7 ± 1.0	0.528	9.0 ± 0.8	9.0 ± 0.8	9.3 ± 1.2	0.864
Central incisor (RCR)	1.2 ± 0.1	1.1 ± 0.2	1.2 ± 0.2	0.469	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.767

C, crown length; R, root length. $p < 0.05$ indicates statistically significant difference

Table 6: Differences in crown length, root length, and RCR by OJ in maxillary and mandibular anterior teeth

	Maxillary teeth				Mandibular teeth			
Parameter	*Normal*	*Increased*	*Decreased*	*p*	*Normal*	*Increased*	*Decreased*	*p*
Right side								
Canine (R)	15.7 ± 1.7	15.4 ± 1.9	15.6 ± 1.8	0.646	14.6 ± 1.5	14.4 ± 1.4	14.7 ± 1.5	0.551
Canine (C)	10.2 ± 1.0	9.7 ± 1.0	10.1 ± 0.9	0.028	10.2 ± 1.0	9.9 ± 0.9	10.2 ± 0.9	0.104
Canine (RCR)	1.6 ± 0.2	1.6 ± 0.2	1.6 ± 0.2	0.508	1.4 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	0.691
Lateral incisor (R)	12.6 ± 1.3	12.3 ± 1.0	12.6 ± 1.3	0.286	12.9 ± 1.4	12.7 ± 1.3	13.2 ± 1.3	0.101
Lateral incisor (C)	9.7 ± 0.9	9.4 ± 0.9	9.6 ± 1.0	0.228	9.2 ± 0.7	9.1 ± 0.6	9.4 ± 0.8	0.028
Lateral incisor (RCR)	1.3 ± 0.2	1.3 ± 0.1	1.3 ± 0.2	0.680	1.4 ± 0.2	1.4 ± 0.2	1.4 ± 0.1	0.924
Central incisor (R)	12.6 ± 1.4	12.7 ± 1.3	12.4 ± 1.3	0.281	11.8 ± 1.2	11.7 ± 1.4	11.9 ± 1.1	0.675
Central incisor (C)	10.9 ± 0.9	10.8 ± 0.8	10.8 ± 0.9	0.638	9.0 ± 0.9	9.1 ± 0.8	9.2 ± 0.8	0.098
Central incisor (RCR)	1.2 ± 0.2	1.2 ± 0.1	1.2 ± 0.2	0.581	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.424
Left side								
Canine (R)	15.6 ± 1.8	15.2 ± 1.3	15.5 ± 2.1	0.590	14.7 ± 1.5	14.4 ± 1.4	14.7 ± 1.4	0.771
Canine (C)	10.3 ± 0.9	9.9 ± 0.9	10.1 ± 1.0	0.629	10.1 ± 0.9	9.7 ± 0.9	10.1 ± 0.9	0.001

(Contd...)

Table 6: *(Contd...)*

	Maxillary teeth				*Mandibular teeth*			
Parameter	*Normal*	*Increased*	*Decreased*	*p*	*Normal*	*Increased*	*Decreased*	*p*
Canine (RCR)	1.5 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	0.423	1.5 ± 0.2	1.5 ± 0.1	1.5 ± 0.2	0.218
Lateral incisor (R)	12.5 ± 1.3	12.3 ± 1.2	12.4 ± 1.3	0.608	13.0 ± 1.2	12.6 ± 1.1	13.1 ± 1.4	0.147
Lateral incisor (C)	9.6 ± 0.8	9.6 ± 0.8	9.6 ± 1.0	0.874	9.1 ± 0.7	9.1 ± 0.8	9.4 ± 0.8	0.001
Lateral incisor (RCR)	1.3 ± 0.2	1.3 ± 0.1	1.3 ± 0.2	0.865	1.4 ± 0.2	1.4 ± 0.2	1.4 ± 0.2	0.217
Central incisor (R)	12.4 ± 1.5	12.6 ± 1.3	12.4 ± 1.2	0.630	11.8 ± 1.4	11.9 ± 1.4	11.9 ± 1.1	0.647
Central incisor (C)	10.8 ± 0.8	10.7 ± 0.9	10.8 ± 1.0	0.113	8.9 ± 0.8	8.9 ± 0.8	9.4 ± 1.1	0.086
Central incisor (RCR)	1.2 ± 0.2	1.2 ± 0.1	1.2 ± 0.1	0.901	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.449

C, crown length; R, root length. $p < 0.05$ indicates statistically significant difference

Table 7: Differences in crown length, root length, and RCR by OB in maxillary and mandibular anterior teeth

	Maxillary teeth				*Mandibular teeth*			
Parameter	*Normal bite*	*Deep bite*	*Open bite*	*p*	*Normal bite*	*Deep bite*	*Open bite*	*p*
Right side								
Canine (R)	15.7 ± 1.7	15.6 ± 1.4	15.7 ± 2.0	0.950	14.6 ± 1.6	14.7 ± 1.2	14.6 ± 1.5	0.933
Canine (C)	10.1 ± 1.0	10.4 ± 0.9	10.0 ± 1.0	0.109	10.1 ± 0.9	10.4 ± 1.0	10.1 ± 0.9	0.075
Canine (RCR)	1.6 ± 0.2	1.5 ± 0.2	1.6 ± 0.2	0.267	1.5 ± 0.2	1.4 ± 0.1	1.5 ± 0.2	0.338
Lateral incisor (R)	12.5 ± 1.2	12.7 ± 1.1	12.5 ± 1.3	0.710	13.0 ± 1.4	13.0 ± 1.1	12.9 ± 1.5	0.601
Lateral incisor (C)	9.7 ± 0.9	9.8 ± 0.9	9.3 ± 1.0	0.07	9.2 ± 0.7	9.4 ± 0.7	9.2 ± 0.9	0.190
Lateral incisor (RCR)	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.187	1.4 ± 0.2	1.4 ± 0.1	1.4 ± 0.2	0.463
Central incisor (R)	12.5 ± 1.4	12.9 ± 1.3	12.4 ± 1.2	0.102	11.8 ± 1.1	12.1 ± 1.1	11.7 ± 1.4	0.254
Central incisor (C)	10.8 ± 0.9	11.2 ± 0.8	10.7 ± 0.9	0.008	8.9 ± 0.8	9.4 ± 0.8	9.1 ± 0.9	0.005
Central incisor (RCR)	1.2 ± 0.2	1.2 ± 0.1	1.2 ± 0.1	0.854	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.452
Left side								
Canine (R)	15.4 ± 1.9	15.4 ± 1.3	15.6 ± 2.2	0.142	14.6 ± 1.4	14.7 ± 1.5	14.6 ± 1.5	0.320
Canine (C)	10.1 ± 1.0	10.4 ± 0.9	10.1 ± 0.9	0.001	9.9 ± 0.8	10.4 ± 1.0	9.9 ± 0.9	0.05
Canine (RCR)	1.5 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	0.402	1.5 ± 0.2	1.4 ± 0.2	1.5 ± 0.2	0.698
Lateral incisor (R)	12.3 ± 1.3	12.6 ± 1.0	12.4 ± 1.4	0.498	13.0 ± 1.2	13.0 ± 1.0	12.8 ± 1.5	0.464
Lateral incisor (C)	9.6 ± 0.8	9.8 ± 0.9	9.5 ± 1.0	0.197	9.1 ± 0.7	9.6 ± 0.7	9.2 ± 0.8	0.002
Lateral incisor (RCR)	1.3 ± 0.2	1.3 ± 0.1	1.3 ± 0.2	0.622	1.4 ± 0.2	1.4 ± 0.1	1.4 ± 0.2	0.054
Central incisor (R)	12.3 ± 1.5	12.8 ± 1.0	12.4 ± 1.3	0.848	11.8 ± 1.2	12.1 ± 1.2	11.8 ± 1.4	0.967
Central incisor (C)	10.7 ± 0.9	11.2 ± 0.8	10.6 ± 0.9	0.195	9.0 ± 1.0	9.4 ± 0.8	9.0 ± 0.9	0.07
Central incisor (RCR)	1.2 ± 0.2	1.1 ± 0.1	1.2 ± 0.1	0.187	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.205

C, crown length; R, root length. $p < 0.05$ indicates statistically significant difference

Generally, these findings indicate that skeletal malocclusion classes do not significantly affect RCR, and gender differences in RCR are minimal.

Discussion

The RCR is an important factor in dental treatment. This ratio is essential in the diagnosis, treatment planning, anchorage considerations, force distribution, and long-term stability.[14] In orthodontics, the RCR is important for assessing the correlation between a tooth's crown and root, impacting decisions related to the tooth's support within the bone and its stability during OT.[15] In this study, it was noted that the average RCR among Yemeni population for all anterior teeth ranged from 1.2 to 1.6, which was lower than the result reported among Saudi, Iranian, Malaysian, and Hungarian, German, and Japanese populations.[16–19] The variation in the findings compared with other studies may be attributed to ethnic differences and variations in measurement techniques. Notably, it is important to highlight that all previous studies used OPGs for their assessments. The results revealed that the highest RCR was for the maxillary canines (1.6 ± 0.2), which is similar to the finding among Saudi populations (1.93).[16] Whereas the highest RCR was for mandibular canine among Iranian (2.37), Malaysian (2.39), Finnish (2.22), and Korean populations (1.88).[17,18.20,21] The lowest RCR in maxillary arch was for central incisor (1.2 ± 0.2), which is also in agreement with Saudi (1.6 ± 0.2), Malaysian (1.62), and Iranian populations (1.71).[16–18] This agreement could be explained by the long crown of maxillary central incisor.

Regarding the mandibular arch, the lowest RCR was for central incisor in Yemeni (1.3), which is also in agreement with Saudi (1.51), Iranian (1.85), and Korean populations (1.49), while the lateral incisor was the lowest RCR in Malaysian population (1.93).[7,16–18] Nevertheless, the RCR for the maxillary and mandibular incisors in the present study and the Korean study were lower (1.5), while in the other previous studies they were more than 1.5; this variation in the results could be attributed to ethnic differences or different measurement methods used.[7] However, all the previous studies were conducted on OPGs. Concerning to gender, this study found that, on average, males generally had greater crown and root lengths for all teeth in both jaws compared with females, which was statistically different for most of the crowns and roots of anterior teeth. However, the mean crown height of the left mandibular central incisor was higher in females than in males with no significant difference. Among Yemeni adults, there were less gender differences in the mean RCR of the maxillary and the mandibular anterior teeth, while the root length and crown length had significant gender differences.

The result of this study is in agreement with previous researches; for the maxillary anterior teeth, no significant gender differences in mean RCR were found between males and females, which is consistent with studies conducted in Saudi, Korean, and Malaysian populations.[7,16,18] However, the findings are in disagreement with study in Iranian and in Finnish populations, which found that the mean RCR of maxillary anterior teeth in males was higher than in females.[17,20] Also, the study of RCR in permanent dentition across Hungarian, Japanese, and German population revealed that there were no significant differences observed between genders.[19] The present study found that the RCR for maxillary central incisors was higher in males (1.2 ± 0.1) than in females (1.15 ± 0.1), which is in agreement with a previous study of a Finnish population that used OPGs.[20] Another study of a Korean population also using OPGs found that the RCR for maxillary central incisors was equal in males and females (1.49 ± 0.20).[21]

In relation to skeletal relationship, based on the results of this study, it was noted that individuals with class II malocclusion demonstrated the shortest average root length in the maxillary anterior teeth. This observation holds significant clinical implications, as other studies have emphasized that the extraction of premolars for class II camouflage treatment and the presence of excessive OJ may be regarded as potential risk factors for external apical root resorption (RR) following OT. Sameshima and Sinclair reported that treatment involving tooth extraction for the correction of excessive OJ and a skeletal class II malocclusion can lead to significant RR in the anterior teeth of adult patients due to prolonged treatment duration.[22,23]

With regard to OJ, the result of this study found no significant differences in RCR between normal, increased, and decreased OJ in both maxillary and mandibular incisors. In contrast, a study by Choi et al., on Korean adults, showed no significant differences in RCR between normal, increased, and decreased OJ in maxillary incisors, but significant differences in mandibular incisors.[7] However, there were significant differences in the crown length of the maxillary right canine, mandibular left canine, and mandibular right and left lateral incisors.[7] The results of the one-way ANOVA test indicate that there were no significant differences between normal, increased, and decreased OJ regarding to RCR and root length. but, there were significance differences in the crown length of mandibular lateral incisors, mandibular left central incisor, and maxillary right canine.

In relation to OB, this study revealed that there were no significant differences in RCR among normal, deep, and open bite in both maxillary and mandibular incisors, except for the mandibular left lateral incisor. In contrast, a study by Choi et al. on a Korean population showed no significant differences in RCR among normal, deep, and open bite in maxillary incisors, but significant differences in mandibular incisors. However, there were significant differences in the crown lengths of the maxillary right canine, mandibular left canine, and mandibular right and left lateral incisors. However, there were significant differences in the crown lengths of both maxillary and mandibular left canine, mandibular right central incisor, and mandibular left lateral incisor. Also, the results showed no notable variations in the root length of maxillary and mandibular incisors between individuals with an open bite and those with a normal bite. These results align closely with the findings of Arriola-Guillén et al., who conducted a similar comparison that revealed comparable root lengths for maxillary incisors and mandibular central incisors in individuals with or without an open bite.[24] The one-way ANOVA test results indicate that there were no significant differences in the RCR and root length between normal, deep, and open bite in the Yemeni adults, except the RCR of the mandibular left lateral incisor, and indicate significant differences in the crown length of some of the anterior teeth.

The study's strengths include the use of CBCT for precise 3D measurements and a robust sample size of Yemeni adults with diverse malocclusion types. The study notes a few limitations. Firstly, the sample can be larger since an entire Yemeni population was considered. Secondly, during the sample collection period, one of the limitations was that only one radiographic center had a full-head CBCT machine, while the other centers only had 12 × 12 CBCT machines, which cannot capture the full head, which create a potential for selection bias, as participants with more convenient access to this technology may be excessively represented in the study. Thirdly, the study faced limitations in comparing data with earlier findings because of variations in assessment methods employed in previous studies. Yet, it is important to note that the reliability and validity of the 2D data, in contrast to the 3D readings in this study, may not produce comparable or reliable results. The study recommends future studies to be conducted to examine the RCR before and after OT, specifically focusing on skeletal malocclusion or extraction and nonextraction cases. Longitudinal studies can also be undertaken to observe changes in RCR into age-related variations.

Conclusion

The present study concludes that the mean crown and root lengths were significantly higher for males compared with females. However, the mean RCR of the anterior teeth had less gender differences. There were no significant differences in RCR of the three skeletal malocclusion classes. Participants with increased OJ showed the lowest mean values of both root and crown lengths. Participants with a deep bite displayed significantly higher crown length for the mandibular incisors and canines than patients with a normal bite or an open bite. This approach can provide valuable insights and help establish a comprehensive understanding of dental development in Yemeni adults.

Data Availability Statement

All data generated or analyzed during this study are available from the corresponding author upon a reasonable request.

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