SULAIMANI Dental Joural

Scientific Journal Published by the College of Dentistry,University of Sulaimani

ISSN 4656-2309
sdj.univsul.edu.iq

Volume 12
Issue 2
December 2025

Sulaimani

Dental Journal

An Open Access Journal Published by the College of Dentistry, University of Sulaimani

Publication Office: College of Dentistry, University of Sulaimani, Sulaymaniyah, Iraq Tel: +(964) 533270913 - +(964) 7702106211 / P.O. Box: 1124-30 Sulaymaniyah - Iraq
E-mail: sdj@univsul.edu.iq

ISSN: 2309-4656

Volume 12

Issue 2

August 2025

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Original Article

Morphometric Analysis of Mental Foramen Using Cone Beam Computed Tomography in a Sample of the Erbil Population

Rebaz S. Ismail[1], Jafar Naghshbandi[1], Anwar B. Bataineh[2], Alisir Babakuliyev[3], Mahmoud K. Mohsin[4], Abdulla Nakshbandi[5]*

Abstract

Objective: This study aims to analyze the mental foramen (MF) morphometric characteristics using Cone Beam Computed Tomography and compare its location based on gender differences in the Erbil population.

Methods: The study included 52 Cone-Beam Computed Tomography scans. The following aspects were assessed: the position of the mental foramen (MF) in relation to the lower teeth, the distance of the mental foramen from the midline of the mandible, the distance of the mental foramen from the inferior border of the mandible, and the vertical and transverse distances of the mental foramen.

Results: The study identified significant gender differences in the location of the mental foramen. Males had a greater distance from the mental foramen to the midline of the mandible on the left side (25.49 mm vs. 24.04 mm) and a greater distance from the mental foramen to the inferior border of the mandible on the right side (14.03 mm vs. 12.84 mm). The transverse distance of the mental foramen was also larger in males on the left side (4.47 mm vs. 3.84 mm). The mental foramen was most located between the first and second premolars. Significant differences were observed in the mental foramen's position between the right and left sides.

Conclusions: The findings highlight significant gender-based variations in the location of the mental foramen, which can influence clinical approaches in dental and surgical procedures.

Keywords: *Mental foramen, Cone-Beam Computed Tomography, Mandibular canal, Mental nerve.*

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Submitted: January 16, 2025, Accepted: May 7, 2025, Published: August 1, 2025.

Cite this article as: Ismail RS, Naghshbandi J, Bataineh AB, Babakuliyev A, Mohsin MK, Nakshbandi A. Morphometric Analysis of Mental Foramen Using Cone Beam Computed Tomography in a Sample of the Erbil Population. Sulaimani Dent J. 2025;12(2):1-10.

DOI: https://doi.org/10.17656/sdj.10205

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Introduction

The mental foramen (MF) is located on the outer side of the mandibular body[1]. The inferior alveolar nerve (IAN) traverses the mandibular canal within the mandibular body, on both sides of the jaw. The mandibular foramen serves as the posterior opening of this canal, whilst the MF serves as the anterior opening[2]. Occasionally, smaller additional openings near the MF, known as accessory mental foramina (AMFs), may be observed and present anatomical variations relevant to clinical procedures. The IAN divides into two branches anteriorly: the incisive nerve remains within the jaw to supply innervation to the incisors and canine teeth on the same side, while the mental nerve escapes through the MF to provide sensory perception to the chin and lower lip[1-3,4].

The MF, where the mental nerve exits the jaw, is typically located either above the second premolar or between the roots of the first and second mandibular premolars[5-6]. The MF is a critical location in implantology, providing local anesthesia to the surgical site. Before surgery, it is crucial to evaluate the position, structure, and anatomical variations of the mental nerve to prevent any harm[6-8]. To ensure that these procedures are both efficient and secure, it is imperative to have a comprehensive understanding of the morphometric characteristics and variations of the MF.

Multiple studies have investigated the morphology and spatial distribution of the MF in diverse populations across the globe[9]. The availability of statistics regarding the population of Erbil, Iraq, is significantly limited. Considering the potential influence of genetic and environmental factors on anatomical differences, conducting research focused on this particular demography is essential. In addition, there has been no prior research that has utilized Cone Beam Computed Tomography (CBCT) to examine the morphometry of the MF in the Erbil community. This lack of investigation has resulted in a significant gap in our knowledge of this characteristic within our civilization. Cultural sensitivities in our area also limit the use of dry skulls and mandibles for research purposes, as there is widespread social opposition to the use of human remains in scientific studies. As a result, getting anatomical data from dry skulls to describe the MF is especially difficult. This study is critical because it aims to close a knowledge gap by providing valuable insights into the morphology and location of the MF using CBCT. As a result, we will make a considerable contribution to the existing body of knowledge while also tackling a previously unexplored area in our region.

CBCT was used in this retrospective study to investigate the location of the MF in the Erbil population. In the past, conventional radiography and other two-dimensional imaging technologies were the primary instruments for dental diagnosis and treatment planning. However, these approaches are limited in that they only provide a two-dimensional image of the anatomy. Many studies have already investigated differences in the MF using cadavers or dry mandibles[10-12]. CBCT, with its ability to produce high-resolution 3D images, offers unparalleled insight into the anatomy of the MF, surpassing traditional imaging methods. Hence, to provide an accurate description of the anatomical characteristics of the MF, it is essential to assess the sagittal, coronal, and axial sections[6,13-16]. The objective of this study is to utilize CBCT images to analyze the morphometric measurements and exact distances from the MF to the midline of the mandible (MM) and from the MF to the inferior border of the mandible (IM).

It seeks to investigate the positioning of the MF in relation to the lower teeth, as well as assess the width and height of the MF's diameter. To identify any discrepancies, the measurements and supplementary data will be compared among both male and female patients, as well as between the left and right sides of the mandible.

Materials and methods

To assess the location of the mental foramen (MF) in a sample of individuals from the Erbil population, a retrospective study was conducted using Cone Beam Computed Tomography (CBCT) scans. The scans were selected from an initial pool of 112 CBCT images obtained from two private dental polyclinics in Erbil City. After applying inclusion criteria, a total of 52 scans were included in the study, comprising 26 males (50%) and 26 females (50%). The mean age of the participants was 53.97 years, with a range of 26 to 82 years. All the CBCT scans examined showed an MF on both sides. Inclusion criteria were rigorously applied, resulting in the exclusion of 60 scans that did not meet the specified criteria.

CBCT scans were utilized for diagnosis and treatment planning in orthodontics, maxillary sinus lift procedures, the removal of impacted third molars, and the placement of dental implants. The scans were later used in the study.

Participant Selection

Inclusion criteria

The study included cases who were over the age of 18 and residents of Erbil. Participants were selected based on scans clearly showing the mental foramen (MF) on both sides, with the entire mandible visible on both sides.

Exclusion Criteria

Patients under the age of 18 were excluded because of incomplete mandibular growth. Additionally, patients with pathological changes or segmented images of the mandible, craniofacial lesions or anomalies, a history of dental trauma, implanted teeth, or congenital conditions such as cleft palate were not included in the study.

CBCT image acquisition and investigation

All CBCT scans were carried out using the New-Tom Giano CBCT 3D imaging equipment (QR Sr, Via Silvestrini, 20-37135 Verona, Italy). The system includes a high-frequency, stationary anode X-ray source that operates at 60-90 kV and 1-10 mA in pulsed mode, with a focal spot size of 0.5 mm. It employs a flat-panel amorphous silicon detector and offers an X-ray emission time ranging from 3.6 to 9.0 seconds, along with a scan time of 18 seconds. The minimum reconstruction time is 15 seconds, and it has a 16-bit signal grey scale dynamic range. The system provides a selectable Field of View (FOV), typically ranging from 5 × 5 cm to 16 × 13 cm, allowing for targeted or full arch imaging depending on diagnostic needs. The effective dose is 103 µSv.

The system supports both standing and seated patient positioning and is wheelchair accessible. It utilizes NNT™ software, which includes a free viewer and sharing application. The available field of view (FOV) sizes are 11 x 8 cm, 11 x 5 cm, 8 x 8 cm, 8 x 5 cm, and 5 x 5 cm.

All images were assessed to determine and measure the following parameters: The horizontal position of the mental MF relative to the lower teeth was categorized as being below the mandibular first premolar (PM) tooth, between the lower first and second PM teeth, below the lower second PM tooth, or between the lower second PM and first molar (M) teeth. Additionally, measurements were taken to determine the distance between the lower margins of the MF and the IM, the distance between the anterior margin of the MF and the MM, the vertical diameter (VD) of the MF, and the transverse diameter (TD) of the MF (Figure 1). To identify the horizontal location of the MF on CBCT, we first generated 3D images using the NNT viewer software. This program creates a comprehensive 3D model of the mandible using volume rendering techniques. Then, to enhance the clarity and precision of the evaluation of the MF on the opposing side, we removed one side of the jaw. This allowed for the determination of the MF's horizontal location relative to the lower teeth with accuracy, as shown in Figure 1a.

Two parameters were measured and studied in the axial slice: the TD between the mesial and distal border of the MF, and the distance from the anterior border of the MF to the MM. These measurements are depicted in Figure 1b.

We measured and analyzed the VD of the MF and the distance between the inferior border of it and the IM in the coronal view. Figure 1c illustrates these measurements.

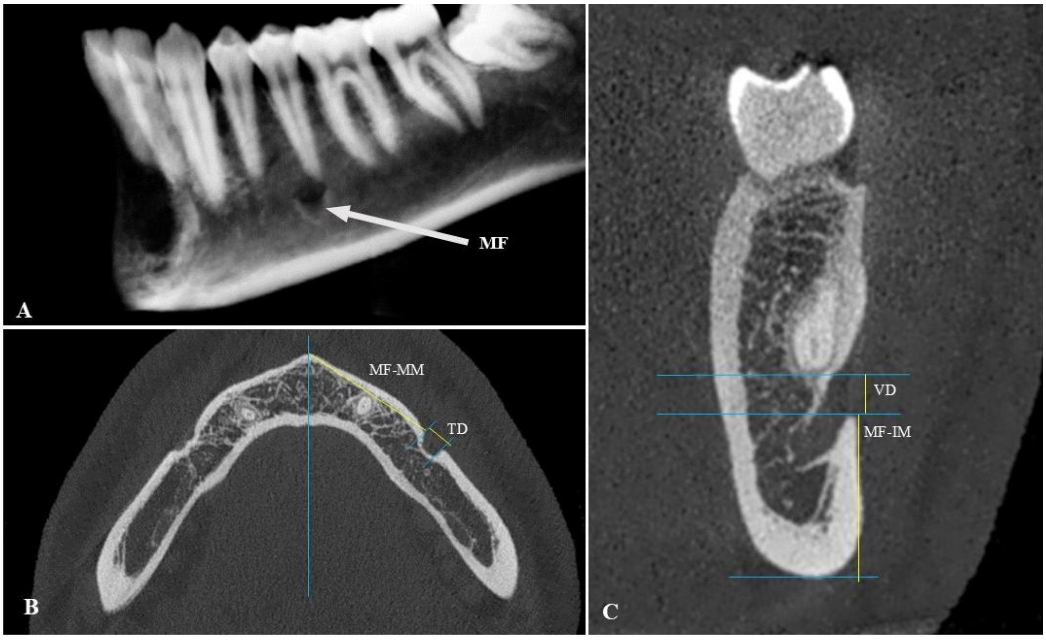

Figure 1: Sagittal sections show the location of the mental foramen (MF) in relation to the lower teeth (A), axial cross-sections illustrating the distance from the anterior border of the MF to the MM and the TD of the MF (B), and coronal cross-sections depicting the distance from the lower border of the MF to the LM along with the VD of the MF (C).

Statistical Analysis

Data will be analyzed separately depending on gender and the side (right or left) of the MF. Statistical analysis was carried out using SPSS. Measurements were analyzed using appropriate statistical tests based on the data type. The Chi-square test was applied to assess categorical variables such as the location of the mental foramen in relation to lower teeth. The paired t-test was used to compare continuous measurements between the left and right sides within the same individuals, while the independent t-test was employed to compare measurements between male and female participants. A p-value of < 0.05 was considered statistically significant.

Results

Sample distribution

The total sample size consisted of 52 subjects, comprising 26 males (50%) and 26 females (50%). The average age was 53.97 years, with a range of 26 to 82 years. All the CBCT scans examined showed an MF on both sides.

Measurement of the distance between the anterior border of MF and MM

The highest distance was 31.3 mm, and the shortest distance was 18.8 mm. The average distance was 24.91 on the right side and 24.77 on the left. There were no statistically significant differences in distances between the right and left sides (Table 1).

The mean distances of MF from MM on the right side of male subjects were 25.28 (± 1.5mm) and 24.54 (±2.63mm) of female subjects on the same side; there was no statistically significant difference in the distances on the right side between gender groups (Table 2). The mean distances of MF from MM on the left side of male cases were 25.49 (±1.8 mm) and 24.04 (±2.44mm) in female cases; there was a statistically significant difference in the distances on the left side between genders (Table 1).

Measurement of the distance between the inferior border of MF and IM

The minimum and highest distances were 9.9 and 17.9 mm, respectively. The average distance was 13.43 mm (±1.75 mm) on the right side and 13.7 mm (±1.61 mm) on the left. The differences in distances between the right and left sides were not statistically significant. (Table 2).

The mean distances of MF from IM on the right side of male subjects were 14.03 (±1.6 mm) and 12.84 (±1.71 mm) for female subjects on the same side; there was a statistically significant difference in the distances on the right side between the two gender groups (Table 4). The mean distances of MF from IM on the left side of male cases were 14.06 (±1.4 mm) and 13.35 (±1.75 mm) of female cases; there was no statistically significant difference in the distances on the left side between genders (Table 2).

Measurement of the TD of MF

The most significant distance was 6.8 mm, and the smallest was 1.8 mm. The average distance was 4.02 (±0.93 mm) on the right side and 4.16 (±0.96 mm) on the left. Between the right and left sides, there were no statistically significant differences in distances. (Table 5).

The mean TD of MF on the right side of male subjects was 4.08 (±1.01 mm) and 3.96 (±0.85) of female subjects on the same side; there was no statistically significant difference in the distances on the right side between gender groups (Table 6). The mean transverse distance of MF on the left side of male cases was 4.47 (± 1 mm) and 3.84 (± 0.82 mm) for female cases; there was a statistically significant difference in the distances on the left side between genders (Table 3).

Measurement of the VD of MF

The most significant distance was 5.4 mm, and the smallest was 1.4 mm. The average distance was 3.18 mm (±0.99 mm) on the left side and 3.27 mm (±0.93 mm) on the right. Between the right and left sides, there were no statistically significant differences in distances. (Table 4).

The mean VD of MF on the right side of male subjects was 3.23 (± 0.88 mm) and 3.3 (±0.99) of female subjects on the same side, there was no statistically significant difference of the distances on the right side between gender groups (Table 8). The mean VD of MF on the left side of male cases was 3.42 (± 1 mm) and 2.94 (± 0.94mm) of female cases; there was no statistically significant difference in the distances on the left side between the genders (Table 4).

Position of MF in relation to lower teeth

In 37.5% of the lower teeth, the MF was most frequently situated between the first and second premolar teeth. The MF aligned the first premolar in 2.88% of cases, the second premolar in 36.5% of cases, and between the second premolar and the first molar in 23.1% of cases (Figure 2).

The p-value reflects a statistically significant difference in the distribution of mental foramen locations on the right and left sides of the mandible (Table 5). According to this data, the mental foramina on the right side were most commonly positioned below the second premolar teeth, whereas on the left side, they were most commonly found between the first and second premolars.

There was a statistically significant difference. There were no statistically significant differences between males and females in terms of both the right and left sides (Table 5).

Table 1: Differences in mean distances of MF from MM based on sides and genders.

Side	Mean	SD	p-value	Gender	N	Mean	SD	p-value
Right	24.91	2.15	0.492	Male	26	25.28	1.5	0.22
				Female	26	24.54	2.63	
Left	24.77	2.25		Male	26	25.49	1.8	0.01
				Female	26	24.04	2.44	

Table 2: Differences in mean distances of MF from IM based on sides and genders.

Side	Mean	SD	p-valu	Gender	N	Mean	SD	p-value
Right	13.43	1.75	0.112	Male	26	14.03	1.6	0.012
				Female	26	12.84	1.71	
Left	13.7	1.61		Male	26	14.06	1.4	0.114
				Female	26	13.35	1.75	

Table 3: Differences in mean TD of MF based on sides and genders.

Side	Mean	SD	p-value	Gender	N	Mean	SD	p-value
Right	4.02	0.93	0.288	Male	26	4.08	1.01	0.648
				Female	26	3.96	0.85	
Left	4.16	0.96		Male	26	4.47	1	0.017
				Female	26	3.84	0.82	

Table 4: Differences in mean VD of MF based on sides and genders.

Side	Mean	SD	p-value	Gender	N	Mean	SD	p-value
Right	3.27	0.93	0.457	Male	26	3.23	0.88	0.792
				Female	26	3.3	0.99	
Left	3.18	0.99		Male	26	3.42	1	0.081
				Female	26	2.94	0.94	

N = Sample size, SD = Standard deviation

Table 5: Position of MF in relation to lower teeth based on sides and gender differences.

Side	Gender	N	In line with the first PM	Between the first and second PM	In line with the second PM	Between the second PM and the first M	p-value	
Right	Male	26	0	9	12	5	0.57	0.001
	Female	26	0	9	9	8		
	Total	52	0	18	21	13		
Left	Male	26	0	11	10	5	0.299	
	Female	26	3	10	7	6		
	Total	52	3	21	17	11		

N = Sample size

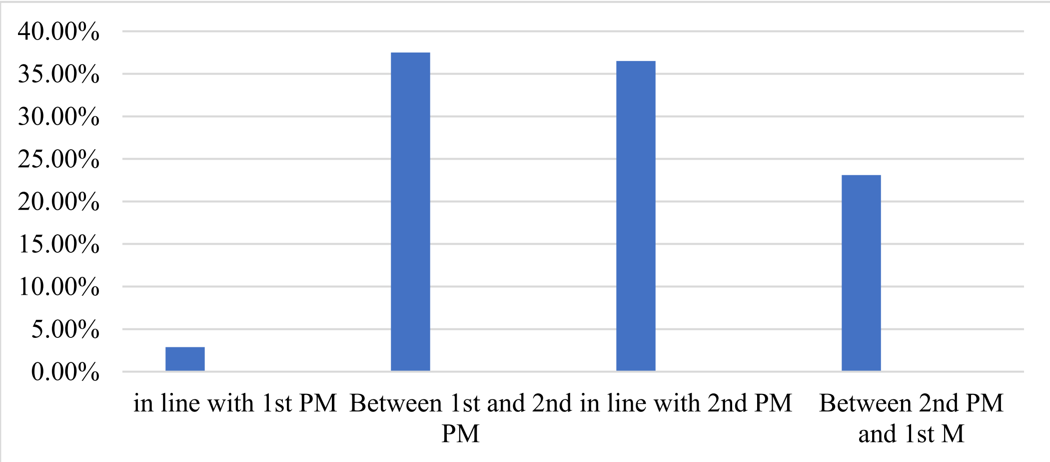

Figure 2: Frequency of MF position relative to lower teeth.

Discussion

The primary objective of this research was to determine the MF's location in relation to the lower teeth within a sample from the Erbil population. We also evaluated the TD and VD of the MF and documented its proximity to the MM and the IM. Furthermore, we examined variations based on gender and mandibular sides. Our analysis revealed certain differences in the MF's position between the right and left sides of the mandible, as well as between male and female subjects.

Our study found that the most common position of the MF is between the first and second premolars, consistent with previous studies[8,17]. However, our results differ from those of studies on the Saudi Al Hasa population[18] and in Spain[19], where the MF was more commonly found at or below the second premolar. Similarly, a CBCT study on the Palestinian population also showed a higher percentage of MF located under the second premolar[3].

The variation in MF position compared to other studies may be due to ethnic differences, as craniofacial anatomy can vary among populations. Differences in sample size, age distribution, and imaging or classification methods may also contribute to these discrepancies.

When analyzing lateral differences, a statistically significant variation was detected between the right and left sides of the mandible. On the right side, the MF was primarily aligned with the second premolar in 36.5% of cases, while on the left side, it was most frequently located between the first and second premolars. This asymmetry, potentially due to natural anatomical variations, developmental differences, or population-specific traits, is essential for clinicians to be aware of during diagnostic and therapeutic procedures. Understanding these differences is crucial to avoid complications such as nerve injury or ineffective anesthesia.

Our findings align with previous studies that reported no significant difference in the MF distance from the MM between the right and left sides. Although slightly higher mean values were observed in studies on Iranian (25.86 mm right, 25.53 mm left)[20], Thai (28.0 mm right, 27.8 mm left)[21], and Caucasian (mean 27.61 mm)[8] populations, the values fall within a comparable range, supporting the consistency of MF positioning across different ethnic groups.

In our study, no significant gender difference was found in the MF distance from the MM on the right side, consistent with findings from an Iranian population. 20 However, a significant difference was observed on the left side, with males showing a greater distance than females. This site-specific gender variation has not been reported in previous studies and may reflect subtle anatomical or population-specific differences.

The mean distance from the MF to the IM showed no significant side-to-side difference in our study, which is consistent with findings from Romanian specimens[22]. Although their reported values (12.1 mm on the right, 12.0 mm on the left) were slightly lower, the overall range remains comparable. A study from Nepal reported that the mean distance from the inferior border of the MF to the IM was greater in males than in females on both sides, with statistically significant gender differences. Similarly, our study found a significantly greater mean distance in males (14.03 mm ± 1.6 mm) than in females (12.84 mm ± 1.71 mm) on the right side, aligning with the Nepali findings. However, while the Nepali study also showed a significant difference on the left side, our results did not reveal a statistically significant gender difference on that side, despite males showing a slightly higher mean distance (14.06 mm ± 1.4 mm) compared to females (13.35 mm ± 1.75 mm) .23

The mean transverse diameter (TD) of the MF in our study showed no significant side-to-side or gender differences, consistent with previous studies. Our values (approximately 4 mm on both sides) closely match those reported in Turkey[24] and Poland[25]. Similarly, no significant gender differences were observed, aligning with findings from Sri Lanka, where comparable TDs were reported for males and females[26].

While our study found a statistically significant gender difference in the TD of the MF on the left side—with males showing larger values than females—this contrasts with both the Polish[25] and Sri Lankan[26] studies, which reported no significant gender difference on the left. Interestingly, the Polish study found a significant difference on the right side, with males having larger TDs than females, which contrasts with our findings, which show no gender difference on that side.

These variations might be attributed to population-specific anatomical features, differences in sample sizes across studies, variations in methodology, or the approaches used in conducting the research. Additionally, a study conducted on a Brazilian population reported a TD of 3.20 mm (ranging from 1.50 to 5.55 mm), with no significant difference between males (3.32 mm) and females (3.14 mm)[27]. While our results show a higher mean TD compared to that study, they are consistent with it in that both studies found no significant gender differences.

Our study found a higher mean VD of the MF (3.27 mm on the right, 3.18 mm on the left) compared to a previous study, which reported values of 2.16 mm (right) and 2.07 mm (left)[28]. While both studies found no significant side-to-side differences, the study from Sri Lanka also reported lower VD values (2.45 mm right, 2.60 mm left)[26], with no significant gender or side differences.

Our study found no significant gender differences in the VD of the MF, with values of 3.23 mm (males) and 3.3 mm (females) on the right, and 3.42 mm (males) and 2.94 mm (females) on the left. These results align with a previous study that also reported no significant gender differences[26].

A Brazilian study using CBCT found a mean VD of 3.11 mm (range: 1.27–5.55 mm), consistent with our findings. However, unlike our study, they observed a significant gender difference (3.41 mm in males, 2.99 mm in females)[27]. Similarly, a Polish study also reported significant gender differences in VD, with males having higher values on both sides (3.55 mm right, 3.41 mm left) compared to females[25]. These differences may be due to variations in populations or imaging techniques.

The location of the MF varies significantly between males and females, as our study found, and this underscores critical issues for therapeutic management. Specifically, males showed a longer TD of the MF on the left side and a greater distance from the anterior border of the MF to the MM on the left side. Males also exhibited a substantially greater distance between the IM and the inferior border of MF on the right side. These results imply that gender-related anatomical changes can influence the spatial relationships of the MF in mandibular morphology.

Several variables may contribute to these variations, including sexual dimorphism, which often results in men having larger, more robust mandibles due to increased bone density and the effects of testosterone. Furthermore, side-specific variations resulting from innate mandibular asymmetry may be more noticeable in men. Sex-based differences in bone development are explained mainly by hormonal impacts during growth periods[29]. Genetic factors are also important; changes in mandibular size and shape can be caused by variances in genes linked to craniofacial development. Environmental factors, such as functional loads and nutritional condition[30-31] also influence individual differences in mandibular size. Any of these variables may impact the location of the MF. Lastly, the discovered differences may be unique to the population under study and not applicable to other populations.

Anatomical differences can have a major impact on the efficacy of local anesthetics in the vicinity of the MF, especially the longer transverse lengths in men. For men to have enough anesthetic coverage and prevent insufficient pain management during procedures, different injection strategies may be needed.

These anatomical differences must be carefully considered in the context of surgical treatments, particularly when inserting implants in the mandibular region near the MF. The likelihood of nerve damage and surgical problems, including paresthesia and bleeding, can be influenced by the MF's closeness to the intended implant site[7,11-13]. According to our research, men showed a longer distance between the MF and the MM as well as a larger TD of the MF. This anatomical variance may increase the likelihood of implant misplacement, potentially leading to nerve injury or sensory impairment. Therefore, to prevent encroaching on the mental nerve and guarantee effective implant placement, meticulous preoperative imaging and exact planning are essential.

Healthcare professionals can improve patient outcomes and procedure safety by limiting the likelihood of complications and taking these gender-related anatomical variances into account. Since the mental nerve innervates the lower lip and chin, precise localization is crucial when administering anesthesia to anesthetize these areas. Additionally, this information is necessary for properly tending to cut and suturing wounds in this area[19]. The discovered differences underscore the importance of a customized evaluation utilizing modern imaging methods, such as CBCT.

It is important to consider the limitations of this study. First, with only 52 participants, the sample size was quite modest. Although the CBCT scans were obtained from two dental facilities in Erbil, the generalizability of the results might be limited due to the target group under investigation. Initially, 112 CBCT scans were considered; however, many were rejected because, in the majority of these CBCTs, only one side of the mandible was visible, as requested by the dentist for specific procedures. It was essential for both sides of the mandible to be visible in this study to enable precise comparisons. Furthermore, many instances have been excluded due to lower tooth loss, which may have impacted the accuracy of the findings. Because proper localization of the MF depends on the presence of the entire lower dentition, this exclusion criterion was required. Moreover, there may have been a bias in the study's selection process, as most patients required CBCT for impacted molars or were seeking dental implants to replace missing teeth. These elements may limit the extent to which the findings can be applied.

Another limitation is the absence of recorded ethnic data. Although the scans were obtained from patients in Erbil—a region predominantly populated by individuals of Kurdish ethnicity—we did not specifically document the ethnic backgrounds of the participants. As such, while the majority of the sample is likely Kurdish, it is possible that individuals from other ethnic groups were included. This limitation should be taken into account when interpreting the role of ethnic variation in the observed anatomical differences. Future studies should aim to record and analyze ethnic background to understand its influence on craniofacial anatomical landmarks better. To validate and expand on the results of this study, larger, more varied sample sizes and the inclusion of additional variables are recommended for future research.

For example, the distance between the superior border of the MF and the alveolar crest should be measured specifically in cases where the lower premolars and first molar are present. This is because, in cases where these teeth are missing, the results may be biased due to bone resorption that naturally occurs after tooth loss, resulting in a significantly shorter distance compared to cases where the teeth are intact.

Conclusion

This study utilized CBCT scans to provide a comprehensive morphometric characterization of the MF in a sample of 52 patients. Statistically significant gender-based variations were observed, with men exhibiting greater distance from the MF to the IM on the right side and the MM on the left. In addition, males displayed a larger TD of the MF on the left side compared to females. These results highlight the importance of considering gender and side-specific anatomical characteristics in clinical practice to enhance dental procedure accuracy and safety. Further studies with larger and more diverse populations are warranted to validate these results and explore their implications in clinical practices.

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Original Article

Comparison of Quality of Root Canal Obturation in Single-Rooted Teeth Performed by Undergraduate Students Using Manual and Rotary Methods (Cross-Sectional Study)

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Abstract

Objective: The study aimed to reveal the influence of different root canal instrumentation methods (manual and rotary) on the features of root canal obturation, as well as determine which method gives the superior quality of obturation.

Methods: A total of 165 case sheets of endodontically treated teeth (incisors, canines, and single-rooted premolars) were included in our samples from the outpatients in the University of Sulaimani, College of Dentistry, each with the radiograph of the treated tooth attached to it. The case sheets were separated into manual and rotary groups. The evaluation was done for three parameters (homogeneity, taperness and length of filling material).

Results: The results show a statistically significant ($p < 0.05$) relationship between manual and rotary instrumentation regarding all three parameters evaluated. There is a higher ratio of adequate length of filling material, adequate homogeneity, and adequate taperness in rotary instrumentation than in manual instrumentation.

Conclusions: This study concludes that rotary NiTi instrumentation improves the quality of root canal obturation regarding the 3 parameters. The findings advocate for the inclusion of rotary NiTi instruments in the undergraduate dental curriculum to enhance endodontic treatment outcomes. In the future, more resources are needed regarding the homogeneity of the obturation by different instrumentation and obturation techniques.

Keywords: *Root canal treatment, Obturation, Manual instrumentation, Rotary instrumentation.*

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Submitted: February 4, 2025, Accepted: June 16, 2025, Published: August 1, 2025.

Cite this article as: Hussein TR, Ibrahim RO, Faris TM, Kazzaz SH. Comparison of Quality of Root Canal Obturation in Single-Rooted Teeth Performed by Undergraduate Students Using Manual and Rotary Methods (Cross-Sectional Study). Sulaimani Dent J. 2025;12(2):11-20.

DOI: https://doi.org/10.17656/sdj.10206

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Published by the College of Dentistry, University of Sulaimani

Introduction

With the increasing importance of preserving the natural teeth, root canal therapy (RCT) is now commonly performed in regular dentistry practice[1]. RCT is conducted to address and resolve the infection in the root canal and to prevent any infection around the apex of the tooth root[2].

Successful root canal treatment is related with clinical procedures that may not follow appropriate requirements and thus do not sufficiently regulate the infection of the root canal due to anatomical distinctions such as isthmuses, lateral canals, recesses, and dentinal tubules; these anatomical variations are typically unapproachable by the instrumentation and antimicrobial agents used during endodontic therapy[3].

The procedure of cleaning and shaping involves mechanical and chemical preparation to remove both organic and inorganic substances using endodontic files and chemicals[4]. Previously, this was done using a standardized method called manual instrumentation, which involved the use of stainless steel hand files. However, during repeated use, it has been revealed that Stainless steel (SS) hand instruments possess restricted flexibility, leading to potential operational errors such as transportation, ledges, or perforations[6]. Additionally, these changes no longer comply with the ISO standards established in 1958 for manual instruments. Nickel-titanium (NiTi) rotary instruments were introduced in the field of endodontics as a solution to the limitations of stainless-steel hand files[7]. The concept of using NiTi alloy for endodontic instruments was first conceived in 1975[8], in the field of endodontics. NiTi alloys have a lower modulus of elasticity compared to stainless steel (SS), allowing for the use of these tools in curved canals with a reduced likelihood of procedural error. Advancements in technology have led to significant changes in the design of the active part of these instruments, including variations in taper and differences in helical angle and cut angle. These instruments incorporate design characteristics that enable doctors to carry out shaping treatments with greater ease, speed, and predictability. However, the implementation of NiTi rotary instruments in undergraduate training has faced challenges due to concerns about instrument fractures and the high cost of infrastructure. This opposition persists despite multiple reports suggesting a low incidence of such complications[9].

The taper of the file influences the shaping techniques used in root canal procedures. When the taper of the root canal increases, it creates more space for irrigation fluids. This allows for a more thorough cleaning process, making the procedure more effective, Additionally, it aids in the obturation of the root canal, resulting in a higher quality of obturation. Simultaneously, a larger taper leads to the removal of a greater quantity of dentin from the walls of the canal. Obturation, also referred to as the filling of the root canals, is a crucial stage in achieving successful root canal therapy. The previous stage of cleaning and shaping has a direct impact on the capacity to fill a root canal. Most approaches utilize a core filling material and sealer to achieve thorough obturation[10]. An ideal root canal obturation should have a 3-dimensional seal of the canal, with no overfill or underfill, and minimal or no voids because inadequate obturation can result in treatment failure[11].

With any obturation technique, several criteria can be used to measure the quality of root canal obturation. The criteria include the distance from the filling material to the radiographic apex, the density of the root-filling material (including any voids), and the taper of the canal, all of which influence the technical quality of the root-filling. The assessment of the technical outcome of RCTs has primarily relied on radiographic evaluation methods. To avoid leakage and enhance the strength of the tooth, it is crucial to achieve a consistent and filled seal from the top to the bottom third of the root canal. The optimal working length should be within a range of 0.5 to 2mm from the radiographical image of the root apex. In addition, employing a rotary file technique for root canal instrumentation will result in a more conical preparation of the channel and enhance the quality of obturation[12].

The objective of this study was to demonstrate the impact of different root canal instrumentation methods (manual and rotary) on the characteristics of root canal obturation and to determine which method yields better outcomes when performed by undergraduate students.

Materials and methods

A random sample of a total of 165 case sheets (73 rotary instrumentation case sheets and 92 manual instrumentation case sheets) was collected. This included radiographs of single-rooted teeth (incisors, canines, single-rooted premolars) that were endodontically treated by 5th-grade undergraduate students in the College of Dentistry, class 2023-2024, using both manual and rotary methods. The radiographs were all periapical radiographs of endodontically treated teeth taken using the bisecting technique and both traditional and digital radiographs were included. This study took about 9 months.

The included periapical radiographs were only of single-rooted teeth. Only case sheets with good quality radiographs, which were taken digitally, were included. Any case sheets with poor quality radiographs or which did not include radiographs of final root canal obturation and radiographs of multiple-rooted teeth were excluded from our research.

The undergraduate students, all in the 5th grade, administered the treatments and took radiographs of the cases used. Radiographs were evaluated by four observers in the 5th class. Two observers evaluated the manual and rotary radiographs using a rotary instrument made from nickel-titanium by the Orodeka company, which was manufactured in China, and assigned scores. The other two observers then reevaluated the radiographs.

The clinical examination, diagnosis, and RCT protocol were conducted under the supervision of endodontists and restorative specialists.

Root canal treatment procedure

In every instance, rubber dam isolation was used along with a local anesthetic. The access cavity was prepared using straight-line access and the step-back technique with a Stainless-steel K-file (Dentsply, Rogen dental) for manual instrumentation. For rotary cases, this was achieved using the FKG Rotary device and FKG NiTi rotary files. Root canal irrigation was done with sodium hypochlorite and normal saline[13].

After shaping and cleaning, the root canal was dried using a paper point (Rogen dental, Meta-Biomed). Obturation was performed using the lateral condensation technique for manual cases, while single cone obturation and modified single cone techniques were employed for rotary cases, utilizing Gutta Percha (Rogen Dental, Meta-Biomed, HTM) (D-line). The type of sealer used was zinc oxide-eugenol under the trade name (EugeSeal safe endo) in a thick consistency.

Evaluation of the root canal filling:

Evaluating the quality of root canal fillings was based on the post-operative radiographs.

Radiographs were evaluated by four students (5th grade), two of whom evaluated rotary instrumentation and manual instrumentation radiographs and both recorded the scores for each radiograph using the criteria shown in Table 1. Then the two other students re-evaluated the radiographs and recorded the scores for each radiograph, using the same criteria and without seeing the scores previously recorded by the other two students. Finally, all the scores were evaluated and compared to ensure accuracy. Minimal differences in scores were found in a couple of cases and the final decisions were made by an endodontic specialist.

The assessment of the root canal fillings was conducted based on the measurement of the distance between the end of the filling and the radiographic apex of the tooth (referred to as the length of the filling), the uniformity of the filling within the canal, and the taper of the filling. The evaluation criteria used are those established by Barrieshi-Nusair et al. The specific descriptions of these indices can be found in Table 1[14].

A T-score system was utilized to evaluate the quality of root filling, specifically the length of the root canal filling. Scores of 0, 1, and 2 were assigned to indicate the quality of the fillings. Conversely, scores (0, 1) were assigned to assess the uniformity of the root canal filling and scores (0, 1) to evaluate the taper of the root canal filling. To obtain a more precise understanding, please refer to Table 1[9,15,16].

Statistical analysis

The statistical analysis was conducted using SPSS 26.0 software (IBM SPSS Statistics, Chicago, IL) with a significance level set at $P < 0.05$. After two weeks, a thorough reexamination of all the results took place, and the level of agreement between the measurements was assessed using the Kappa test. The chi-square test was used to determine the association between rotary and manual instrumentation.

Results

In this study, 165 patients with a mean age of 34.7 ± 14.5 (range, 13-73) years, comprising 94 women (57%) and 71 men (43%), were examined. The interrater reliability for the working length was 0.986, with an asymptotic standard error of 0.014. At the same time, for the taper and the homogeneity of the gutta-percha, there was a perfect agreement with the value of (1) and standard error of (0).

There was a statistically significant relationship between the manual and rotary instrumentation regarding the working length ($x^2(2,165) = 8.2$, $p = 0.014$), as shown in Figure 6. The ratio of adequately filled canals for the rotary instrumentation technique was significantly higher (82%) than for conventional manual instrumentation (65.2%), and the frequency ratio of overfilled canals seemed to be higher in manual conventional technique (17%) than for rotary instrumentation cases (4%). The ratio of underfilled canals was higher in manual instrumentation (17%) than for rotary-treated cases (13%).

Regarding the homogeneity of gutta-percha, a statistically significant relationship was observed ($\chi2 (1, 165) = 49.328$, $p = 0.001$), as shown in Figure 4. The ratio of the inadequate density of obturation in rotary instrumentation cases was significantly lower (17%) than for manual instrumentation (72%), and the ratio of adequate density was significantly higher in rotary instrumentation (82%) than in manual instrumentation (27%).

As for the taperness of the root canal filling, there was also a statistically significant relation between the manual and rotary instrumentation($x^2(1,165) = 18.5$, p=0.001), as shown in Figure 5.

The ratio of adequate taperness in rotary instrumentation was higher (50%) as compared to manual instrumentation (32%), and the ratio of inadequate taperness in rotary instrumentation (32.1%) was almost half of that recorded for manual instrumentation (62.5%).

For a more detailed understanding of the results, please refer to Table 2.

Table 1: Description of the indices, length, homogeneity, and taper of root canal filling.

Variables	Criteria	Definition
Length of root canal filling	0 (under)	Root canal filling end > 2mm from the radiographic apex (Figure 2).
	1 (adequate)	Root canal filling ends < 2mm from the radiographic apex (Figure 1).
	2 (over)	Root canal filling beyond the radiographic apex (Figure 3).
Homogeneity of root canal filling	0 (inadequate)	not uniform homogeneity of root filling and the presence of voids (between root canal filling materials) and canal space (between tooth and root canal filling material) (figure 4).
	1 (adequate)	Uniform homogeneity of root filling without voids (between root canal filling materials) and canal space (between tooth and root canal filling material) (Figure 1).
Taper of root canal filling	0 (inadequate)	Non-harmonious taper from the coronal to the apical part of the root canal filling (Figure 5).
	1 (adequate)	Harmonious taper from the coronal to the apical part of the root canal filling (Figure 1).

Table 2: The results of the evaluation for the 3 parameters of both manual and rotary instrumentation.

Cases	No.	Length		Homogeneity		Taperness	
Manual	92	adequate	(60) cases [ratio=65,2%]	Adequate	(25) cases[ratio=27%]	adequate	(32) cases [ratio=34.7%]
		underfilled	(16) cases[ratio=17%]				
		overfilled	(16) cases [ratio=17%]	Inadequate	(67) cases [ratio=72%]	inadequate	(60) cases [ratio= 65.2%]
Rotary	73	adequate	(60) cases[ratio=82%]	Adequate	(60) cases [ratio=82%]	adequate	(50) cases [ratio= 68.4%]
		underfilled	(10) [ratio=13%]				
		overfilled	(3) cases [ratio=4%]	Inadequate	(13) cases [ratio=17%]	inadequate	(23) cases [ratio=31.5%]
Total	165	adequate	[72.7%]	Adequate	[51.5%]	adequate	[49.7%]
		underfilled	[15,8%]				
		overfilled	[11.5%]	Inadequate	[48.5%]	inadequate	[50.3%]

Figure 3: shows the comparison of adequacy and inadequacy of the working length of the root-filled material between manual and rotary instrumentation.

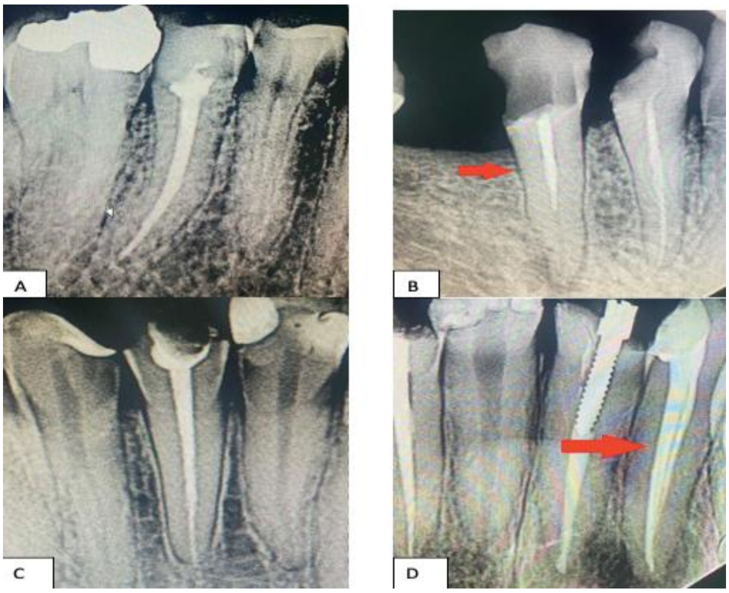
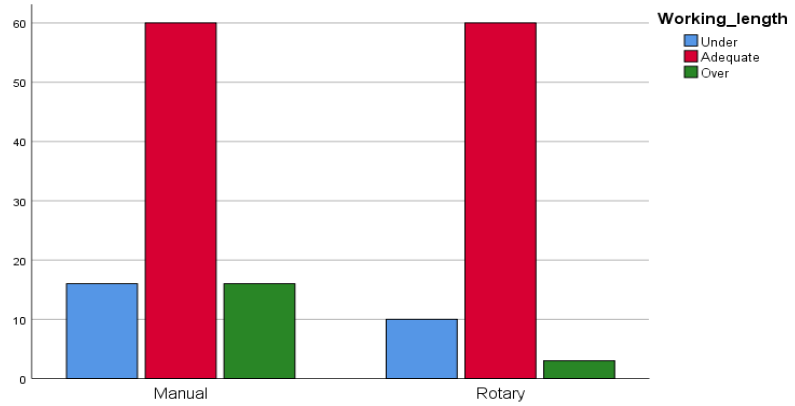


Figure 1: (A) Adequate length, harmonious taper, uniform homogeneity of root canal filling. (B) Root canal filling is located more than 2mm away from the radiographic apex and is not adequately filled. (C) A root canal filling that extends beyond the radiographic apex. (D) Lack of uniformity and inadequate homogeneity in the root filling as well as the presence of spaces between the materials used to fill the root canal represented by the red arrow.

Figure 2: Non-harmonious taper from the coronal to the apical part of the root canal filling.



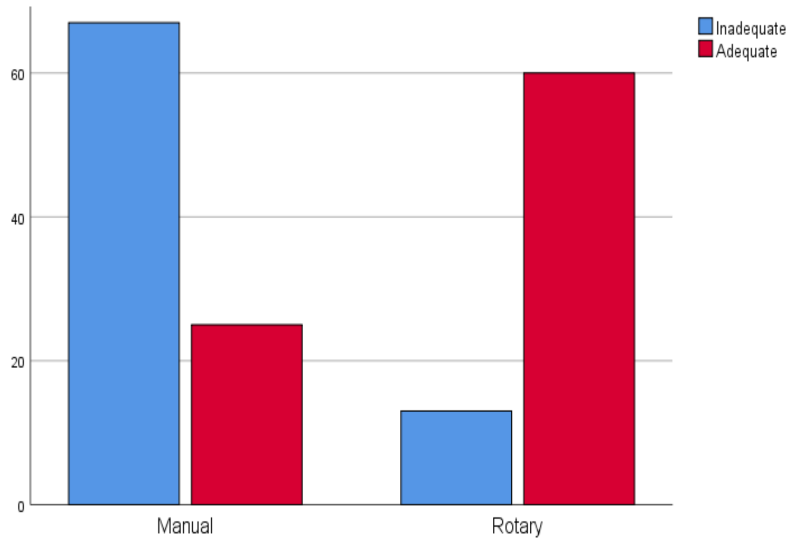


Figure 4: Shows the comparison of adequacy and inadequacy of the homogeneity of the root-filling material between manual and rotary instrumentation.

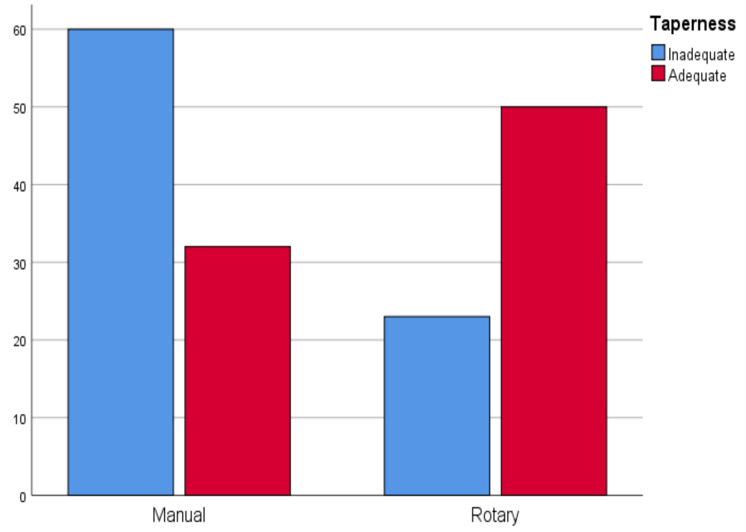


Figure 5 shows the comparison of adequacy and inadequacy of the taperness of the root-filling material between manual and rotary instrumentation.

Discussion

There are two types of instrumentation: the recently used rotary NiTi files with rotary devices and the earlier conventional manual instrumentation using stainless-steel files or NiTi hand files.

Several studies have reported that when inexperienced dental students perform chemo-mechanical preparation the step-back technique may result in insufficient preparation of the root canal or increased procedural mistakes, such as apical transportation, strip perforations, and ledges[17,18]. Certain authors have argued that NiTi instruments have significantly enhanced the quality of root canal shaping compared to stainless steel, as they create a well-tapered root canal shape that is ideal for obturation[12]. A comparison of quantitative and qualitative data indicated that students achieved better canal preparation results with rotary instrumentation[6].

Additionally, various root canal obturation materials with distinct characteristics are routinely used for obturating endodontically instrumented teeth, employing several techniques for obturation.

Using the cold lateral condensation technique may result in voids and incompletely filled canals due to its sensitivity[18]. Voids in close proximity to potentially infected canal walls can potentiate microleakage and, ultimately, the failure of root canal treatment[19].

This study aimed to assess the relationship between the radiographic quality of obturation in single-rooted teeth following instrumentation with conventional stainless steel hand files and rotary NiTi files.

In this study, we have compared the obturation quality in incisors, canines, premolars that typically have a single-root achieved by two types of canal instrumentation (rotary instrumentation and manual conventional stainless steel hand file instrumentation). The quality of obturation using the related techniques (cold lateral condensation technique implemented with hand instrumentation and single cone obturation technique and modified single cone obturation technique used with rotary instrumentation) was compared based on evaluation of periapical radiographs using bisecting technique regarding length of root canal obturation, homogeneity of the canal obturation, and taperness of the root canal obturation.

This study showed a significant relationship between conventional stainless steel file hand instrumentation and rotary NiTi file instrumentation regarding the length of root canal filling material. Significantly higher frequency of adequately filled canals was observed with rotary instrumentation technique than for Conventional manual instrumentation, as shown in Table 2. In addition, there appeared to be a higher frequency ratio of overfilled canals with the manual conventional technique than for rotary instrumentation cases, as shown in Table 2, and the ratio of underfilled canals was higher in manual instrumentation than for rotary treated cases (Table 2).

These findings support those of Robia G.'s study[9] and others[20,21], in contrast to Govindaraju et al and others who found no substantial relationship between the length of obturation and type of instrumentation[22,23,24]. Although Govindaraju et al observed a higher frequency of under-filling of root canals in rotary-treated cases(%13.3) compared to manual (%6.7)[22,23], this might be the result of differences in sample size and type of tooth being treated. Meanwhile, their results were the same as ours regarding the overfilling and adequate filling of canals[22]. Robia G's study[9] found no difference in the frequency of overfilling canals between manual and rotary instrumentation. This result could possibly be due to variations in the obturation technique used and the limited sample size.

Our second comparison parameter was the homogeneity(density) of obturation material. Some researchers considered the lateral adaptation of the root filling material with the dentin wall as a criterion and mostly agreed that if a void was extant between the filling and the canal walls, the density of filling should be regarded as insufficient. These studies stated that inadequate density may result in failure of RCT because of microleakage along the root canal[9,19].

In this study, a highly significant relation has been achieved regarding homogeneity for the rotary system in comparison to conventional hand stainless steel files, and inadequate density of obturation in rotary instrumentation cases was significantly lower than for manual instrumentation cases (Table 2). These results are corroborated by Govinda Raju et al, who concluded that more satisfactory obturation quality is achieved with the rotary system than the manual instrumentation technique[22]. Furthermore, Robia G., in 2011, reported significantly higher occurrence of cases with adequate density (83.3%) in the rotary group than in the manual group(46.7%), while revealing inadequate density of 16.7% among rotary cases (and 53.3% for manual instrumentation cases[9,21].

In contrast, several studies, such as Ul Ehsan et al, reported that the type of instrumentation did not significantly affect the homogeneity of obturation; the frequency of adequate density was not significantly higher for the rotary group than for the manual group[23-26]. This result was perhaps due to variations in the operator's skills and years of experience.

This study showed a significant relationship between the root canal taperness of obturation and the two types of instrumentation system. A higher frequency of adequate taperness of obturation was observed following the use of rotary instrumentation than conventional manual instrumentation, and a higher inadequate taperness of obturation ratio was observed for hand instrumentation than for the rotary system. (Table 2).

These results corroborate the results of Khan et al who found 84% of adequate taperness was achieved following the use of rotary instrumentation and 30% for manual instrumentation, while only 16% of rotary-treated cases had inadequate taperness in comparison to 70% for conventional hand instrumentation [24].

Our results were comparable to those of Jalees et al., who reported a significant difference in root canal filling taper between the two types of instrumentation techniques[23].

Additionally, several studies have reported a significant relationship between the taperness of root canal fillings and the application of the rotary system versus conventional manual hand instrumentation. These studies showed that the rotary method had higher acceptable obturation results and significantly greater effectiveness compared to the manual conventional method[9,19,20,21,23,25].

In this study, we detected a significant relationship between the type of instrumentation and the overall quality of root canal obturation. We determined substantial differences between the two groups (manual, rotary) in the overall quality of obturation.

Under the conditions of this study, inexperienced dental students were more effective at obturating single root canals using the rotary instrumentation method. There was a significantly higher frequency of cases having ideal obturation with the rotary group as compared to the manual group. This result has been supported by many previous studies[20,24,25,27,28], such as Robia G in 2011 also reported a significant relation in T-score between the rotary against manual group (p-value, 0.001), concluding better quality of obturation in the rotary group in comparison to the manual group[9].

Additionally, Jalees et al. stated that the T-score, indicating the general quality of obturation, revealed a statistically significant relationship (p-value, 0.025) between the two groups. A higher frequency of cases with T-score 3 (reflected as having ideal obturation) existed in the rotary group (46.7%) compared to the manual group (20.0%)[23].

While some studies reported no significant relation in quality of instrumentation following the use of rotary and manual instrumentation[29], that could have been because Ni-Ti hand files were used by the conventional manual instrumentation group. The current study's advantages lie in evaluating the quality of root canal obturation accomplished by undergraduate students using manual and rotary methods.

This comparison highlights the effectiveness of various techniques in achieving optimal root canal treatment outcomes. Understanding the differences in quality between manual and rotary instrumentation methods can contribute to the development of dental education curricula and inform clinical practice guidelines, potentially improving patient care and outcomes. Additionally, the study may identify areas where further training or refinement of techniques is needed for undergraduate students.

Overall, their mechanical efficiency and ergonomic benefits make rotary files a preferred choice for many endodontic procedures.

Regarding limitations of this study, generally, obturation quality was evaluated by intraoral periapical radiographs via the bisecting technique, which only provides a two-dimensional image of a three-dimensional form.

Long-term follow-up is essential to assess the clinical and radiographic success of treatments performed using two dissimilar instrumentation methods, as the disinfection procedure performed during treatment may not have been adequately reflected.

Several types of single-rooted teeth were examined for the quality of obturation, including premolars, canines, lateral incisors, and central incisors, which have different canal shapes and which would have affected the specificity of the study. Additionally, while the results may not have accurately represented students' actual skills in accomplishing adequate obturation forms, using only one type of tooth would have resulted in a very limited sample.

In terms of clinical relevance, this study addresses several important areas for both dental education, including skill development and curriculum improvement, and patient care, such as the quality of root canal treatment, patient safety, and comfort.

Conclusion

This study concludes that rotary NiTi instrumentation improves the quality of obturation in terms of length, homogeneity, and taper, particularly when performed by inexperienced dental students. The findings advocate for the inclusion of rotary NiTi instruments in the undergraduate dental curriculum to enhance endodontic treatment outcomes.

Due to their ergonomic benefits and mechanical efficiency, rotary files are often the preferred choice for many endodontic procedures. Future research could be enhanced by including a larger sample size and focusing on a specific type of single-rooted tooth, leading to more specific and reliable results.

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Original Article

Comparative Evaluation of Polishing-Induced Enamel Surface Roughness: An *In Vitro* Study

Saz S. Kamal[1], Fadil A. Kareem[1]*

Abstract

Objective: This study formulated to examine the effect of different polishing modalities and observing the amount of enamel surface roughness induced by each of these polishing devices.

Methods: Fifty- five bovine central incisors were used in the study. The design of the study includes 5 groups and each groups contains 11 samples: Group 1 Aquacare air polisher; Group 2 Rotary and rubber cap using ACCLEAN polishing paste; Group 3 Prophy-Mate Neo; Group 4 Rotary and rubber cap using Pumice; Group 5 AIRFLOW EMS. Lastly, all the air-polishing groups were standardized by polishing the samples for 5 seconds at 90° at 4mm distance. Enamel surface roughness was measured both pre and post-polishing by profilometry, and atomic force microscopy.

Results: Profilometry and atomic force microscopy readings showed that all the study groups except pumice rotary polishing group, showed statistically significant differences in intragroup comparison at $p < 0.05$. On the other hand, ANOVA analysis showed that only the Prophy-Mate Neo group showed statistically significant difference in inter-group comparison ($p < 0.05$). Regarding AFM observations in inter-group comparison, both Prophy-Mate Neo and EMS groups showed statistically significant differences compared to the study groups.

Conclusions: This *in vitro* study finds that of the five different polishing modalities utilized in this study, the rotary polishing technique using pumice as the polishing agent caused the least enamel surface roughness. On the other hand, Prophy-Mate Neo and Airflow EMS caused the highest levels of enamel surface roughness induction.

Keywords: *Dental polishing, Airpolsiher, Enamel surface roughness, Atomic force microscopy, Profilometry.*

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Submitted: April 27, 2025, Accepted: June 13, 2025, Published: August 1, 2025.

Cite this article as: Kamal SS, Kareem FA. Comparative Evaluation of Polishing-Induced Enamel Surface Roughness: An In Vitro Study. Sulaimani Dent J. 2025;12(2):21-30.

DOI: https://doi.org/10.17656/sdj.10207

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Published by the College of Dentistry, University of Sulaimani

Introduction

Periodontal disease refers to a group of diseases that cause inflammation and long-term damage to the tissues surrounding and supporting the teeth, including the gingiva, periodontal ligament, cementum, and alveolar bone. These tissue components are known as the periodontium[1]. Dental biofilm is the primary cause of periodontal disease. Dental biofilm is a necessary factor; however, it is not solely enough to cause periodontal disease[2]. The interplay between the host's immune response, the influence of numerous risk factors, and bacterial invasion caused by dental plaque may explain the diverse range of disease patterns observed in different areas of the oral cavity within the same person[1].

An essential aspect of preventing periodontal disease is the patient's control of dental biofilm. Therefore, it is essential to include patient education and instruction in personal oral hygiene as a crucial component of any treatment strategy for patients diagnosed with periodontal disease. Conventional periodontal therapy encompasses both non-surgical treatment and a range of surgical techniques[3]. Scaling and polishing of the teeth are considered a non-surgical therapy modality that aims to improve the patient's ability to manage dental biofilm at home, rather than substituting for it. Scaling refers to the procedure of removing dental biofilm, mineralized dental biofilm deposits (Calculus), debris, and discoloration from the surfaces of both the visible part and the root of the teeth[4].

Although teeth polishing was referenced in Roman and Greek sources, till Pierre Fauchard, known as the Father of Modern Dentistry, that the practice was recognized. Fauchard used finely powdered coral, eggshells, ginger, or salt to remove dental stains[5]. There are several methods of dental polishing currently available, including rotary polishing and air polishing. Additionally, the methods mentioned above include several agents commonly used in daily dental practice, such as pumice and calcium carbonate. Other abrasive particles used in commercial prophylaxis polishing pastes include aluminum oxide (alumina), zirconium silicate, silicon carbide, aluminum silicate, silicon dioxide, garnet, feldspar, zirconium oxide, carbide compounds, and calcium carbonate. Others include the emery, silica, and perlite[6]. Additionally, many researchers have observed that some polishing particles are thought to have a less abrasive effect on enamel compared to other available particles[7]. Additionally, enamel smoothness results in less dental biofilm accumulation, therefore, decreases the biofilm stagnation area, and has more pleasant aesthetic outcomes by reducing surface stain accumulation property[5].

The use of air polishing devices has the possibility of alteration in the sound enamel surfaces during polishing procedures[8]. Therefore, this research aimed to evaluate and compare the effects of different dental polishing techniques on the surface roughness and abrasion of sound enamel. This study aims to investigate whether polishing with various devices results in significant alterations to the sound enamel surface compared to the standard traditional rotary polishing technique, thereby assessing the safety and efficacy of these devices in clinical practice.

Materials and methods

Sample preparation

Fifty-five freshly extracted caries-free bovine central incisor teeth were selected for the study. Additionally, the main reason for utilizing bovine teeth is that bovine enamel very closely resembles human enamel and is frequently used in research, as suggested by ISO 11405/TS recommendation[9]. After the bovine animals were beheaded in the slaughterhouse in Sulaymaniyah city, the mandibles were collected directly from the butchers. These teeth were extracted from the mandibles to ensure the freshness of the study samples and were cleaned thoroughly to remove all debris, tissue tags, and calculus from the surface using an ultrasonic scaler. The ultrasonic scaler was used at a medium power setting and tip angulation close to zero degrees with the tooth surface; afterward, samples were stored at room temperature in Chloramine T-Trihydrate solution[10]. The crown portion at the cementoenamel junction of each tooth was cut with a metallic sectioning disc (Edenta Company, Switzerland) with a thickness of 0.35 mm and a diameter of 30 mm, at a maximum speed of 10000 RPM, under copious irrigation. After de-coronation, the tooth crown was embedded in an acrylic rectangular base, with a flat facial surface facing outward (Figure 1). All experiments were conducted after obtaining ethical clearance from the Ethical Committee of the College of Dentistry, University of Sulaimani (ethical approval number: COD-EC-24-0032, dated 16 December 2024).

Study design

After formulating the study models and acrylic base housing, the teeth were randomly categorized into 5 groups having 11 teeth in each group, and the sample size were determined utilizing G power software version 3.1.9.7 determined the sample size depending on data from a previous study[12]. Group 1 Aqua Care: In this group the teeth subjected to the spray from the Aqua Care® air polishing device; Group 2 Rotary and rubber cap using ACCLEAN polishing paste (Silicon Dioxide): This group samples treated with rubber-cup polishing using polishing paste; Group 3 Prophy-Mate Neo: Regarding this group, the teeth exposed to the spray from the Prophy-Mate Neo, NSK ® air polishing device; Group 4 Rotary and rubber cap using Pumice: This group the samples treated with rubber-cup polishing using PD pumice powder(Silicon Dioxide); Group 5 AIRFLOW: Lastly, this group, the teeth air polished with the spray from the AIRFLOW, EMS® air polishing device (Figure 2).

Randomization and blinding

In this study, a simple randomization method was employed to allocate the bovine teeth samples into their treatment groups of Aquacare, polishing paste, Prophy-Mate Neo, polishing with pumice, and Airflow EMS. Each sample was assigned to a group using a random number generator, ensuring that the all the study samples were allocated to groups purely by chance. This randomization process was performed by an independent researcher, who was not involved in data collection and analysis to minimize selection bias.

Polishing standardization

Standardization of this study was carried out utilizing a customized dental surveyor, the customization includes fabrication of a special holder for the air polishing devices at a preset angle and a fixed distance between the dental air polisher tip and the samples[12]. On the other hand, before initiating polishing, the surveyor was calibrated using an Inclinometer to ensure the surface of the dental surveyor was properly seated (Figure 3A, 3B). Additionally, all the air polisher devices mounted at a uniform guidance at a distance of 4 mm and a 90° angle at 3 bars of air-pressure on the surveyor to ensure standardized distance and angle of exposure of each device to each enamel sample groups and each sample will be air polished for 5 seconds each[13–15] (Figure 3A-3D). Additionally, the traditional polishing methods utilized a 4000-rpm rotation speed for 30 seconds[16]. Utilizing both polishing paste (ACCLEAN, Henry Schein, medium grit, 50µ, USA) and pumice (medium grit, 50µ, i-dental company, Lithuania) into two different groups.

Polishing particles

All the air polishing groups were sprayed for 5 seconds in a 4 mm distance between the tip of the air polisher and the teeth, and the abrasive powder used for each group is as follow: Aquacare air polisher utilized using sodium bicarbonate 50µ particle size; Prophy-Mate Neo air polisher used with its company designated polishing powder (Flash Pearl Powder) 54µ; Airflow EMS air polisher were used utilizing Airflow Classic Comfort supragingival polishing powder 50µ particle size. Additionally, rotary polishing groups utilized two different polishing agents: polishing with rubber cap and polishing paste carried out utilizing ACCLEAN prophy paste (Henry Schein, USA), and second group polishing by handpiece and rubber cap carried out using pumice PD company (Produits Dentaires SA, Switzerland) medium grit polishing powder.

Surface roughness measurement by profilometry

A contact-type profilometer (Landtek SRT-6200, China) equipped with a diamond-tipped stylus was used for surface roughness measurement. The instrument was first calibrated using the manufacturer's standardizer at a roughness average of 2.68 µm; thereafter, the surface roughness of the test samples was measured. The stylus traversed the enamel surface of the samples at a constant 0.75 mm/s and with a traverse length of 4 mm, ensuring consistent and reproducible measurements for the study samples (Figure 4A and 4B). Additionally, the enamel surface roughness of all study samples was measured both before and after polishing, and the observed outcomes were compared and analyzed.

Surface roughness measurement by Atomic Force Microscopy (AFM)

Atomic force microscopy (AFM) is used to evaluate study samples' alterations to the tooth surface *in vitro* using the Nanosurf C3000 (Flex-Axiom, Switzerland). At a constant force mode of 10 nN, the AFM probes were in contact mode with the enamel surface of the study samples. Using the Nanosurf software. Additionally, a line scan frequency of 250 kHz was used for each sample. Images of 30 × 30 µm² were scanned in three randomly chosen areas at a resolution of 512 × 512 pixels, and a 5-nanometre image magnification was employed. The surface roughness of each specimen was assessed as the root mean square (RMS) of the height distribution in the three-dimensional AFM topographic images, and 3-dimensional images were obtained and analyzed using the designated AFM Flexi-Axiom Mountain software. Likewise, in the profilometry measurement, all the study samples were examined by the AFM machine both before and after polishing.

Statistical Analysis

The data were analyzed using SPSS version 22.0, I.B.M (Chicago, USA) and presented as mean ± standard deviation (SD). The normality of the data was checked using a Shapiro-Wilk analysis. The study employed t-test for evaluation of intragroup statistical differences. Additionally, one-way analysis of variance (ANOVA) was used to examine the data to observe statistical differences for inter-group comparison, followed by post hoc comparison testing utilizing the Tukey test. Statistical significance was attributed to probability values of less than 0.05.

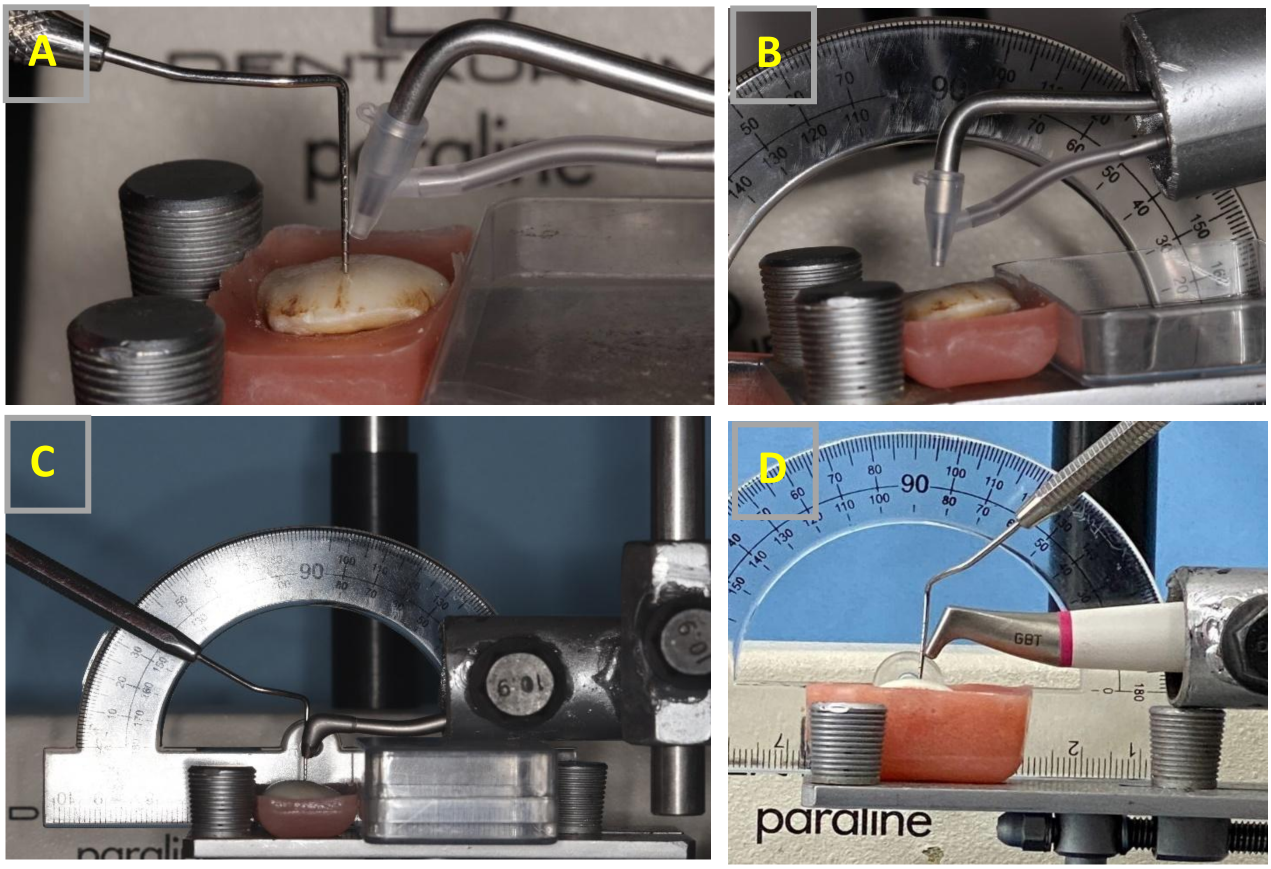

Figure 1: A: Distance standarazation setting at 4 mm distance from enamel surface. B: Standarazing angulation of the airpoloisher to 90° to the enamel surface (Both Photo A&B is Aquacare polishing device). C: Prophy Mate Neo airpolisher device standarazation at 4 mm distance and 90° to the enamel surface . D: AIRFLOW EMS airpolisher device standarazation setting at 4 mm distance and 90° to the enamel surface.

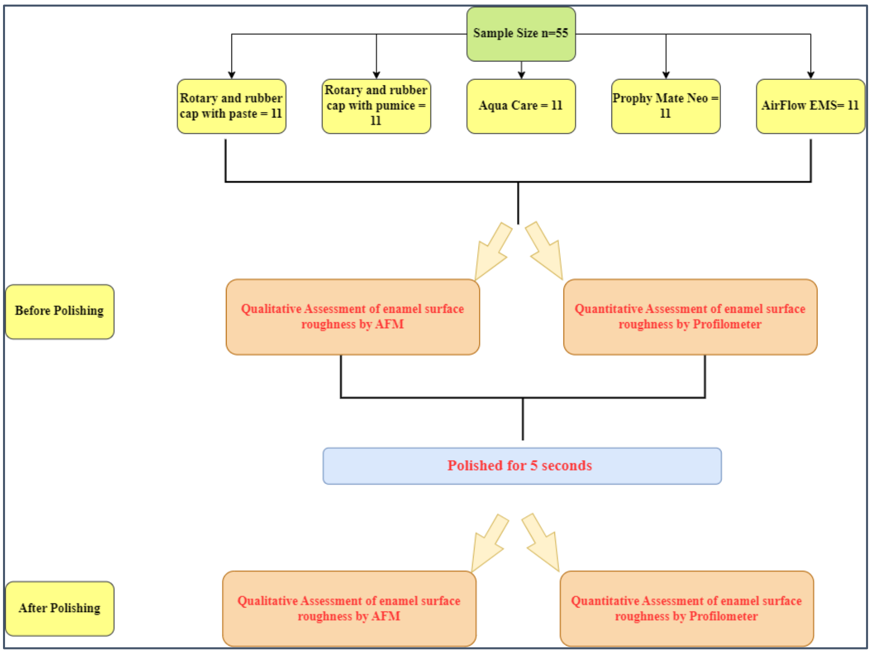

Figure 2: Study design.

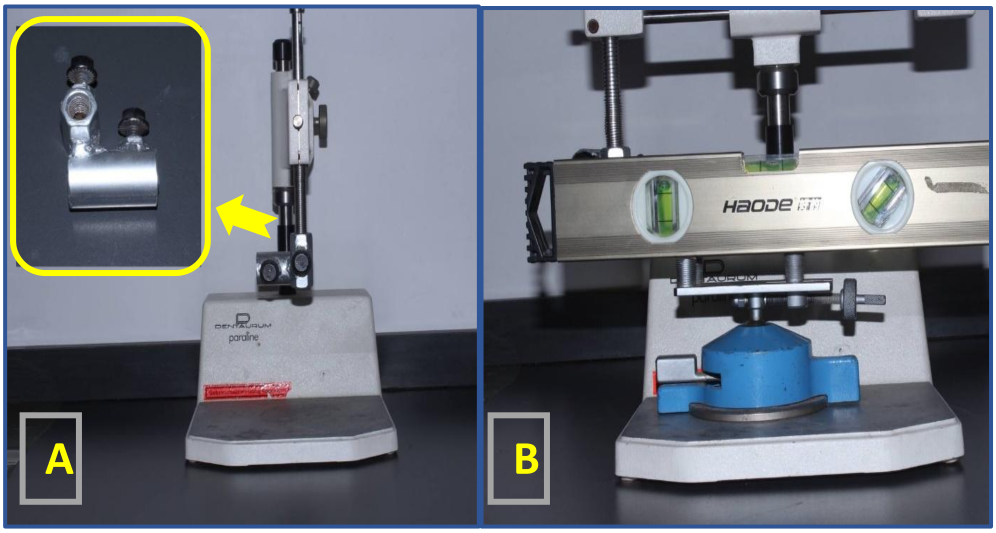

Figure 3: A: Special customization of dental surveyour by fabrication of airpolisher holder. B: leveling of the dental surveyour to enusure flat surface were used for mounting the dental surveyour and proper anglulation of the mounted airpolisher devices.

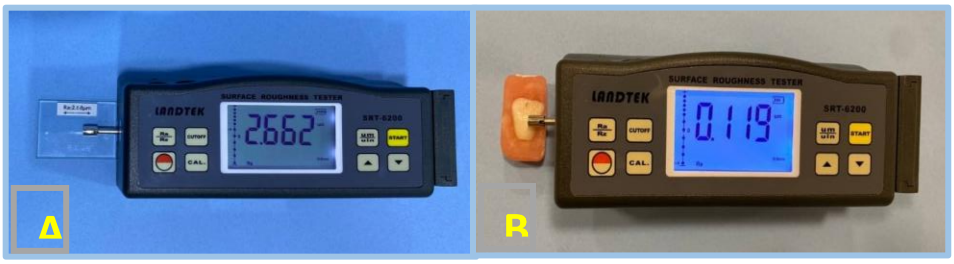

Figure 4: **A**: Calibration of the contact profilometer by the manifacturer standarizer. **B**: Surface roughness measurement by contact profilometer after standarazation.

Results

Profilometry roughness average measurement

Surface roughness profilometry measurement data were compared between before polishing and after polishing for each group by a paired t-test to check whether the means and standard deviation values are similar. Additionally, inter-group comparison of post-polishing

Data was carried out using ANOVA and Tukey test at a difference level of p-value > 0.05.

In the Aquacare group, the mean value of enamel surface roughness increased from 0.1233±0.0451µm to 0.1650±0.0390µm after polishing. This indicates that, regarding intragroup comparison, Aquacare showed a statistically significant difference on the enamel surface (p-value < 0.05) (Table 1). Similarly, the polishing paste group showed a notable increase, where the mean value increased from 0.1121±0.0342µm to 0.1610±0.0406µm after polishing. This increase in the surface roughness value showed a statistically significant difference in within-group comparison (p-value < 0.05). The Prophy-Mate Neo group also indicated a significant increase in the roughness average value, where the mean value of enamel roughness increased from 0.1205±0.0330µm before polishing to 0.21±0.0456µm after polishing, which showed a statistically significant difference in intragroup comparison (p-value < 0.05) (Table 1). The EMS air polishing modality, similarly to the previously mentioned groups, showed a statistically significant difference (p-value < 0.05), in which the surface roughness of the enamel increased from 0.1096 ± 0.0292 µm to 0.1871 ± 0.0322 µm after polishing. On the other hand, the rotary polishing utilizing pumice polishing agent did not show a statistically significant difference (p-value > 0.05)., although the mean value of surface roughness increased from 0.1147±0.0226µm to 0.1247±0.0480µm, this increase didn't show statistically significant difference regarding with-in group comparison (p-value > 0.05) (Table 1).

Additionally, to compare the inter-group differences between the study groups, a one-way ANOVA was conducted. It was revealed that the Prophy Neo group showed a statistically significant difference compared to the other study groups (p-value< 0.05). However, the other remaining test groups showed no statistically significant difference at p > 0.05. This indicates that other groups showed an increase in the enamel surface roughness values, and this alteration yielded no statistically significant difference at a p-value greater than 0.05 regarding inter-group comparison (Table 1).

Summarizing the observed outcome of profilometry roughness average measurements, all the polishing treatments tested, apart from Pumice, indicated statistically significant differences in intragroup comparison changes to the enamel surface compared to the initial baseline values. While intergroup comparison among the study groups, the polishing group treatment, which showed a statistically significant difference at p-value < 0.05, was found to be Prophy Neo by presenting a significantly greater post-polishing mean value compared to the other study groups (Table 1, Figure 5A).

Atomic force microscopy measurement of Root Mean Square (RMS) of heights

Regarding the second method of evaluating enamel surface roughness in this study, atomic force microscopy was employed to measure surface roughness by determining the root mean square (RMS) height in nanometers (nm).

Firstly, observed outcomes were analyzed to show intragroup comparison of observed results by paired t-test at p-value < 0.05. The first group, the Aquacare group, in the within-group comparison revealed a statistically significant difference compared to the baseline data before polishing, which increased the RMS from 310.27 ± 14.09 nm to 398.13 ± 15.70 nm. Likewise, the polishing paste group showed a significant increase in the RMS height from 315.78 ± 13.52 nm to 336.87 ± 14.00 nm in post-polishing data, which yielded a statistically significant difference compared to baseline data at p-value < 0.05. Followed by both Prophy-Mate Neo and EMS polishing modalities, which both showed statistically significant differences (p-value < 0.05) compared to the baseline data before initiating polishing. Finally, the rotary group utilizing pumice as a polishing medium showed a non-statistically significant difference (p-value > 0.05) compared to baseline data (Table 2).

Inter-group comparison of post polishing data utilizing ANOVA and Tukey test, showed that, both of Prophy-Mate Neo and AIRFLOW EMS groups displayed the most substantial increase in surface roughness among all the groups, with RMS heights in Prophy-Mate Neo increasing from 311.93 ± 12.75 nm to 437.12 ± 13.67 nm after polishing and EMS group from 318.51 ± 14.07 nm to 422.12 ± 16.00 nm, showing that both groups, in the ANOVA analysis confirmed that these changes were statistically significant (p-value < 0.05), highlighting the pronounced effect of Prophy-Mate Neo and EMS air polishing modality on enamel surface texture.

Additionally, the rotary polishing group utilizing pumice as a polishing medium showed an increase in the RMS values, which increased from 313.07 ± 12.57 nm to 322.21 ± 13.00 nm. Yet, this increase yielded a non-significant statistical difference at p-value < 0.05, which indicates that the pumice group showed that minimum surface roughness was induced by the rotary polishing technique using pumice (Table 2).

Summarizing the observed surface roughness outcome while measuring the RMS heights by AFM. The Prophy-Mate Neo and AIRFLOW EMS air polishing devices yielded the highest increase in RMS values in both inter-group and intragroup comparisons, indicating greater surface roughness post-treatment. Aquacare and Polishing Paste also resulted in significant increases, though to a lesser extent, which only had a statistically significant increase of RMS in the within-group comparison, p-value < 0.05. Pumice, on the other hand, had a minimal effect on surface roughness (Table 2, Figure 5B).

Table 1: Profilometry outcomes measuring the enamel surface roughness average for all the study groups.

Groups	Roughness Average (µm)	
	Before (Mean ± SD)	After (Mean ± SD)
Aquacare	0.1233 ± 0.0451	0.1650 ± 0.0322 *
Polishing Paste	0.1121 ± 0.0342	0.1610 ± 0.0406 *
Prophy-Mate Neo	0.1205 ± 0.0330	0.21 ± 0.0456 **
Pumice	0.1147 ± 0.0226	0.1247 ± 0.0480
EMS	0.1096 ± 0.0292	0.1871 ± 0.0390 *

*Statistical significance differences of intragroup comparison. p-value ≤0.05 *Statistical significance differences of inter-group comparison. p-value ≤0.05.

Table 2: Atomic force microsopy data measuring root mean square of heights of enamel surface roughness of study samples.

Groups	Root Mean Square (nm)	
	Before (Mean ± SD)	After (Mean ± SD)
Aquacare	310.27 ± 14.09	398.13 ± 15.70 *
Polishing Paste	315.78 ± 13.52	336.87 ± 14.00 *
Prophy-Mate Neo	311.93 ± 12.75	437.12 ± 13.67 **
Pumice	313.07 ± 12.57	322.21 ± 13.00
EMS	318.51 ± 14.07	422.12 ± 16.00 **

Statistical differences of intragroup comparison (with-in comparison) represented by * sign in the columns. p-value less than 0.05 was considered statistically significant. Statistical differences of inter-group comparison (between group comparison) represented by * sign in the columns. p-value less than 0.05 was considered statistically significant.

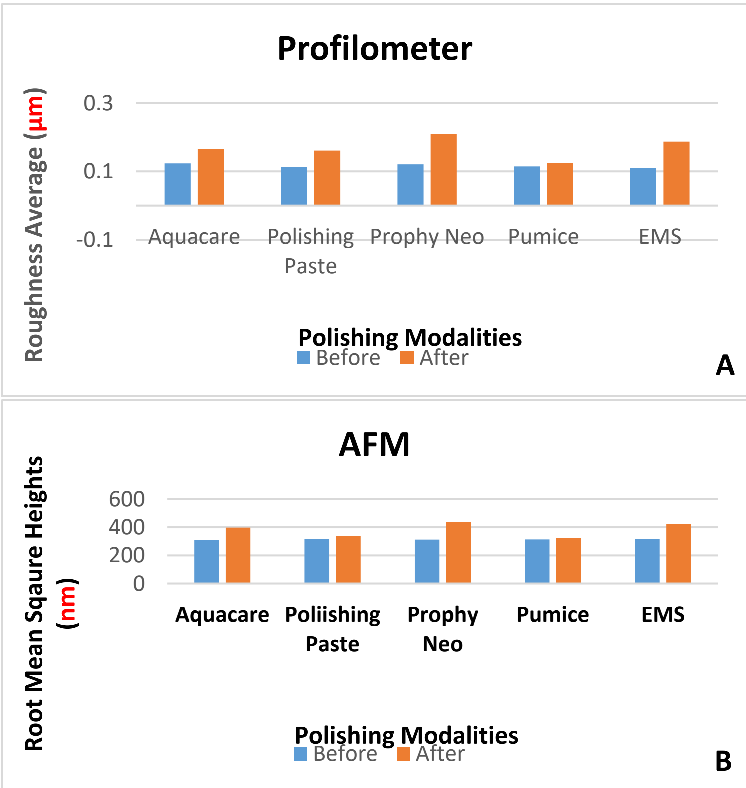

Figure 5: A: Bar chart diagram showing the enamel surface roguhness average measured by profilometry device. B: Bar chart diagram showing the enamel induced surface roughness by measuring the root mean sqaure heights measured by atomic force microscopy.

Discussion

Periodontal maintenance and active mechanical debridement followed by tooth surface polishing to remove dental biofilm suggested to be an effective prevention of modality for periodontal disease[17].

Additionally, these polishing procedures may cause irreversible microscopic damage during inadvertent removal of dental biofilms[18].

Air polishing devices recently gained popularity within the field of dentistry, and more specifically for periodontal maintenance treatment. The main mechanism of action of dental air polishers involves utilizing high high-pressure chamber from which the polishing particles are trapped, and the polishing particles under the high pressure and velocity of air will be forced into a nozzle from which the polishing particles will be released onto the surfaces to be polished, which mainly consist of dental enamel[19]. Subsequently, this pressurized air with water and polishing particle will effectively remove dental biofilms, soft deposits, and extrinsic dental stains.

Dental literature has proposed that after a professional dental prophylaxis session, wear of the dental enamel surface can occur[13]. researchers have measured the extent or frequency of healthy enamel wear in different ways. However, the lack of agreement among dental academics mainly originates from the fact that, the enamel wear that occurred after polishing implies a significant hazard to the tooth surface or it can be considered negligible[13,20,21].

The aim of this *in vitro* study was to evaluate and compare the impact of dental polishing devices on the surface roughness of sound enamel, while utilizing different polishing devices that are currently emerging in the market of dental air polisher devices and to evaluate the degree of their safety and efficacy. On the other hand, utilizing bovine tooth samples was a limitation, although according to ISO 11405/TS recommendations, bovine enamel largely resembles human enamel, however, using human enamel will provide more conclusive data and observational points[9].

In terms of the observed outcomes of this study for evaluation of surface roughness by profilometry device which measured enamel roughness average in µm, showed that all of the polishing modalities except polishing with pumice group showed a significant roughness after polishing compared to baseline data, and these findings are in line with previous research data[16,19,22,23]. On the other hand, the safety of pumice polishing with a rotary handpiece has been reported in many literatures[24,25].

Regarding the surface roughness analysis by AFM, which measures the root mean square of heights in nm, AFM data from this study confirms the profilometry data, in which the paired t-test results that compared within-group, all of the polishing groups except the pumice group showed significant enamel surface roughness and these outcomes are in line with previous literatures[13,26,27]. The main idea of utilizing atomic force microscopy in this type of research is to observe the pattern of roughness induced on the enamel surface, and finally, confirmation of the quantitative observation of the profilometry device[28].

Another key finding of this study worthy of discussion is that, while examining the inter-group comparison ANOVA results, utilizing profilometry and AFM, it was found that in the profilometry reading, the AIRFLOW EMS group showed no statistically significant difference at $p < 0.05$. However, this finding was different when the surface roughness was measured using AFM, which showed that AIRFLOW EMS group showed statistically significant different, and this difference can be mainly related to the fact that profilometry device measure roughness average in µm level and AFM measure surface roughness at nanometer levels, therefore, this significant difference was observed at nanometer level and not revealed significant difference at micrometer level, and this mismatching phenomena can also be observed in other previous literatures[28,29].

Additionally, comparison of inter-group data which carried out using ANOVA and Tukey test revealed that in both profilometry and AFM device, the data revealed that both Prophy-Mate Neo and AIRFLOW EMS device showed highest induced enamel surface roughness compared to other study groups. It is imperative to note that, in comparison to previous literature, it is extremely hard to achieve due to a lack of previous research, and the scarcity of data in this field of research was the main factor that led to the origin and carrying out of this study.

The main limitations of this study are that it was carried out in vitro, which inherently limits the generalizability of the findings, as many intra-oral factors had to be considered, including saliva, temperature fluctuations of the oral cavity, mechanical force of mastication, and overall intraoral conditions and hygiene habits. Additionally, short-term evaluation, which includes an assessment of the enamel surface immediately after polishing. However, long-term evaluation of the enamel surface after various previously mentioned oral environments is necessary to fully understand the durability and abrasive effects of these polishing modalities. On the other hand, limited comparative data in the literature caused difficult contextualization of the observed outcomes, and this limitation underscores the need for further studies in this field to validate and expand upon the current findings.

The recommendation proposed from this study can be suggested as follows: firstly, observation of the effects of the air polishing devices in an *in vivo* study, to evaluate other natural intraoral environmental factors. Additionally, more brands of air polishing devices should be included to have an overview of their clinical efficacy and safety regarding enamel surface roughness induction. On the other hand, utilizing bovine tooth samples was a limitation, although according to ISO 11405/TS recommendations, bovine enamel largely resembles human enamel, however, using human enamel will provide more conclusive data and observational points. Final recommendation includes the use of other polishing particles with different compositions and particle size to observe their abrasive effects on the enamel surface.

Conclusion

All the study groups except rotary polishing technique utilizing pumice as a polishing medium significantly increased enamel roughness ($p < 0.05$), with Prophy-Mate Neo, and AIRFLOW EMS showing the most pronounced enamel surface roughness. Additionally, pumice demonstrated minimal surface alteration, proving its safety on the enamel surface. Clinical implication of these findings suggests that, while air polishing devices effectively remove dental biofilm, they may also induce enamel surface alteration, necessitating careful selection of polishing techniques to minimize enamel surface damage.

Acknowledgement

The authors wish to acknowledge and show sincere appreciation to Sulaimani animal slaughterhouse for providing with bovine samples. gratitude and thanks forwarded to our sincere colleagues and thanks for Periodontics Department, College of Dentistry, University of Sulaimani, who helped with providing various air polishing devices as some of these air polishing device not quite available in every clinic at the current moment, and it is imperative to show our sincere gratitude to the University of Sulaimani, College of Dentistry for their collaboration in providing continuous and endless efforts and support throughout the entire research project.

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Original Article

Cone Beam Computed Tomography Evaluation of the Clinical Correlation between the Stature of the Patient and Tooth Anatomic Odontometry in Iraqi Subpopulation (A Cross-sectional Study)

Shilan N. Dawood [1]

Abstract

Objective: The odontometric assessment of teeth has been considered as crucial for the identification of individuals due to its correlation with body stature. This investigation aims to collect odontometric data on the anatomical dimensions of both mandibular and maxillary anterior and posterior teeth, and to correlate these variables with stature and gender within the Iraqi subpopulation using cone-beam computed tomography analysis.

Methods: This prospective study involved 826 participants, comprising 370 females (44.8%) and 456 males (55.2%), categorized into two height groups: short and tall, based on average height thresholds. Odontometric data, including total tooth length, root length, crown length, and crown width measurements, were recorded via Cone-beam computed tomography. Additionally, physical stature was measured using standardized anthropometric techniques. Statistical analysis was performed using Student's t-test.

Results: Overall, the findings indicate a positive and statistically significant correlation between all odontometric measurements and stature for both genders, with p-values less than 0.05. Notably, maxillary canines exhibited the strongest correlation with stature, followed by maxillary first molars. In contrast, lower central incisors for males and lower second premolars for females showed the weakest correlation. The correlation for crown width was strongest for maxillary canines and mandibular first molars, while lateral incisors and maxillary second molars presented the weakest correlation. Comparing the dimensions of corresponding right and left side teeth revealed some variations, with a few patients displaying differences exceeding 0.45 mm. At the same time, differences were found to be statistically insignificant for the majority of other teeth, with maximum variations reaching only 0.08 mm between contralateral teeth. Furthermore, significant sexual dimorphism was also observed, with male teeth presenting significantly greater dimensions than female teeth, except in the lower central incisors.

Conclusions: The current clinical study highlights the presence of significant sexual dimorphism and confirms a positive and significant relationship between individual stature and tooth dimensions across both genders.

Keywords: *Tooth odontometry, Stature, Permanent dentition, Cone-beam computed tomography.*

Submitted: March 15, 2025, Accepted: June 2, 2025, Published: August 1, 2025.

Cite this article as: Dawood SN. Cone Beam Computed Tomography Evaluation of the Clinical Correlation between the Stature of the Patient and Tooth Anatomic Odontometry in Iraqi Subpopulation (A Cross-sectional Study). Sulaimani Dent J. 2025;12(2):31-43.

DOI: https://doi.org/10.17656/sdj.10208

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Published by the College of Dentistry, University of Sulaimani

Introduction

Dental odontometrics constitutes a quantitative methodology for the analysis and interpretation of tooth dimensions and characteristics, including size and shape[1]. This information serves as valuable data in dentistry, functioning as a foundational element for accurate diagnosis and effective management of dental treatments, as well as for maintaining dental integrity through an extensive understanding of dental anatomy and morphometric variations of teeth among different population that may differ significantly with respect to race, sex and ethnicity, influenced by genetic diversity—a consequence of geographical, historical, and multicultural factors[2, 3].

Most dental anatomy literature presents average anatomic tooth dimensions derived from skulls without accounting for variables such as race, gender, or stature[4]. Consequently, such data is often imprecise, lacking comprehensive details about individual tooth size and morphological characteristics due to individual variations related to stature, age, gender, and race. Establishing uniform ideal tooth dimensions applicable across all human races based solely on studies conducted within a limited number of racial groups is impractical, as variations exist significantly across different races concerning stature[4, 5].

Does stature correlate with tooth sizes and length? The relationship between stature and tooth dimensions remains contentious. Although the statements that larger teeth are typically associated with larger jaws, which in turn correspond to a larger body, along with "greater height possesses longer teeth due to their connection to facial height" appear logical, the validity of these statements is still lacking[6, 7]. Investigating the interplay between tooth dimensions and body size is essential across forensic, endodontic, esthetic, and clinical contexts within dentistry. Comprehensive awareness of tooth width and root lengths within populations can enhance treatment efficacy and success. In endodontics, these measurements assist clinicians in assessing preoperative working length (WL), a determinant for thorough instrumentation within radicular spaces, mitigating periapical tissue injury risks, controlling debris extrusion, and ensuring proper obturation[8, 9]. Moreover, adherence to numeric guidelines concerning size, length, and shape can significantly facilitate achieving esthetic goals, such as creating a pleasing smile[10, 11].

Previous studies explored "normal" and altered tooth and root measurements, predominantly through in vitro examinations of extracted teeth. Though effective, this approach often suffers from inadequate sample sizes due to difficulties in acquiring undamaged teeth. Other investigations employed various radiographic techniques, including conventional periapical or panoramic radiographs[12,13]. However, these methodologies suffer from notable limitations, such as superimposition, distortion from adjacent structures, and magnification issues resulting from the two-dimensional representation of three-dimensional objects. Recently, cone beam computed tomography (CBCT) emerged as a non-invasive and advantageous radiographic alternative, providing precise odontometric data and enabling two-dimensional views of three dimensional structures, thereby facilitating enhanced preoperative assessments for various clinical needs[14, 15, 16]. Sherrard et al. evaluated CBCT images against periapical radiographs from extracted porcine teeth to ascertain the accuracy and precision of CBCT-derived measurements for total tooth and root lengths, demonstrating high reproducibility without significant deviation from actual tooth lengths. Similarly, Nguyen et al. determined that CBCT represents the most reliable method for measuring teeth, root, and crown lengths[8, 12].

Nevertheless, research examining the correlation between patient height and anatomical tooth dimensions remains scarce. While few studies have failed to identify a statistically significant correlation between tooth dimensions and an individual's height[6, 17], other research has demonstrated a definite relationship between stature and various dental measurements[18, 19]. To our knowledge, no studies or published works exist that analyze normal tooth measurements in conjunction with individual height among adult Iraqi subpopulations. Consequently, this study aims to digitally establish odontometric data for anatomical tooth dimensions (encompassing root lengths and crown widths/lengths) for both maxillary and mandibular anterior and posterior teeth, and to correlate the relationship between each variable and stature and gender using CBCT analysis within the Iraqi demographic. Additionally, the study aims to determine the extent to which these two variables contribute to variation within the population. Ultimately, the insights derived from this research will provide valuable information regarding the dental norms of this subpopulation and potentially aid practitioners in refining and enhancing their dental assessments for patients.

Materials and methods

Sample selection

The study encompassed 826 participants, including 370 females (44.8%) and 456 males (55.2%), with an average age of 43.2 years (ranging from 18 to over 55 years). All participants were of Iraqi descent and had been raised in Iraq. Moreover, all participants were healthy individuals who required radiographic CBCT assessments as part of dental procedures, such as endodontic treatment, orthodontic evaluations, or assessments related to impacted teeth. Ethical clearance for conducting the study and sample selection was granted by the Ethics Committee of the University of Sulaimani, College of Dentistry (protocol number 272/2011). Each participant completed an informed consent form after receiving explanation of the study's objectives.

Female and male groups were divided into 2 groups, each based on the average height of the individuals.

Patients with heights below the average threshold were classified as short, while those with a height above the average were classified as tall. For females, individuals below 158.2 cm were categorized as short, whereas those above this height were classified as tall. In the male group, subjects above 172.3 cm were tall, and those below this were considered short[20]. Inclusion criteria mandated that individuals possess mature teeth fully erupted to the occlusal plane, exhibiting intact, non-carious, and sound cusp anatomy, and fully developed roots with closed apices. Conversely, cases involving broken or fractured crowns, profound wear, incomplete growth of root apices, notable root resorption, calcification, or other dental complications (such as malalignment, missing teeth, crowned teeth, or other procedures hindering accurate length measurements) were excluded from analysis.

Stature measurement

Stature (H) for all selected subjects was recorded as the vertical distance from the vertex to the floor, utilizing standardized anthropometric techniques. Measurements were taken with the patient standing upright on a solid horizontal surface, barefoot, and with heels together and feet flat against the ground. The head was oriented in the Frankfurt plane, with the subject's back as straight as possible, achieved by rounding or relaxing the shoulders with the shoulder blocks and buttocks touching the wall behind. A straight vertical anthropometry was positioned behind the patient, with the movable rod lowered to contact the vertex in the midsagittal plane; hair was clipped if necessary to expose the scalp at the vertex.

Radiographic evaluation and tooth measurements

During CBCT procedures for measuring teeth, the patient's head was centrally positioned within the scan field, assisted by a lateral laser marker for positioning. Participants were instructed to achieve maximum intercuspation and to maintain head and tongue position throughout the process. Complete field views ensured comprehensive imaging. The CBCT unit utilized in this study was the NewTom Giano HR (Cefla, Imola, Italy), operated under the following parameters: 5-8 mA, 90 kV, 3.6-5.4 seconds exposure time, an 11×16 cm field of view, and a voxel size of 0.3mm. Each scan underwent thorough on-site assessment following a structured screening protocol.

The data created in DICOM (Digital Imaging and Communication in Medicine) format were imported into NewTom's NNT® imaging software for three dimensional reconstructions[18,19]. Following contrast and brightness adjustments, the images were meticulously evaluated using various software features, including zooming and image enhancement. All odontometric measurements of teeth were recorded in millimeters (mm) using both sagittal and coronal image views. For teeth with multiple apices, the longest root apex was used for measurements.

The following definitions were used for the CBCT-based measurements as shown in Figure 1. The crown length (CL) is the distance between the reference line from the cementoenamel junction (CEJ) to the incisal edge or the tip of the cusp. The root length (RL) is the distance between the reference line from the cementoenamel junction (CEJ) to the apex of the tooth root(s). The total tooth length (TL) is the measurement from the highest points of the crown (incisal edge/cusp tip) to the apex of the root along the center of the cervical margin. Crown width (CW), which is the vertical distance between the contact points on the approximate surfaces of the tooth crown, is measured perpendicular to the long axis of the tooth.

Statistical analysis

The collected data were entered into the Statistical Package for the Social Sciences (SPSS) software (version 26, Chicago, IL) for encoding and analysis, with a significance threshold set at $p < 0.05$ for statistical tests. To assess reliability, S.N.D. re-evaluated 42% of the overall sample within a three-week interval, and the agreement between the measurements was assessed using a paired sample t-test. The Shapiro-Wilk normality test confirmed that all samples followed a normal distribution. First, the correlation was measured using linear regression analysis. Then, means and standard deviations for all variables were subsequently calculated by gender for each tooth type. Differences were assessed using independent sample t-tests to evaluate correlations between tooth dimensions (TL, RL, CL, and CW) and stature. A paired-sample t-test was applied to assess the significance of the differences between right and left side measurements.

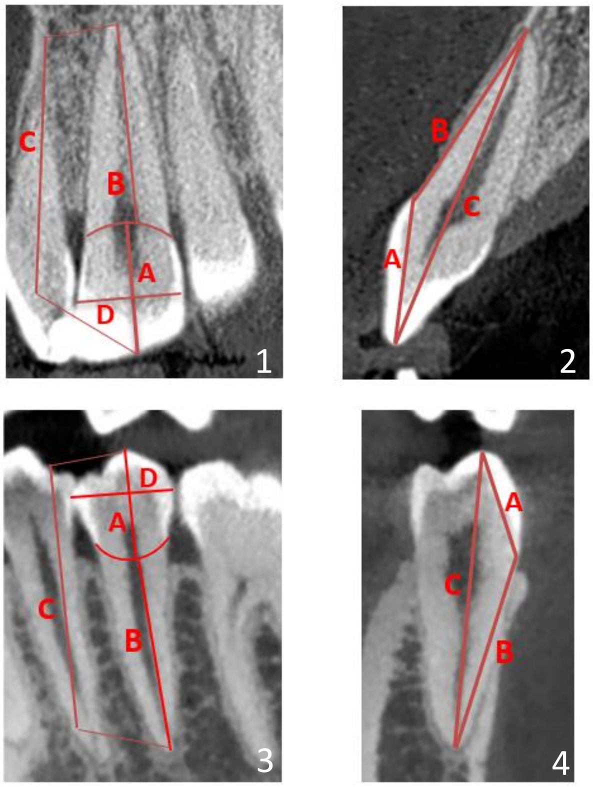

Figure 1: Demonstration of tooth size measurements. a) Crown length; b) Root length; c) Tooth length; d) Crown width.

Results

In this study, 826 CBCT scans were examined, including 370 females (100 were short and 270 were tall), and 456 males (176 were short and 280 were tall) male. Table 1 and Figures 2 and 3 show the correlation between height and odontometric parameters, demonstrating a significant positive relationship that indicates a direct association between tooth dimensions and stature in both males and females.

Tables 2 and 3 show the relationship between individual stature and tooth length in both genders. In ranking, maxillary canines exhibited the highest correlation with stature, followed by mandibular canines. Male teeth showed a length increase of approximately 3 mm in taller individuals and 2 mm in females. Consequently, maxillary and mandibular first molars demonstrated increases ranging from 1.5 mm to 2 mm in both taller males and females. Following this, upper central and lateral incisors presented increases of 1 mm to 1.5 mm in tall males and 0.9 mm to 1 mm in tall females. In contrast, lower central and lateral incisors reflected an increase of 1 mm to 1.2 mm in both genders, except lower central incisors among males. Next, a rise of 0.7 mm to 1 mm was observed across both upper and lower first and second premolars in both taller groups, except lower second premolars in females. Ultimately, the lower central incisors of males and the lower second premolars of females exhibited the weakest correlation with individual stature.

In terms of crown width, the mean crown width of the maxillary canines was greater than that of the mandibular canines, with an average of 0.75 mm in males and 0.89 mm in females, while the lower arch measured approximately 0.71 mm in males and 0.82 mm in females. In both genders, maxillary first premolars were wider than their second premolars, leading to average width differentials ranging from 0.27 mm to 0.33 mm. Conversely, mandibular second premolars were larger than first premolars, exhibiting averages from 0.17 mm to 0.22 mm greater width. In the maxilla, central incisors were noted to be wider than lateral incisors, with average differences of 0.19 mm in males and 0.18 mm in females in central (0.1 mm for males and 0.12 mm for females in lateral). While in the mandible, the lateral incisors were wider than the central incisors in both genders. Lastly, mandibular first molars were broader than maxillary first molars by approximately a difference of 0.55 mm in males and 0.61 mm in females, whereas maxillary first molars averaged around 0.54 mm in males and 0.55 mm in females, remaining broader than both upper and lower second molars in both genders, as shown in Tables 2 and 3. Furthermore, Table 4 illustrates the differences in width and length between corresponding teeth on the right and left sides. Specific to tooth length, statistical analysis indicated notable differences in maxillary canines, first premolars, and first molars, registering differences of approximately 0.42, 0.29, and 0.32 mm, respectively, along with mandibular lateral incisors, second premolars, and first molars exhibited discrepancies averaging around 0.37, 0.35, and 0.32 mm, respectively. In terms of crown size, maxillary central incisors and maxillary first premolars represented the most variable measurements, registering differences of approximately 0.21 and 0.27 mm, respectively. In comparison, mandibular lateral incisors and second molars demonstrated variability of approximately 0.27 mm and 0.31 mm, respectively. For the majority of other teeth analyzed, differences were found to be statistically insignificant, with maximum variations reaching only 0.08 mm between corresponding right and left sides in both maxillary and mandibular teeth across genders. Finally, a comparison between males and females is presented in Table 5. The results revealed that, except for the lower central incisors, male teeth generally exhibited significantly greater mean anatomical measurements than those of females, especially within the taller group. Among all teeth, canines and first molars demonstrated the most marked sexual dimorphism in terms of absolute size, whereas the least pronounced was evident in lateral incisors and maxillary second molars.

Table 1: Linear regression analysis between height and odontometric parameters.

Tooth		R^2	F-statistic	P-value
Maxillary				
	TL	0.629	1400.3	0.0001
	CW	0.253	1226.43	0.0001
	TL	0.695	605.95	0.0001
	CW	0.586	1166.63	0.001
	TL	0.210	414.24	0.0001
	CW	0.635	1434.44	0.0001
	TL	0.278	319.24	0.001
	CW	0.660	1600.28	0.002
	TL	0.684	1787.95	0.002
	CW	0.666	1647.52	0.001
	TL	0.225	240.63	0.0001
	CW	0.710	2023.19	0.0001
	TL	0.707	1991.19	0.003
	CW	0.416	588.32	0.002
Mandibular				
	TL	0.167	166.33	0.0001
	CW	0.690	1837.37	0.001
	TL	0.579	1134.87	0.002
	CW	0.642	1480.74	0.002
	TL	0.669	1672.12	0.001
	CW	0.620	1348.11	0.0001
	TL	0.706	1985.61	0. 001
	CW	0.623	1364.35	0.002
	TL	0.449	673.25	0.002
	CW	0625	1377.54	0.003
	TL	0.607	1277.28	0.0001
	CW	0.703	1949.95	0.0001
	TL	0.635	1435.69	0.004
	CW	0.702	1943.19	0.001

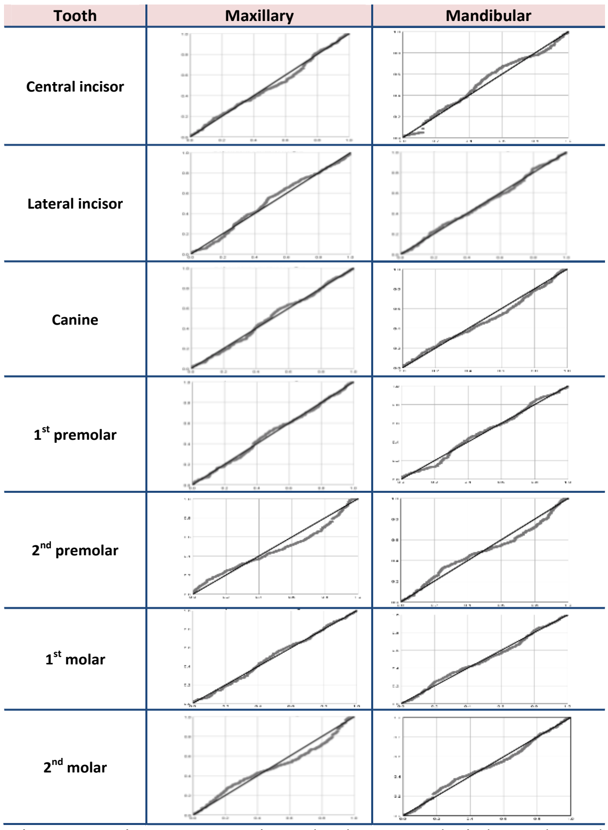

Figure 2: Linear regression plot between height and tooth length.

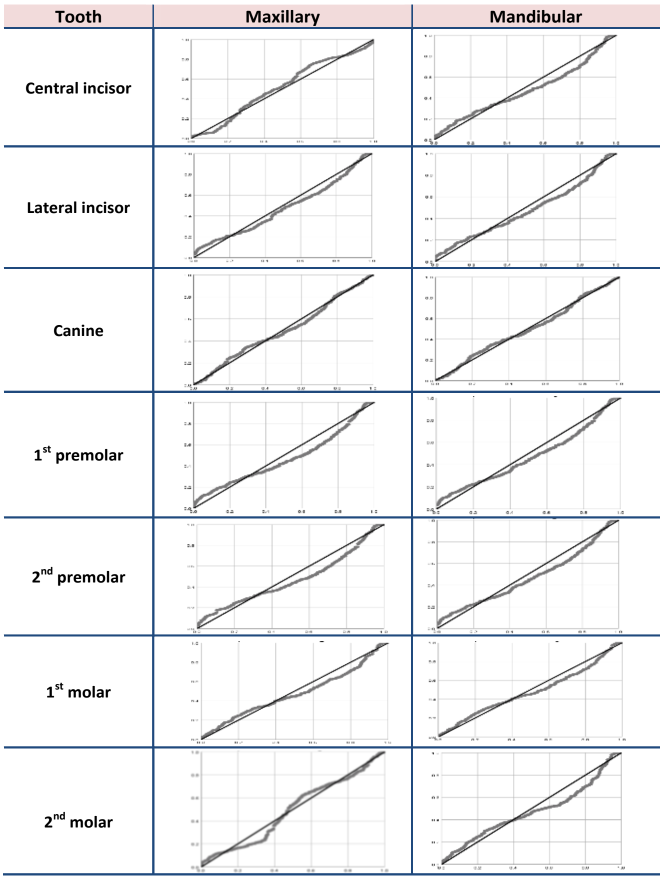

Figure 3: Linear regression plot between height and crown width.

Table 2: Comparison of odontometric measurements of the maxillary dentition in (mm) among male and female patients by stature.

Tooth	Height	TL Mean± SD	P-value	RL Mean± SD	P-value	CL Mean± SD	P-value	CW Mean± SD	P-value
Male									
1	<172.3	23.80±0.59	0.004	12.88±0.40	0.003	10.87±0.15	0.09	9.10±0.37	0.01
	>172.3	25.09±0.18		13.85±0.13		11.24±0.05		9.29±0.44	
2	<172.3	22.40±0.38	0.001	13.09±0.21	0.02	9.28± 0.14	0.004	6.90±0.04	0.002
	>172.3	23.42±0.12		13.60±0.07		9.62±0.04		7.00± 0.01	
3	<172.3	28.66± 1.21	0.001	18.51±0.91	0.0001	10.07±0.22	0.0001	7.94±0.32	0.0002
	>172.3	31.28±0.38		20.67±0.30		10.61±0.07		8.69±0.1	
4	<172.3	23.58± 0.37	0.008	14.90±0.22	0.06	8.66±0.12	0.03	7.62±0.11	0.001
	>172.3	24.39±0.11		15.43±0.07		8.96±0.04		7.89±0.03	
5	<172.3	23.34±0.30	0.003	14.80±0.17	0.002	8.62±0.11	0.01	7.25±0.11	0.02
	>172.3	24.10±0.96		15.20±0.05		8.90±0.03		7.52±0.03	
6	<172.3	22.44± 0.75	0.0001	14.87± 0.54	0.001	7.51±0.16	0.001	10.61±0.22	0.001
	>172.3	24.08±0.23		16.16±0.18		7.91±0.05		11.15±0.07	
7	<172.3	21.88±0.59	0.03	14.68±0.47	0.01	7.15±0.09	0.02	9.15±0.03	0.001
	>172.3	23.17±0.18		15.80±0.15		7.37±0.03		9.07±0.01	
Female									
1	<158.2	22.85±1.22	0.001	12.42±0.05	0.01	10.39±0.02	0.02	9.04±0.01	0.005
	>158.2	23.93± 0.07		13.76±1.1		10.71±1.23		9.22±0.03	
2	<158.2	21.75±0.05	0.09	12.84±1.10	0.02	8.88±0.04	0.003	6.41±0.03	0.003
	>158.2	22.64± 1.02		13.53±0.43		9.11±0.17		6.53±0.05	
3	<158.2	26.51± 0.04	0.001	16.56±0.15	0.001	9.87±0.12	0.001	7.32±0.11	0.001
	>158.2	28.51±0.32		18.20±0.07		10.31±0.22		8.21±0.09	
4	<158.2	22.06± 0.17	0.01	13.72±0.78	0.04	8.31±0.04	0.002	6.83±0.45	0.002
	>158.2	22.92± 0.26		14.13±0.07		8.79±0.33		7.15±0.54	
5	<158.2	22.27±1.31	0.006	13.97±0.41	0.08	8.28±0.54	0.003	6.48±0.62	0.005
	>158.2	22.98±0.58		14.11± 0.63		8.77±0.11		6.81±0.55	
6	<158.2	19.91±0.07	0.001	12.41±0.11	0.001	7.42±1.22	0.003	9.82±1.45	0.001
	>158.2	21.91±0.21		14.11±0.75		7.80±0.99		10.37±1.04	
7	<158.2	19.87±1.62	0.02	12.88±0.88	0.01	6.93±2.31	0.03	8.67±0.56	0.002
	>158.2	21.43±1.78		14.32±0.73		7.11±0.87		8.76±0.16	

SD: Standard deviation; TL: Total length; RL: Root length; CL: Crown length; CW: Crown width. P value is significant at 5% level. 1: central incisor; 2: lateral incisor; 3: Canine; 4: 1st premolar; 5: 2nd premolar; 6: 1st molar; 7: 2nd molar.

Table 3: Comparison of odontometric measurements of the mandibular dentition (mm) among male and female patients by stature.

Tooth	Height	TL Mean± SD	P-value	RL Mean± SD	P-value	CL Mean± SD	P-value	CW Mean± SD	P-value
Male									
1	<172.3	21.36±0.08	0.002	12.16±0.03	0.04	9.19±0.12	0.02	5.42±0.20	0.03
	>172.3	21.52±0.02		12.08±0.01		9.45±0.31		5.85±0.09	
2	<172.3	23.59±0.51	0.04	13.85±0.42	0.002	9.72± 0.07	0.003	5.84±0.05	0.001
	>172.3	24.62±0.15		14.74±0.13		9.87±0.02		5.95± 0.04	
3	<172.3	28.54± 1.21	0.001	17.49±0.99	0.002	11.21±0.19	0.001	7.50±0.34	0.001
	>172.3	31.18±0.36		19.56±0.30		11.62±0.06		8.21±0.11	
4	<172.3	23.03± 0.33	0.001	14.36± 0.16	0.01	8.65±0.15	0.002	7.16±0.08	0.03
	>172.3	23.89±0.09		14.71±0.05		8.98±0.04		7.33±0.05	
5	<172.3	22.79±0.33	0.03	14.33±0.31	0.006	8.45±0.01	0.04	7.51±0.08	0.02
	>172.3	23.50±0.10		15.02±0.10		8.47±0.01		7.69±0.05	
6	<172.3	23.02± 0.87	0.001	15.41± 0.74	0.002	7.59±0.11	0.001	11.58±0.26	0.001
	>172.3	24.78±0.26		16.92±0.22		7.82±0.03		12.13±0.10	
7	<172.3	22.40±0.55	0.01	15.27±0.39	0.05	7.10±0.14	0.003	11.02±0.10	0.002
	>172.3	23.91±0.16		16.10±0.12		7.40±0.04		11.24±0.05	
Female									
1	<158.2	21.93±0.08	0.001	13.07±0.04	0.002	8.85±0.04	0.03	4.67±0.33	0.01
	>158.2	22.98±0.10		13.36±0.07		9.15± 0.06		5.10±0.32	
2	<158.2	22.83±0.15	0.01	13.45±0.11	0.03	9.37± 0.04	0.01	5.13±0.02	0.02
	>158.2	23.93± 0.18		14.23±0.09		9.70±0.01		5.24± 0.03	
3	<158.2	26.24±0.31	0.0001	15.42±0.24	0.002	10.81±0.05	0.003	6.86±0.11	0.001
	>158.2	28.34±0.27		17.12±0.18		11.22±0.12		7.68±0.08	
4	<158.2	21.93±0.13	0.005	13.16± 0.13	0.002	8.41±0.46	0.02	6.49±0.45	0.001
	>158.2	22.86±0.42		14.12±0.07		8.74±0.08		6.71±0.56	
5	<158.2	22.71±0.47	0.03	14.82±0.01	0.002	7.89±0.05	0.001	6.86±0.07	0.001
	>158.2	23.05±0.22		14.84±0.01		8.21±0.02		7.08±0.12	
6	<158.2	21.47±0.29	0.001	14.14±0.23	0.03	7.32±0.05	0.01	10.75±0.07	0.001
	>158.2	23.51±1.22		15.80±0.25		7.71±0.01		11.36±0.14	
7	<158.2	21.44±0.19	0.002	14.30±0.04	0.03	6.94±0.01	0.03	10.34±0.07	0.02
	>158.2	22.62±0.06		15.40±0.21		7.22±1.45		10.74±0.02	

Table 4: Comparison of the teeth length and crown width measurements (mm) between right and left maxillary and mandibular teeth.

Tooth type		TL Mean± SD	P-value	CW Mean± SD	P-value
Upper arch					
1	Right	24.17±0.77	0.85	9.06±0.64	0.001
	Left	24.18±0.83		9.27±0.70	
2	Right	22.67±0.49	0.60	6.81±4.27	0.08
	Left	22.66±0.54		6.73±4.25	
3	Right	29.23±1.65	0 .001	8.15±0.48	0.51
	Left	29.65±1.72		8.15±0.44	
4	Right	23.84±0.89	0 .0001	7.50±0.31	0.001
	Left	24.13±0.99		7.77±0.62	
5	Right	23.28±0.68	0.07	7.05±5.38	0.06
	Left	23.30±0.64		7.12±5.44	
6	Right	23.25±1.56	0.008	10.59±0.41	0.07
	Left	22.93±1.41		10.67±0.43	
7	Right	21.89±1.11	0 .06	8.93±6.23	0.07
	Left	21.94±1.15		8.95±6.21	
Lower arch					
1	Right	21.89±0.55	0.06	5.36±0.47	0.20
	Left	21.86±0.45		5.35±0.40	
2	Right	23.95±0.64	0.001	5.99±0.52	0.11
	Left	23.58±0.67		5.72±0.27	
3	Right	29.56±1.78	0.08	7.77±0.45	0.05
	Left	29.63±1.86		7.71±0.42	
4	Right	23.01±0.58	0.07	7.00±0.32	0.81
	Left	23.07±0.56		7.00±0.30	
5	Right	23.11±0.32	0.04	7.31±5.34	0.09
	Left	23.46±.0.36		7.36±5.33	
6	Right	23.45±1.10	0.003	11.56±0.71	0.06
	Left	23.77±1.00		11.64±0.77	
7	Right	22.69±0.70	0.05	10.83±0.38	0.001
	Left	22.73±0.70		11.14±0.49	

Table 5: Comparison of odontometric measurements of the maxillary and mandibular dentition (mm) between males and females.

Tooth	Gender	TL Mean± SD	P-value	RL Mean± SD	P-value	CL Mean± SD	P-value	CW Mean± SD	P-value
Maxillary									
1	Male	24.59±0.74	0.0001	13.48±0.54	0.03	11.10±0.54	0.01	9.10±0.41	0.002
	Female	23.63±0.49		13.39±0.59		10.62±0.14		9.10±0.42	
2	Male	22.90±0.47	00.2	13.40±0.28	0.001	9.49±0.19	0.01	6.96±0.05	0.002
	Female	22.40±0.40		13.34±0.30		9.04±0.10		6.49±0.05	
3	Male	30.27±1.50	0.001	19.84±1.21	0.001	10.40±0.30	0.001	8.40±0.42	0.003
	Female	27.97±0.91		17.75±0.72		10.19±0.19		7.89±0.35	
4	Male	24.08±0.46	0.04	15.22±0.29	0.02	8.84±0.17	0.01	7.79±0.15	0.04
	Female	22.68±0.39		14.01±0.18		8.66±0.21		7.06±0.14	
5	Male	23.85±0.38	0.01	15.04±0.22	0.01	8.79±0.15	0.03	7.42±0.15	0.02
	Female	22.71±0.27		14.07±0.06		8.63±0.21		6.72±0.14	
6	Male	23.44±0.94	0.0001	15.66±0.72	0.002	7.76±0.22	0.001	10.94±0.30	0.003
	Female	21.37±0.30		13.65±0.75		7.69±0.16		10.22±0.24	
7	Male	22.67±0.74	0.02	15.37±0.62	0.03	7.29±0.12	0.04	9.10±0.04	0.04
	Female	21.0±0.71		13.93±0.64		7.06±0.08		8.75±0.04	
Mandibular									
1	Male	21.46±0.09	0.001	12.11±0.04	0.003	9.35±0.14	0.002	5.69±0.25	0.001
	Female	22.35±0.26		13.28±0.12		9.07±0.13		4.98±0.19	
2	Male	24.22±0.49	0.04	14.39±0.52	0.03	9.81±0.08	0.04	5.91±0.07	0.03
	Female	23.63±0.60		14.02±0.34		9.61±0.14		5.35±0.13	
3	Male	23.44±0.39	0.001	14.58±0.20	0.001	8.85±0.19	0.002	7.26±0.10	0.002
	Female	22.61±0.41		13.86±0.42		8.65±0.14		6.65±0.09	
4	Male	23.23±.41	0.01	14.76±.39	0.03	8.47±.01	0.01	7.62±.10	0.01
	Female	22.95±.15		14.83±.00		8.12±.14		7.02±.09	
5	Male	23.23±0.41	0.02	14.76±0.39	0.03	8.47±0.01	0.003	7.62±0.10	0.002
	Female	22.95±0.15		14.83±0.00		8.12±0.14		7.02±0.09	
6	Male	24.10±1.03	0.0001	16.36±0.90	0.002	7.73±0.1	0.002	11.92±0.32	0.001
	Female	22.95±0.91		15.35±0.74		7.60±0.17		11.19±0.27	
7	Male	23.08±0.65	0.02	15.78±0.48	0.01	7.28±0.17	0.01	11.16±0.12	0.03
	Female	22.24±0.61		15.10±0.49		7.14±0.12		10.63±0.17	

Discussions

The individual's stature may correlate with tooth length, given that tooth height contributes to overall facial height[23]. In contrast, fewer studies have reported differing results regarding the correlation between stature and tooth dimensions, which differs from our findings. Sterrett et al. investigated the potential relationship between the width, length, and width-to-length ratios of the maxillary anterior teeth in Caucasian individuals and their overall height. They could not find any statistically significant correlation between tooth dimensions and subject height[17]. Additionally, Raghavendra et al. conducted a study to assess the relationship between the clinical crown height of maxillary central incisors and the overall body height of participants. Their results showed no statistically significant correlation between crown length and body height[24]. Similarly, Jayawardena et al. observed no significant association between stature and incisor tooth lengths, suggesting a weak genetic link between tooth dimensions and height[6].

As expected, width measurements further substantiated that males typically possess larger dimensions than females, confirmed by this study's findings. This discrepancy is likely due to the larger skeletal frameworks characteristic of males. Additionally, both nutritional and hormonal influences contribute to craniofacial morphological variations between genders[25, 26]. A comparable observation was made in a study conducted by Anderson and Thompson, which indicated a strong correlation between tooth form and skeletal maturation in both males and females[27]. In both sexes, crown diameters consistently demonstrated correlations with stature. The most notable sexual associations were specifically observed in the canines and mandibular first molars, whereas the least pronounced was evident in the lateral incisors and maxillary second molars.

Comparing the dimensions of corresponding right and left side teeth revealed some variations in the current study. Statistical analyses regarding tooth length identified that maxillary canines, first premolars, and first molars, along with mandibular lateral incisors, second premolars, and first molars exhibited discrepancies, with a few patients displaying differences exceeding 0.45 mm between contralateral teeth. For the majority of other teeth analyzed, differences were found to be statistically insignificant, with maximum variations reaching only 0.08 mm between corresponding right and left sides in both maxillary and mandibular teeth across genders. The variation in tooth width and height was relatively small and considered negligible, aligning with results from other demographic studies[28]. The observed side similarity may derive from common factors that impact tooth size, such as genetics, nutrition, and hormonal fluctuations that affect both sides of the jaw symmetrically[29, 30].

The study's outcomes also revealed a statistically significant sexual dimorphism in stature, consistent with findings from other population groups. The results highlighted that, except for lower central incisors, male teeth presented significantly greater dimensions compared to female teeth, particularly within the taller cohort. In terms of absolute dimensions, canines and first molars exhibited the most pronounced sexual dimorphism.

The observed sexual dimorphism in tooth size may be attributed to Alvesalo's findings, suggesting that sex chromosomes not only influence tooth structure, root size, and shape, but also overall body morphology, including craniofacial features. Subsequently, Alvesalo indicated that the Y chromosome promotes both enamel and dentin growth, while the X chromosome is chiefly limited to enamel. The disparate effects of the Y and X chromosomes on cellular proliferation and function, particularly the Y chromosome's influence on cell division, may contribute to the gender dimorphism noted in crown morphology, tooth number, size, and other somatic traits such as stature growth[31, 32].

Conclusion

In conclusion, tooth size measurements obtained through CBCT demonstrate a strong correlation with individual stature, reflecting close alignment with actual lengths. Findings from the present study illustrate the presence of sexual dimorphism, revealing a positive correlation between individual stature and tooth dimensions across genders, which necessitates a more integrated treatment methodology. Moreover, it can be concluded that there were variations between the right and left side teeth, confirming the presence of asymmetry, while other teeth showed statistically insignificant symmetry between the two sides across genders. Further research with larger sample sizes is imperative in this domain. This study represents one of the limited investigations linking individual height with tooth size, yielding valuable data that could inform comparative studies on tooth dimensions.

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Original Article

Cone Beam Computed Tomography Evaluation of the Styloid Process Length Variations in a Sample Group of the Iraqi Population

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Abstract

Objective: The scarce literature data on the mean length of the styloid process in the Iraqi population gave rise to the need for this study to determine the mean length of the styloid process in an Iraqi subpopulation, highlighting the possible importance in clinical and surgical conditions considered.

Methods: Cone-Beam Computed Tomography (CBCT) images of 229 Iraqi patients comprising 73 males (31.1%) and 156 females (68.9%), with a mean age of 40.48 ±16.326, were included in this retrospective study. The data obtained were transformed into SPSS v25, and descriptive and inferential analyses were performed.

Results: The mean length of the styloid process in males was found to be 26.16 ±1.08324mm on the right side and 26.42±1.12595mm on the left side, while the mean length of styloid process in females was found to be 26.13±1.12595mm on the right side and 26.15±0.74133mm on the left side.

Conclusions: There was no statistically significant difference in the length of the styloid process between the two sex groups ($p > 0.05$) or between the right and left sides of each sex group ($p > 0.05$).

Keywords: *Styloid process; CBCT; Eagle syndrome; Styloid ossification; Elongated styloid process.*

Submitted: April 25, 2025, Accepted: July 18, 2025, Published: August 1, 2025.

Cite this article as: Al-Hity TR, Abdulla AO, Hussein SA, Mohammed BA, Noori AJ, Al-Zahawi AR. Cone Beam Computed Tomography Evaluation of the Styloid Process Length Variations in a Sample Group of the Iraqi Population. Sulaimani Dent J. 2025;12(2):44-49

DOI: https://doi.org/10.17656/sdj.10209

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Published by the College of Dentistry, University of Sulaimani

Introduction

The styloid process is a vital needle-like anatomical projection originating inferiorly from the petrous bone anterior to the stylomastoid foramen[1]. It includes proximal and distal parts; the latter being contained within the vaginal process of the tympanic part of the temporal bone and containing the shaft and the apex. The shaft has three attached muscles: the stylohyoid, styloglossus, and stylopharyngeus. The apex has two attached ligaments: the stylohyoid and stylomandibular ligaments. These attachments enable movement of the tongue, mandible, hyoid bone, pharynx, and larynx. The styloid process is surrounded by significant nerves and vessels. Medially lies the internal jugular vein, internal carotid artery, vagus nerve, glossopharyngeal nerve, and accessory nerve. The occipital artery and hypoglossal nerve lie laterally[2,3]. The styloid process is one of the robust anatomical landmarks in parotid surgery that can easily identify the trunk of the facial nerve[4].

The styloid process's reported length is inconsistent both across individuals, ranging from 15.2 mm to 97 mm, and within the same individual, differing between left and right sides[5,6]. Nevertheless, a length more than 30 mm is considered elongated[7]. Styloid elongation may be a feature of Eagle syndrome[8], characterized by pain in the base of the tongue, throat, jawbone, or temporomandibular joint, usually triggered by swallowing, moving the jaw, or turning the neck[8,9]. Elongated styloid process has been recently associated with neurological symptoms, indicating it may be a causative factor in the development of compression in the internal carotid artery[3,10], internal jugular vein [11,12], irritation of the cervical sympathetic plexus, or stroke[13-15]. These newly described associated neurological morbidities perhaps explain the rising interest in the importance of its variation in the pathogenesis of various conditions like Eagle syndrome[10]. Incidence of an elongated styloid process is estimated to occur in 4% of the general population and is more common in women than men (ratio of 1:3)[7,16]. Among that estimated 4%, about 4% have associated symptoms. Therefore, the incidence of Eagle syndrome is estimated to be 0.16%[8,17,18]. Eagle syndrome patients tend to be between 30 and 50 years old, although a wider age range has been reported[19].

Numerous proposed theories have addressed the etiology of the variance in styloid ossification and elongation[3,20,21]. Anatomic variation theory describes the elongation as anatomic rather than being caused by styloid process and styloid ligament ossification. Hyperplasic reaction theory describes the styloid process as stimulated by pharyngeal trauma, leading to ossification of the styloid and its attached ligaments. Metaplastic reaction theory suggests a traumatic stimulus leads to metaplastic alterations in the cells of the attached styloid ligament, resulting in ossification[22,23]. Developments in the radiology and medical imaging fields allow radiographic evaluation of the elongated process that enhances diagnosis of symptoms related to Eagle's syndrome and other associated neurological symptoms[24]. Considering the advantages and wide use of CBCT imaging modality due to its quick acquisition and detailed three dimensional information[25], this study aimed to utilize CBCTs to determine the mean length of the styloid process in an Iraqi sub-population, highlighting the possible importance in clinical and surgical conditions.

Materials and methods

Cone-beam computed tomography (CBCT) images of 229 Iraqi patients comprising 73 males (31.1%) and 156 females (68.9%), with a mean age of 40.48 ±16.326, were included in this retrospective study. Ethical approval for the study was obtained from the Ethics Committee at the College of Dentistry / University of Sulaimani (Number: 224/23 on 26-11-2023). Data obtained were transformed into SPSS v25 and descriptive and inferential analyses were done.

CBCTs were performed from July 2023 to Nov of 2023 in the FOTON Maxillofacial Imaging Center, using the Carestream CS9600 CBCT machine for treatment planning of various oral procedures.

The inclusion criteria for the CBCT study were: A) Patients older than 20 years. B) CBCT showed a styloid process for both sides, right and left. Patients with a fracture of the styloid process and any CBCT with an unclear styloid process were excluded.

CBCT was performed for each patient using CS9600 (Carestream Dental, Atlanta, GA, United States) and a field of view of 16x17cm with an exposure protocol of 120kVp and a current of 5.0mA for 40.0 s. Voxel size 150 microns, high resolution Dose 2653 mGY.cm2. The patient's occlusal plane was set parallel to the floor using ear rods and chin rest, using a CS3D Imaging viewer (Carestream Dental, Atlanta, GA, United States.). Measurements were performed primarily in the sagittal section and confirmed in the coronal section to ensure accuracy. The starting point of the measurement was the junction between the base of the styloid process and the inferior surface of the temporal bone. In contrast, the endpoint was the most distal tip of the styloid process, visible on CBCT, as shown in Figure 1. Two expert dental radiologists measured the length of the styloid process on both the left and the right side. A standardized technique was used in all cases. All measurements were performed using the software's oblique slicing, with views rotated to align for curved styloid processes; polyline measurements were used to follow the curvature accurately.

The data were tested for normality and homogeneity of variance using one-way ANOVA. Tukey's HSD post hoc test was used for multiple comparisons.

Results

The mean length of the styloid process in males was found to be 26.16 mm on the right side and 26.42 mm on the left side, while the mean length of the styloid process in females was found to be 26.13 mm on the right side and 26.15 mm on the left side.

No statistically significant difference was found between the two sex groups ($p>0.05$) (Table 1) or between the right and left sides in either sex group ($p>0.05$) (Table 2). In both sex groups a significant positive correlation was found between the right and left sides ($p<0.01$), Table 2.

Discussion

The knowledge of the styloid process and its anatomical variations among the population may help clinicians diagnose Eagle's syndrome so they can prevent the worsening of the symptoms related to an elongated styloid process[24].

Studies have shown a significant variation in the length of the styloid process between different populations, ethnic groups, and geographical areas[26].

Table 1: The mean and SD of the styloid process length according to the right and left positions.

Side	Sex	No.	Mean	SD	Median	Interquartile Range	Mann-Whitney U Test		
							U	Z	p
Right	Male	73	26.1616	1.08324	24.9000	11.10	5615.5	0.168	0.867*
	Female	156	26.1276	0.79503	24.5000	9.73			
Left	Male	73	26.4247	1.12595	24.4000	8.65	5724.5	0.065	0.948*
	Female	156	26.1500	0.74133	24.6500	9.78			

* Not significant

Table 2: The mean and SD of the styloid process length according to sex.

Side	Sex	No.	Mean	SD	Wilcoxon Signed Ranks Test		Spearman's rho	
					Z	p	r	p
Male	Right	73	26.1616	9.25517	-1.041	0.298*	0.854	0.001**
	Left		26.4247	9.62011				
Female	Right	156	26.1276	9.92993	-0.515	0.607*	0.839	0.001**
	Left		26.1500	9.25925				

* Not significant
** Highly significant

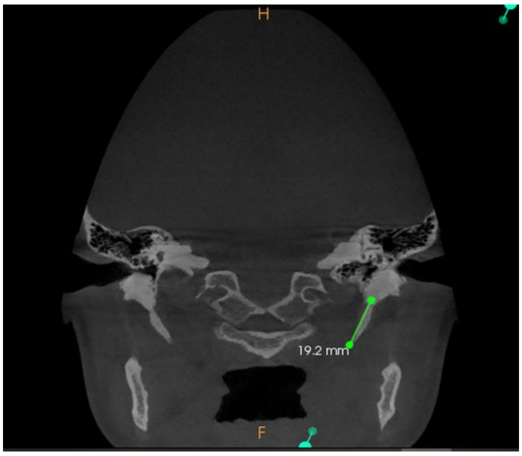

Figure 1: Styloid process measurement using multiplanar CT imaging.

The limited literature data on the average length of the styloid process in the Iraqi population, as well as other data related to the prevalence of an elongated styloid process and Eagle's syndrome, have intensified the requirement for this study.

To comprehend styloid process's anatomical structure and the mechanism underlying its elongation and calcification, we must comprehend its development. The styloid process originates from Reichert's cartilage, which develops from the second pharyngeal arch and tends to calcify during ontogenesis. Within the first eight years of life, the styloid process gets calcified, then lengthening until approximately the age of thirty, at which point it becomes stagnant[26-28]. Our study group included patients older than 20 years, given the styloid process's calcification and elongation pattern. Compared to Lengelé and Dhem (1988) and Natsis et al. (2015), whose study groups comprised both men and women aged 26 to 93 and 20 to older than 60, respectively, our research group had almost the same age range[8,29].

Previous literature has shown that different methods are used to measure the length of the styloid process. This can be done anatomically by measuring the length of the styloid process using dry skull bones or by radiographs, such as orthopantomograms (OPGs), lateral cephalometric radiographs, anteroposterior skull radiographs, and computed tomography scanning[29-33]. Because the styloid process is a very fragile part of the cranium, it can easily fracture, causing difficulty in measuring dry skulls. Furthermore, it can be difficult to measure the part of the styloid process that is hidden by the vaginal process and the outer part of the external acoustic meatus[26,34]. To avoid distortion or superimpositions of structures associated with the plain radiographs[35], in this study two radiographers measured the styloid process length using CBCT. Cone beam computed tomography has been previously proven as an effective method in the evaluation of not only the styloid process length but its other topographic and morphological characteristics when compared to panoramic radiographs[17,36]. CBCT scans allow reproducible and reliable measurements for bone tissues that enable its use for forensic procedures[37].

According to de Oliveira et al. (2008), the length of the styloid process can range from 20-30 mm, but it may differ from person to person and even from side to side in the same individual[38]. The mean length of the styloid process in this study was found to be 26.16 mm in males on the right side and 26.42 mm on the left side, while the mean length of the styloid process in females was found to be 26.13 mm on the right side and 26.15 mm on the left side. The findings in this study are still comparable with most reports in studies describing an average length between 20.0 and 30.0 mm[34,39]. Previous literature reported that the normal length of the styloid process varies across different geological regions; for example, 25- 30 mm was reported in Europe[6] and 24.12 ± 7.28 mm in Thailand[40]. In Central India, the mean length of the styloid process in males was found to be 22.70 mm on the right side, and 22.16 mm on the left. In females, it was 22.30 mm on the right and 21.28 mm on the left side. Based on data collected in Greece[34], the normal range of styloid process length in the Greek population was 18.0–33.0 mm, where the median values of the length were 25.2 mm on the right and 24.7 mm on the left side. The study in Greece found a normal range of 21.0–30.0 mm[26]. Consequently, there is no agreement among researchers about which length of the styloid process should be called elongated[24]. According to Keur et al. (1986), if the length of the styloid process appears to be 30 mm or more on radiography this may well be considered elongated; however, Jung et al. proposed that the styloid process should be considered elongated when its length exceeds 45 mm[41]. These differences could be attributed to the use of different methods for measuring the styloid process.

Regarding sexual dimorphism, it has been reported that the length of the styloid in males is larger than that in females on both the right and left sides, with a statistical significance[29]. In contrast, in a Japanese cadaver study to measure the average styloid process length and diameter in the Japanese population, it has been reported that females had longer full lengths of non-elongated styloid processes than males ($p = 0.004$)[31]. However, the present study found no statistically significant difference in the length of the styloid process between the sexes. In agreement with our study, it has been found that there is no statistically significant difference in the length of the styloid process between the left and right side ($P=0.724$). Our study results showed no statistically significant difference between the right and left sides in either sex group ($p>0.05$). Meanwhile, in the same study, a statistically significant difference was noted in the length of the styloid process regarding gender ($P=0.023$)[20,32], which contradicts our study's finding of no statistically significant difference between the two sex groups ($p>0.05$). This may be due to the factors that could affect styloid process length, including race, lifestyle, and dietary habits. These study results may not reflect the results of other studies in other countries.

Conclusion

The mean length of the styloid process in the Iraqi subgroup was found in males to be 26.16 mm on the right side and 26.42 mm on the left side, while the mean length of the styloid process in females was found to be 26.13 mm on the right side and 26.15 mm on the left side. There was no significant difference between the two sex groups or between the right and left sides in each sex group.

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Original Article

Digital Assessment of Transverse Maxillary Arch Measurements for Predicting Arch Length: Implications for Early Orthodontic Diagnosis and Preventive Dentistry

Aras M. Rauf[1]*

Abstract

Objective: The aim of this study was to investigate the possible correlation between the maxillary dental arch length and three other transverse linear measurements on three-dimensional digital models for developing a predictive model to be applied in early orthodontic diagnosis and prevention of the possible future malocclusion.

Methods: A sample of 108 digital models of maxillary dental arches was derived from the scanned images belonging to orthodontic patients aged 18 to 25 years in Sulaimani City. Transverse dimensions and arch length were digitally measured, and the data were analyzed with the Statistical Package for the Social Sciences (SPSS, V. 25).

Results: A pilot study was conducted to assess the reliability of measurements between conventional and digital methods for evaluating dental arch dimensions. The results showed no statistically significant differences between the two approaches. No significant gender differences were found in regard to the measurements. Correlation analysis demonstrated no significant relationship between dental arch length and inter-molar width (rho = 0.028, p = 0.776), inter-premolar width (rho = 0.004, p = 0.965), or inter-canine width (rho = 0.046, p = 0.638). However, significant positive correlations were observed among the three transverse arch dimensions: inter-molar and inter-premolar widths (rho = 0.687), inter-molar and inter-canine widths (rho = 0.682), and inter-premolar and inter-canine widths (rho = 0.926).

Conclusions: Within the study's limitations, no significant correlations were found between arch length and transverse linear measurements; therefore, a predictive model could not be established. Although inter-premolar and inter-molar widths showed statistically significant correlations, they did not contribute meaningfully to predicting arch length. Personalized evaluation using digital tools remains essential for accurate orthodontic planning and prevention of future malocclusion.

Keywords: *Digital dental model, Maxillary arch, Transverse dimensions, 3D analysis, Arch length prediction.*

Submitted: April 9, 2025, Accepted: July 19, 2025, Published: August 1, 2025.

Cite this article as: Rauf AM. Digital Assessment of Transverse Maxillary Arch Measurements for Predicting Arch Length: Implications for Early Orthodontic Diagnosis and Preventive Dentistry. Sulaimani Dent J. 2025;12(2):50-58.

DOI: https://doi.org/10.17656/sdj.10210

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Published by the College of Dentistry, University of Sulaimani

Introduction

Analysis of dental arch dimensions is essential in orthodontic practice to support accurate diagnosis, treatment planning, and the long-term stability of therapeutic outcomes, thereby preventing any possible malocclusion. Dental arch length is a critical parameter that influences the prevalence of malocclusion, particularly dental crowding and spacing anomalies. Accurate prediction of arch length remains complex due to the interplay of multiple factors, including individual variations in tooth size, arch width, arch form, palatal morphology, and craniofacial skeletal relationships. These variables are influenced by genetic, racial, cultural, and environmental elements, emphasizing the need for population-specific data[1-6].

A comprehensive understanding of arch dimensions provides clinicians with the ability to assess space availability, predict orthodontic treatment needs, and make informed decisions regarding extractions, expansions, or interproximal reductions. Conventionally, these assessments relied on physical impressions and plaster models. However, the evolution of dental technology has led to the widespread adoption of digital tools that offer higher accuracy, reproducibility, and convenience. The shift towards digitalization in dental practice has significantly improved diagnostic precision and workflow efficiency. Digital impressions and three-dimensional (3D) models have become increasingly preferred due to their enhanced patient comfort, reduced chairside time, cost-effectiveness, and ease of data storage and transfer[7-10].

For such systems to be effective, diverse and representative datasets are necessary. Currently, most orthodontic prediction models are derived from Western or East Asian populations, with limited data available from Middle Eastern or Kurdish populations, which may exhibit distinct craniofacial morphologies[3, 11-13].

Several studies have attempted to correlate dental arch length with transverse measurements such as inter-canine, inter-premolar, and inter-molar. While some have reported moderate to strong correlations, others found little to no association, highlighting the variability among populations and methodologies. The inconsistency in findings underscores the need for region-specific research using standardized digital protocols[14-19].

The use of intraoral scanners and advanced image analysis software enables accurate and reproducible measurements, eliminating the limitations of material distortions and manual handling errors. These digital technologies also facilitate arch symmetry evaluation, simulation of treatment outcomes, and communication among interdisciplinary teams. In addition to the integration of artificial intelligence into dental diagnostics that is revolutionizing the field[20, 21].

Despite the advancements in digital analysis and a growing body of literature on arch dimensions, no study has investigated the association between maxillary arch length and other linear dental measurements, specifically in a Kurdish population. This knowledge gap is particularly significant given the growing use of digital models.

An investigation of the utility of intercanine and intermolar widths of the maxilla in gender determination concluded that these measurements exhibit dimorphic patterns and may serve as supportive tools in forensic identification across different populations and contexts[22]. Lavelle (1972) examined variations in tooth size across different racial groups and occlusal categories, highlighting significant disparities that underscore the need for population-specific dental standards in both clinical and anthropological applications[23]. Hassanali and Odhiambo (2000) analyzed dental arch widths in a Kenyan population, reporting distinct dimensional characteristics that are essential for effective orthodontic diagnosis and culturally tailored treatment planning[24]. In parallel, Mangano et al. (2022) conducted a narrative review on the role of intraoral scanners in modern dentistry, emphasizing their accuracy, reproducibility, and patient-centered advantages over traditional impression techniques[25]. These findings collectively demonstrate the importance of considering anatomical, demographic, and technological factors when assessing dental arch dimensions.

This study aimed to evaluate the correlation between maxillary arch length and transverse linear measurements. Establishing such correlations can provide a foundation for developing population-specific predictive models.

Materials and methods

Sample Selection

This cross-sectional study analyzed 3D digital images acquired through intraoral scanning using a Medit i700 Wireless scanner. The images were collected from patients aged 18 to 25 years (considering the skeletal maturity) attending orthodontic clinics in Sulaimani City. Sample size calculation, conducted using G*Power software (version 3.1), indicated a minimum of 108 images based on a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, power = 0.80, and three predictors. Out of 112 scans, 108 were included in the analysis.

Scanning procedure

Intraoral scanning was performed using the Medit i700 scanner according to a standardized protocol to ensure methodological rigor and reproducibility. Patients were positioned in an upright seated posture with the occlusal plane aligned parallel to the floor, and instructed to remain motionless throughout the procedure. The scanning sequence commenced with the maxillary arch, followed by the mandibular arch, and concluded with the buccal scan to record the occlusal relationship.[26-28]

To minimize operator-dependent variability, all scans were conducted by calibrated personnel. Scan quality was evaluated based on predefined criteria, including complete surface coverage, absence of stitching artifacts or voids, and clear visualization of key anatomical structures. Any scans failing to meet these quality control standards were repeated to ensure the accuracy and reliability of the digital data. Medit Design software was used which allows precise measurement of distance, area, and angles on 3D models.

Inclusion Criteria

The 3D models of the scanned images were selected for the investigation according to the following criteria:

-Complete permanent dentition (excluding third molars) without extensive dental caries that may affect the readings

- Class I dental and skeletal relationships from the clinical records

- No more than mild dental crowding indicated by the clinical records

- Absence of systemic or congenital diseases affecting craniofacial development

- No previous orthodontic treatment or trauma

- A self-reported Kurdish ancestry for at least three generations

Exclusion criteria

Patients who declined to provide informed consent, those with distorted or low-quality digital scans, and patients with esthetic or restorative dental treatments that significantly modified the natural morphology, size, were excluded from the study

Measurements: Each maxillary 3D model of dental arch was prepared for measurement by first trimming any excess borders, followed by proper alignment along the X, Y, and Z axes. The occlusal plane and midline were then adjusted, and specific anatomical landmarks were identified on each tooth. The model bases were constructed in accordance with the standards of the American Board of Orthodontics (ABO). Subsequently, the necessary data were generated using the designated software. The selected parameters were chosen based on their potential impact on the overall arch length and alignment. The following measurements were obtained from the 3D digital models:

- Inter-molar width (IMW): Distance between the central fossae of the first permanent molars

- Inter-premolar width (IPMW): Distance between the distal pits of the first premolars

- Inter-canine width (ICW): Distance between the cusp tips of the canines

- Upper dental arch length (UDAL): Sum of the mesiodistal widths of all teeth (linear tooth widths) from the first molar on one side to the first molar on the opposite side.

Posterior teeth were assessed occlusally, and anterior teeth were measured facially (The Mesio-distal width of the teeth was measured by tracing distances from point-to-point on the digital models). Magnification tools were used to enhance accuracy.

To ensure reliability, 10% of the cases were randomly selected and remeasured by a second examiner. Inter-examiner consistency was evaluated using Cohen's kappa (Kappa value = 1).

Ethical Considerations

Ethical approval was granted by the Ethics Committee of the College of Dentistry, University of Sulaimani (Reg. No. 750 on February, 5th 2025). Additionally, verbal informed consent was obtained from all participants prior to their voluntary involvement in the study. All data were anonymized, and the study adhered to the principles of the Declaration of Helsinki.

Pilot Study

A pilot study involving 15 randomly selected cases (not included in the main analysis) was conducted to assess the applicability of the methods and reliability of the readings. Each subject had both plaster and digital models. Blind measurements were taken conventionally using a digital Vernier caliper (Mitutoyo, Japan with accuracy: 0.01 mm) and digitally using 3D software. The two sets of readings were compared using Cohen's kappa to assess method reliability.

Statistical Analysis

Data analysis was performed using SPSS version 25. Normality was assessed with the Shapiro-Wilk test. Mann-Whitney tests compared mean ranks by gender. Correlations were analyzed using Spearman's rho. Significance was set at $p \leq 0.05$.

Results

A reliability test was done on the data from the pilot study. The results showed no significant differences between the conventional and digital methods for linear measurements of the dental arches (Table 1). No statistically significant difference was observed between the 2 readings.

The normality of data was tested by the Shapiro-Wilk test. Accordingly, the inter-molar width was the only variable with normally distributed data, while the rest were abnormally distributed (Table 2).

No statistically significant differences were detected between males and females regarding the mean ranks of the following variables: Inter-molar width ($p = 0.728$), inter-premolar width ($p = 0.332$), inter-canine width ($p = 0.397$), and dental arch length ($p = 0.936$). Accordingly, correlations were made for the whole sample (Table 3).

No statistically significant correlation was found between dental arch length and inter-molar width (rho = 0.028, $p = 0.776$) (Figure 1).

It is evident in Figure 2 that there was no statistically significant correlation between dental arch length and inter-premolar width (rho = 0.004, $p = 0.965$) (Table 3).

No statistically significant correlation was found between dental arch length and inter-canine width (rho = 0.046, $p = 0.638$) (Figure 3).

Positive statistically significant correlation was found between the following sets of variables: Inter-molar width and inter-premolar width (rho = 0.687, $p < 0.001$); inter-molar width and inter-canine width (rho = 0.682, $p < 0.001$); inter-premolar width and inter-canine width (rho = 0.926, $p < 0.001$), as presented in Table 4.

Discussion

The development and growth of the dental arches undergo a dynamic process characterized by continuous changes that influence the linear dimensions of both arches.

Advancements in digital technology now allow for accurate, safe, and relatively rapid measurements using three-dimensional (3D) models[13].

Table 1: Reliability of the data, comparing the conventional versus digital method of measurement.

Measuring method	Mean	N	Std. Deviation	p value
Conventional_IMW	43.66	15	2.82	0.104
Digital_IMW	43.80	15	2.91	
Conventional_IPMW	34.68	15	3.74	0.073
Digital_IPMW	34.93	15	3.76	
Conventional_ICW	31.46	15	2.59	0.995
Digital_ICW	31.26	15	2.67	
Conventional_UDAL	87.88	15	2.55	0.670
Digital_UDAL	87.05	15	2.47	

Table 2: Testing the normality of data.

	Shapiro-Wilk test		
Variables	Statistic	df	p-value
Inter-molar width	0.984	108	0.240
Inter-premolar width	0.969	108	0.013
Inter-canine width	0.959	108	0.002
Dental arch length	0.934	108	< 0.001

Table 3: The study variables by gender.

	Gender	N	Mean	SD	Mean rank	P*
Inter-molar width	Male	51	44.84	2.33	55.61	0.728
	Female	57	44.65	2.33	53.51	
Inter-premolar width	Male	51	34.30	2.83	57.59	0.332
	Female	57	33.76	2.71	51.74	
Inter-canine width	Male	51	31.90	2.75	57.20	0.397
	Female	57	31.40	2.32	52.09	
Dental arch length	Male	51	89.71	2.29	54.25	0.936
	Female	57	89.72	2.75	54.73	

Table 4: Correlations between the three independent variables of the study.

Variable Y	Variable X	rho	p-value
Inter-molar width	Inter-premolar width	0.687	< 0.001
Inter-molar width	Inter-canine width	0.682	< 0.001
Inter-premolar width	Inter-canine width	0.926	< 0.001

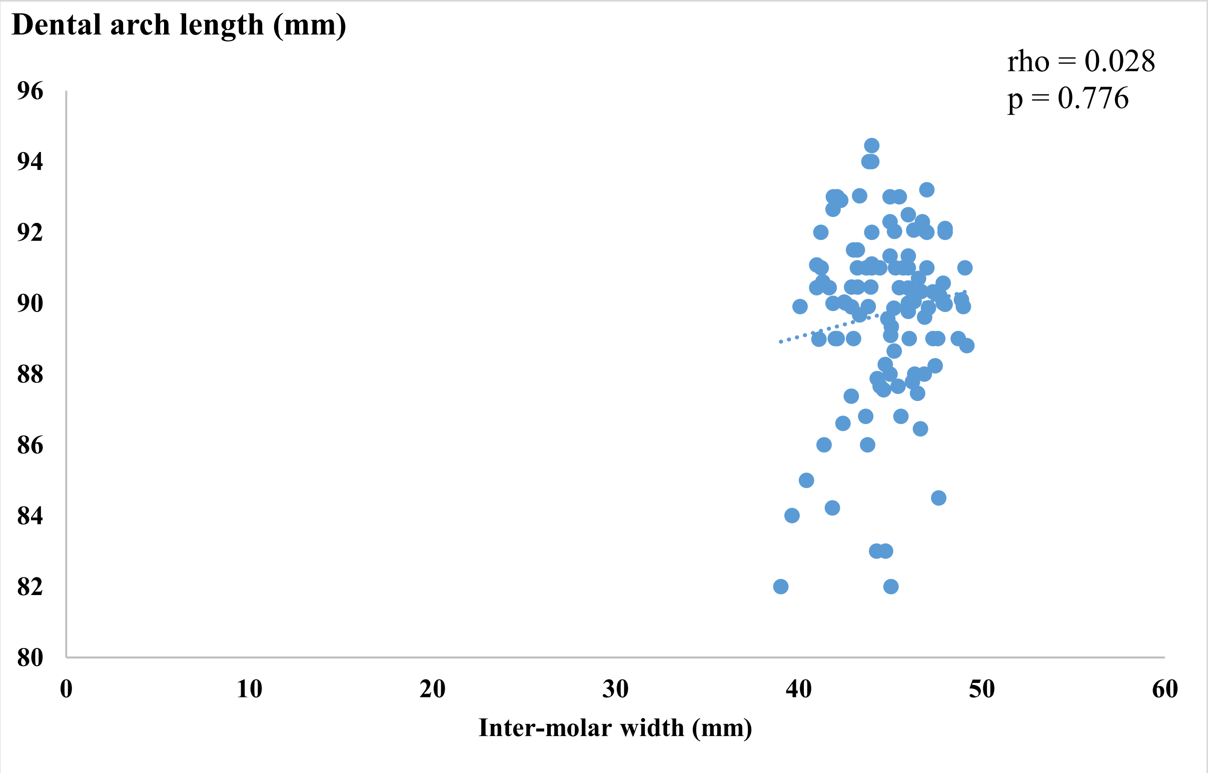

Figure 1: Correlation between dental arch length and inter-molar width.

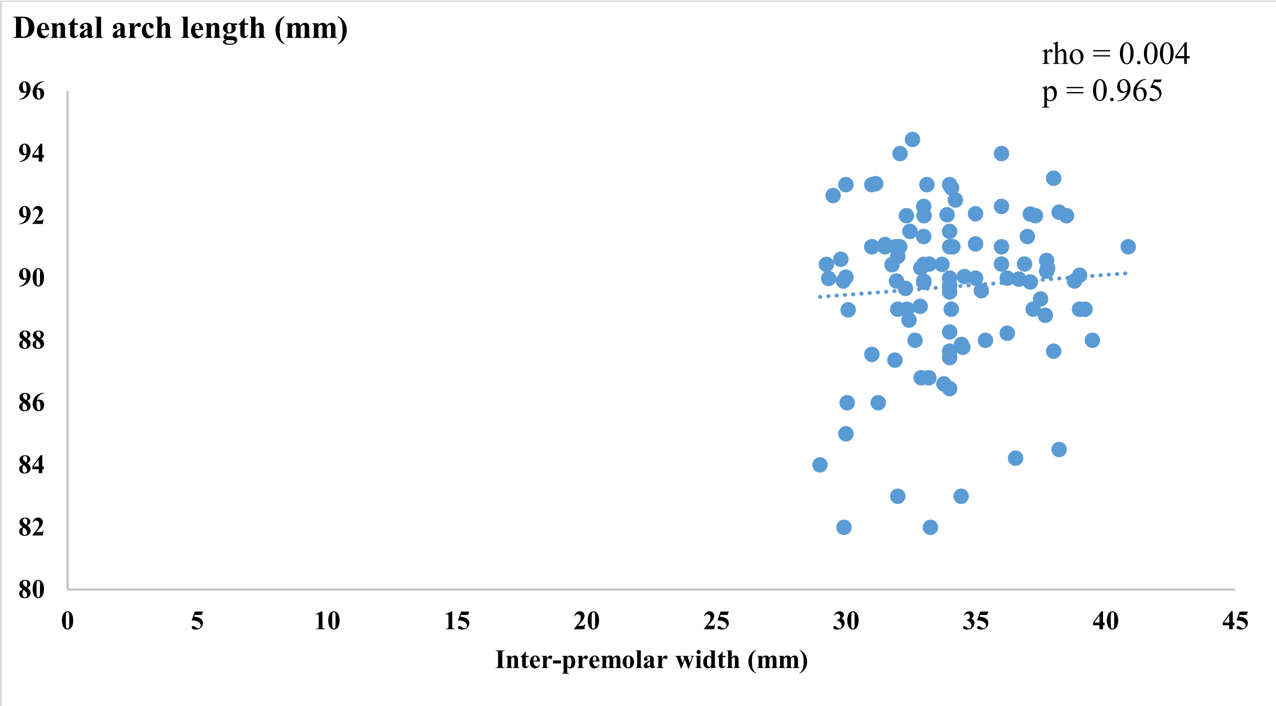

Figure 2: Correlation between dental arch length and inter-premolar width.

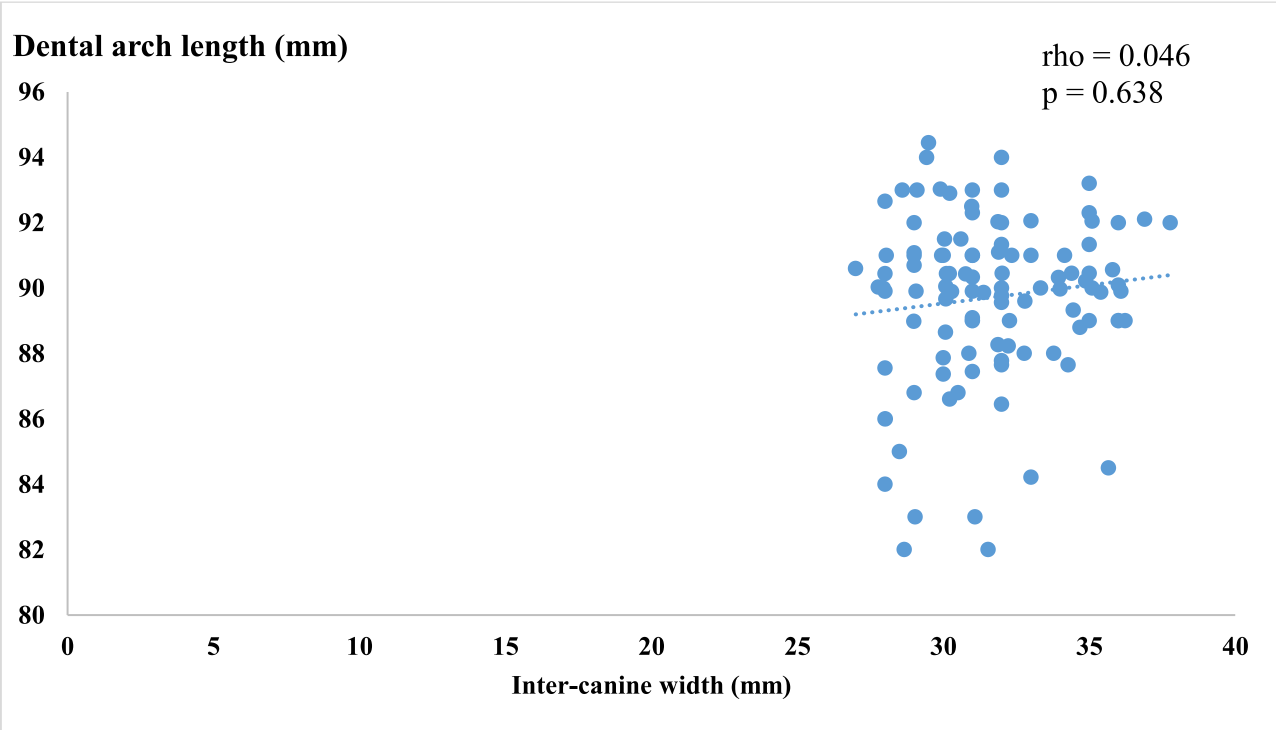

Figure 3: Correlation between dental arch length and inter-canine width.

Several authors have reported varying degrees of correlation among different dental arch measurements[4,15-17], while others have found weak or no correlations at all[14, 18]. The current findings revealed no significant correlations between dental arch length and transverse arch dimensions, particularly in terms of width measurements. This absence of correlation may be attributed to variations in growth patterns, diverse alveolar and palatal morphologies, and racial or ethnic differences.

This study explored the gender differences and inter-variable correlations. No statistically significant differences were found between males and females across the measured variables: intermolar width, interpremolar width, intercanine width, and dental arch length. These findings are consistent with previous studies that reported minimal or non-significant sexual dimorphism in transverse dental arch dimensions among late adolescents and young adults, especially when sample sizes are relatively balanced and age ranges are controlled[29,30].

The use of the Mann–Whitney U test for non-parametric comparisons further supports the validity of these findings, as it does not require standard distribution assumptions. Although some earlier studies have reported slightly larger arch dimensions in males,[28] our results suggest that gender may not play a substantial role in influencing transverse arch dimensions or dental arch length in this population.

Crucially, these results indicate that dental arch length functions independently of transverse arch parameters, challenging the previous assumption that arch width can serve as a reliable predictor of arch length[32,33]. A possible explanation for this lack of correlation lies in the complex three-dimensional curvature and geometry of the dental arch, which may not be adequately represented by linear transverse measurements alone.

Conversely, highly significant and strong positive correlations were observed among the three transverse variables themselves. Inter-premolar and inter-canine widths suggest a strong structural interdependence within the anterior-posterior segments of the arch. These findings align with previous studies that report coordinated growth and proportional relationships among the transverse dimensions of the dental arch[34,35]. This internal coherence likely reflects genetic and developmental constraints in craniofacial morphology, resulting in harmonious dimensional scaling across the transverse plane.

From a clinical standpoint, the study's findings underscore the importance of evaluating each dimension of the dental arch independently during orthodontic diagnosis and treatment planning. Comprehensive digital assessments or direct measurements are essential for accurate arch evaluation[33].

This study emphasizes three key points: (1) transverse dental measurements are strongly interrelated but do not predict arch length; (2) gender does not significantly influence these variables in the sample studied; and (3) anterior dental arch alterations have a more pronounced effect on arch length than posterior changes. Sample size, measurement artifacts, or population-specific racial characteristics may influence these outcomes.

Finally, incorporating transverse arch width measurements into routine orthodontic evaluations provides valuable clinical insight. For example, greater inter-molar width may indicate increased space availability, which can influence the decision between arch expansion and tooth extraction during treatment planning[37]. It is also noteworthy that conventional plaster models and digital models yielded comparable results[38]. Due to the absence of significant correlations in this study, regression analysis was not conducted, and consequently, no predictive equation was developed.

Study limitations

Future research using 3D digital models and larger, more diverse populations may further elucidate the spatial dynamics of dental arch morphology and refine predictive modeling for clinical applications in the field of preventive dentistry and early orthodontic practice.

Conclusion

The study concludes that maxillary arch length cannot be reliably predicted based on inter-molar, inter-premolar, or inter-canine widths alone. In the examined Kurdish population, these linear width measurements did not exhibit a significant correlation with arch length, therefore, a predictive model could not be established. Although inter-premolar and inter-molar widths showed statistically significant correlations, they did not contribute meaningfully to predicting arch length. Hence, personalized evaluation using digital tools remains essential for accurate orthodontic planning and prevention of malocclusion.

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