ORIGINAL ARTICLE

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Apical foramen position in relation to proximal root surfaces of the premolar teeth in Kurdistan region of Iraq: A retrospective CBCT assessment

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Purpose: The purpose of the study is to determine the location of the apical foramen (AF) in relation to the root surfaces of human permanent premolar teeth in the population of Iraqi Kurdistan using cone beam computed tomography (CBCT) imaging.

Methods: CBCT images from 103 patients from the Iraqi Kurdistan region were evaluated. Multiplanar images were captured to check the position of the AF in relation to the root canal surfaces of premolars. The data were analyzed using Fisher's, Chi-square, and t-tests.

Results: The most common AF location of all premolars was central, followed by distal and then mesial, except for the mandibular right second premolar where central and mesial were the most prevalent. The mean distance between the AF and anatomic apex on the right side of all the first premolars was 0.6205 mm. That of the second premolars was 0.6205 mm in males and 0.5854 mm in females. There was no significant difference between both sides and genders.

Conclusion: In the Kurdistan region of Iraq, the most common location for the apical foramina of all premolar teeth is central AF, followed by the distal location. A minimum 1 mm of distance from the anatomic apex in mandibular premolars could be appropriate for root canal therapy.

Keywords: Anatomical root apex; apical foramen location; cone beam computed tomography; mandibular; maxillary, premolar teeth.

Introduction

Complete cleaning and shaping of the root canals, along with a three-dimensional sealed tight root canal system (RCS) filling, are considered to be the most essential and widely practiced endodontic procedures worldwide (1). Morphological knowledge of the apical region should be accurate, as instrumentation and filling of root canals are based, to a great extent, on that information (2,3).

Understanding the apical area and the morphology of the tooth root canal is a complex and crucial aspect that clinical operators need to consider when making decisions during endodontic treatment (3). Numerous factors contribute to the variations found in root canal and apical foramen (AF) studies, including ethnicity, age, and gender. A successful endodontic procedure begins with a thorough assessment of the root canals and their anatomical variability (1-3).

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Cone beam computed tomography (CBCT) is a valuable 3D orthogonal imaging tool for the maxillofacial skeleton and internal structures consuming a lower dose of radiation compared to conventional CT (4) and has been shown to be more accurate than digital X-rays in identifying RCS. It is precise in determining root canal morphology and AF location in relation to the root surfaces which need perfect identification during access preparation and reduce errors and failures in endodontic treatments by eliminating the issue of root superimposition from neighboring anatomical structures. The precise assessment of the AF distance proved to be a very helpful tool in clinical dental practice and has to be taken into consideration during root canal procedure. Complete debridement of these regions through mechanical instrumentation is impractical, and necrotic tissue remnants and microorganisms in the apical portion affect the post-treatment outcome (5).

CBCT images provide insight into the spatial resolution of anatomical variations and enable clinicians to visualize any necessary access modifications for treatment.

From the anatomical and clinical background, the narrowest part of the root canal is the apical constriction or minor foramen. From this point, the canal gradually widens to terminate at the AF or major foramen. The cementodentinal junction is the histological landmark where the pulp ends and the periodontal ligament starts. It is expected to be located at the apical constriction, but its position can be irregular (Fig. 1). AF is the main opening to the apical part of the root canal and is the site where endodontic filling is endotreatment (6). In most cases, "apex" and "AF" are used interchangeably. The anatomical apex refers to the anatomical end of the root as seen in radiography. On the other hand, AF is the main opening of the root canal in relation to the apex. The AF can be located in mesial, distal, buccal, and lingual positions (7). Recent studies have reported that in over 60% of canals, the AF is not located at the apex. Furthermore, the distance between the AF and radiographic decay can vary within 3 mm (8). This apical deviation of the foramen is due to aging and cement deposition. Besides, the degree of deviation varies by tooth type. During the past three decades, various methods such as clearing, modeling, histologic, and radiographic techniques have been employed to assess the structure of the root canal. Recently, the application of CBCT has significantly increased. CBCT can provide a 3D observation of anatomical structures and pathological conditions. In 2018, Estrela et al. used CBCT to investigate the position of the AF compared to the anatomical apex in maxillary and mandibular teeth (9). Now, the application of micro CT has added more advancement for the accurate evaluation of the root apex (Fig. 2).

Materials and Methods

The study protocol was approved by the Institutional Ethics Committee of the College of Dentistry, University of Duhok, Kurdistan Region, Iraq. The case records 696 premolars from 103 patients (51 males and 52 females) who underwent CBCT scans between November 2021 and September 2022 were retrieved from the databases of three private dental imaging centers located in three governorates in the Kurdistan Region of Iraq. In this retrospective study, CBCT images of permanent premolar teeth from Duhok, Erbil, and Sulaymaniyah were included. To obtain a representative sample of the Kurdish population in this region, we selected the main public dental clinic in the capital of these governorates as the setting of data collection. The CBCT images were selected from two types of CBCT machines (NewTom Giano Verona, Italy, Villa 3D Planner, Italy, and Anatomage in vivo dental viewer, Italy) (Fig. 3).

The machines were operated at 90 kVp and 10mA. The field of view was 8 × 8 cm, and the voxel size was 75 µm.

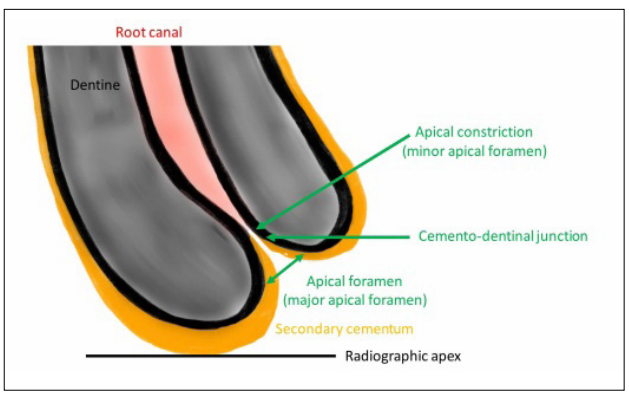

Fig. 1. Diagrammatic representation of the root apex (6).

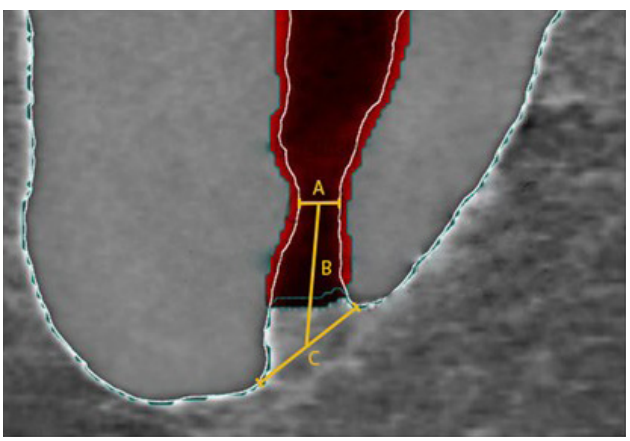

Fig. 2. Representation of the distances measured at the apical foramen region using micro-computed tomography. (a), a narrow diameter of the physiological foramen. (b), distance between the physiological and anatomical foramen. (c), diameter (width) of the anatomical foramen (7).

Images in sections of 0.5 mm with intervals of 1 mm in coronal and sagittal plans in terms of the 10 mm were prepared by NNT software, for appropriate examination of the teeth, in the axial view, only lower one-third of the roots were investigated then the roots were examined horizontally (parallel to the occlusal surface) so that they passed through the upper sections of the teeth and parallel to the sagittal plane. In the first mode, images were cross-sectional or in sagittal view, enabling examination of the buccal and lingual surfaces. In the second mode, the coronal view of mesiodistal teeth was investigated. It is worth noting that the AF may be positioned mesiodistally or buccolingually in relation to the outer surface of the tooth. Hence, in both coronal and sagittal views, the distance between the AF and the perpendicular and tangential lines on the radiographic apex (in 10 mm) was measured using NNT software. Furthermore, distance from AF to the anatomic apex was observed in axial, sagittal, and coronal planes. Healthy teeth with no previous endodontic treatments, restorations, or root resorption were chosen as inclusion criteria. Teeth with open apices (not fully formed), root resorption or calcification (partial or complete radiographic obliteration of the pulp chamber and root canals), as well as teeth with previous endodontic treatment, were excluded.

The images were evaluated and the data were captured in Microsoft Excel 2016. The data were then exported to the Statistical Package for the Social Sciences (SPSS version 26, IBM Corp., IL, USA).

The Chi-square test was used to compare proportions. The Fisher's exact test was used instead of the Chi-square when the expected value of more than 20% of the cells of the table was <5. Kolmogorov–Smirnov test, unpaired "t", and paired "t" tests were used for sample comparison. The level of significance was set at 0.05. The results were presented in SPSS software, and the outcome was represented in a form of tables and bar chart.

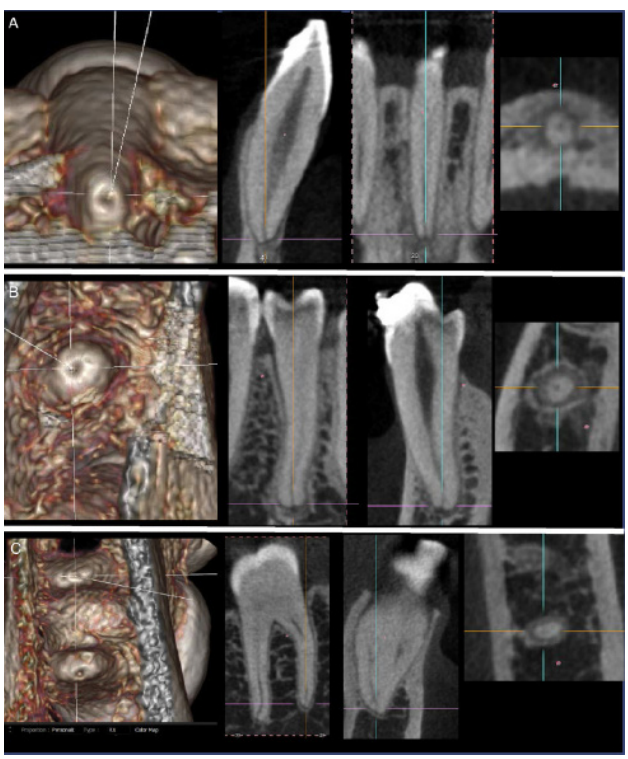

Fig. 3. Determination of apical foramen position using multiplanar cone beam computed tomography. Axial, sagittal, coronal, and 3D sections.

Results

Six hundred and ninety-six premolars who met specific inclusion criteria and were between the ages of 18 and 60 participated in this study. There were 51 males (49.51%) and 52 females (50.49%), as shown in Fig. 4. (Table 1)

For the right maxillary first premolar teeth (R.UFPT), the majority of apical foramina in both males and females are centrally located, with 58.3% and 51.1%, respectively. The second most common location is distal for both males and females, with percentages of 37.5% and 42.2%, respectively. The least common location for both males and females is mesial, with percentages of 4.2% and 6.7%, respectively.

For left maxillary first premolar teeth (L.UFPT), the distribution of apical foramina was relatively similar between males and females. The most common location was centrally located, accounting for 53.2% and 47.9% in males and females, respectively. The second most common location is distal for males and females, accounting for 44.7% and 52.1%, respectively. A very small percentage of apical foramina were located mesially in males (2.1%).

For the right maxillary second premolar teeth (R.USPT), the majority of apical foramina in both males and females were centrally located, with 69.2% and 66.7%, respectively. The second most common location was distally located in both males and females, with 28.2% and 31.1%, respectively. A very small percentage of apical foramina were located mesially for both males and females (2.6% and 2.2%,

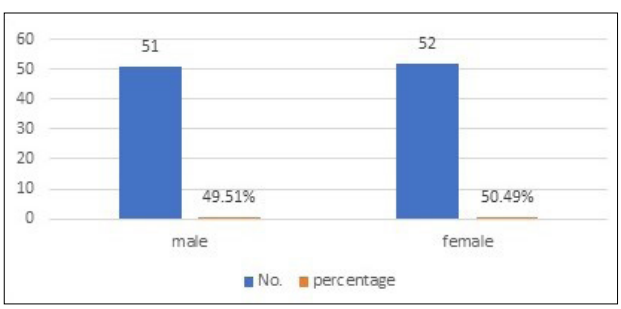

Fig. 4. Frequency analysis of included volunteers

Table 1. Prevalence of AF locations in maxillary premolar teeth in both genders

Location of apical foramina	Male No. (%)	Female No. (%)	Total No. (%)
Right UFPT			
Centrally located	28 (58.3)	23 (51.1)	51 (54.7)
Distally located	18 (37.5)	19 (42.2)	37 (39.8)
Mesial located	2 (4.2)	3 (6.7)	5 (5.5)
Total	48 (100)	45 (100)	93 (100)
Right USPT			
Centrally located	27 (69.2)	30 (66.7)	57 (68)
Distally located	11 (28.2)	14 (31.1)	25 (29.6)
Mesial located	1 (2.6)	1 (2.2)	2 (2.4)
Total	39 (100)	45 (100)	84 (100)
Left UFPT			
Centrally located	25 (53.2)	23 (47.9)	48 (50.5)
Distally located	21 (44.7)	25 (52.1)	46 (48.4)
Mesial located	1 (2.1)	0 (0.0)	1 (1.1)
Total	47 (100)	48 (100)	95 (100)
Left USPT			
Centrally located	20 (54.1)	26 (63.4)	46 (58.7)
Distally located	15 (40.5)	12 (29.3)	27 (34.9)
Mesial located	2 (5.4)	3 (7.3)	5 (6.4)
Total	37 (100)	41 (100)	78 (100)

AF: Apical foramen; UFPT: Upper First Premolar Teeth; USPT: Upper Second Premolar Teeth.

respectively).

For the left maxillary second premolar teeth (L.USPT), the majority of apical foramina were centrally located, with 54.1% in males and 63.4% in females. A smaller percentage of apical foramina were located distally for both males and females (40.5% and 29.3%, respectively), while a very small percentage was recorded for the mesial location in males and females (5.4% and 7.3%, respectively). (Table 2)

For the right mandibular first premolar teeth (R.LFPT), the majority of apical foramina were centrally located in both males and females, with 58.1% and 53.5%, respectively. The second most common location was distal, with 30.2% for males and 23.3% for females. The least common location was mesial, with 11.6% for males and 23.3% for females.

For left mandibular first premolar teeth (L.LFPT), the majority of apical foramina were centrally located, with 48.8% in males and 72.7% in females. A smaller percentage of apical foramina were located distally for both males and females (29.3% and 18.2%, respectively), while the least common location was mesial for both males and females (22% and 9.1%, respectively).

The majority of the apical foramina in mandibular right second premolar (R.LSPT) teeth were centrally located in both males and females (65% and 58%, respectively). The second most common location was mesial for both males and females (20% and 26%, respectively). The least common location was distal for males and females (15% and 16%, respectively).

For the mandibular left second premolar teeth (L.LSPT), the central location was the most common in both males and females, with percentages of 75.7% and 68.8%, respectively. The second most common type is distal, occurring in both males and females at rates of 16.2% and 22.9%, respectively, while the mesial location had the lowest percentage for both males and females (8.1%, 8.3%), respectively.

Average (±standard deviation [SD]) distance from AF to the anatomic apex of the first and second premolars in male was 0.61–0.62 mm with ± SD of 0.142 and $p = 0.54$ in the right and left quadrant and for females was 0.58–0.60 mm with ± SD of 0.129 and $p = 0.22$ for both right and left quadrant. According to t-test, no statistical significant difference was found in the distance between the AF and the anatomic apex of the first and second premolars in both right and left quadrants ($p = 0.857$). Comparison of mean distance between the AF and anatomic apex of the first and second premolars between the right and left side in both males and females has been shown in tables (3,4). (Table 3)

Table 2. Prevalence of AF locations in mandibular premolar teeth for both genders

Location of apical foramina	Male No. (%)	Female No. (%)	Total No. (%)	p-value
Right LFPT				
Centrally located	25 (58.1)	23 (53.5)	48 (55.8)	
Distally located	13 (30.2)	10 (23.3)	23 (26.6)	
Mesial located	5 (11.6)	10 (23.3)	15 (17.6)	
Total	43 (100)	43 (100)	86 (100)	
Right LSPT				
Centrally located	26 (65)	29 (58)	55 (61.5)	
Distally located	6 (15)	8 (16)	14 (15.5)	
Mesial located	8 (20)	13 (26)	21 (23)	
Total	40 (100)	50 (100)	90 (100)	
Left LFPT				
Centrally located	20 (48.8)	32 (72.7)	52 (60.7)	
Distally located	12 (29.3)	8 (18.2)	20 (23.7)	
Mesial located	9 (22.0)	4 (9.1)	13 (15.6)	0.067**
Total	41 (100)	44 (100)	85 (100)	
Left LSPT				
Centrally located	28 (75.7)	33 (68.8)	61 (72.3)	
Distally located	6 (16.2)	11 (22.9)	17 (19.5)	
Mesial located	3 (8.1)	4 (8.3)	7 (8.2)	
Total	37 (100)	48 (100)	85 (100)	

*By Fisher's exact test. **By Chi-square test. UFPT: Upper First Premolar Teeth; USPT: Upper Second Premolar Teeth. There is a statistically significant difference in the location of apical foramina between males and females, for the location of apical foramina in the left first premolar teeth. The p-value for this location is 0.067, which is marginally significant at the 0.05 level.

Table 3. Comparison of mean distance between apical foramen and anatomic apex of right first premolar and right second premolar between males and females (mm)

Age group	Mean ± SD		p-value
	Males	Females	
First premolars	0.6227±0.13954	0.5878±0.12082	0.544
Second premolars	0.6205±0.13907	0.5854±0.11082	0.204

SD: Standard deviation.

Table 4. Comparison of mean distance between apical foramen and anatomic apex of left first premolar and left second premolar between males and females

Age group	Mean ± SD		p-value
	Right	Left	
First premolars	0.6205±0.14237	0.6227±0.13954	0.857
Second premolars	0.6024±0.12940	0.5878±0.12082	0.279

SD: Standard deviation.

The mean distance of AF and anatomic apex on the right side of the first premolar is 0.6205 mm with p = 0.544 and the second premolar is 0.6205 mm with p = 0.204 which did not differ significantly between males and females. (Table 4)

Discussion

A clear understanding of root anatomy and canal morphology is vital for efficiently performing biomechanical cleaning and shaping, which is crucial for achieving predictable endodontic outcomes. Nevertheless, the variation in root canal morphology presents clinical difficulties that might lead to unfavorable endodontic treatment. CBCT is an excellent ex vivo and in vivo method for evaluating external and internal root morphology compared to conventional 2D radiography (6-9).

In the present study on the maxillary first premolars (R.UFPT and L.UFPT), the most common deviation in the location of apical foramina in males and females was central (52.6%), followed by distal (44.1%) and mesial (3.3%). There were some differences between quadrants and genders in these teeth. No cases were recorded for females in the mesial location on the left side, and the distal location was more common on the left side for both genders compared to the right side. Similar results were also found in a recent study conducted on the Brazilian population (9), which reported that the most common AF location of the maxillary first premolars (39.9%) was central.

In the present study, the most common location for the maxillary second right and left premolar teeth (R.USPT, L.USPT) was the central position, accounting for 63.4% of cases. This was followed by the distal location at 32.2% and the mesial location at 4.4%. Almost all the locations

of the AF are the same in both quadrants and in both genders, except for the distal location in the left upper second premolar tooth (L.USPT), which was more common in males than in females. A similar result was found in a study conducted on a subpopulation in Yemen, which also reported that the center was the most frequently observed location for the second upper premolars (10). In a study conducted in Brazil (9), it was found that the most common location for AF among the second upper premolars was central, accounting for 57.4%.

In the present study, the location of the AF for mandibular first right and left premolars (R.LFPT, L.LFPT) in both genders is mostly in the center (58.3%), followed by distal (25.1%) and mesial (16.6%). In the R.LFPT, the distal and central locations were similar between genders, but the mesial location was more common in females than males. However, in the left LFPT, the central location was more common in females than males, while the mesial and distal locations were more common in males than females.

These results are confirmed by other studies conducted in Kuwaiti population (11), and in Brazil (9), where the central location was found to be the most common among their sample studies of the mandibular first premolars. However, a specific subgroup within the Iranian population contradicted the present findings. They found that the most common location for apical foramina among the mandibular first premolars was distal (12).

We observe significant variations among different populations, which may be attributed to factors such as gender, sample size, ancestry, data collection methods, and study design (13).

For the mandibular right and left second premolars (RLSPT, LLSPT) in our study, both genders showed that the most prevalent location is the center location, accounting for 66.9% of cases. This is followed by the distal location at 17.5% and the mesial location at 15.6%. Central location in both quadrants is more common in males than females. In terms of the right side, mesial and distal locations are almost similar in both genders. In terms of mesial location, both genders have a similar percentage on the left side. However, in females, the distal location is more common compared to males. A similar finding was observed in the Yemeni subpopulation, where the center was reported as the most frequent location (10). Furthermore, another similar finding was seen in the Brazilian population in 2018 (9), where the most common location was central, accounting for 42.85% and 50.98%, respectively.

The present study found that according to the average distance from AF to the anatomic apex of the first and second premolars in male and female it was 0.61–0.62 mm with ± SD of 0.142 and p = 0.54 and 0.58–0.60 mm with ± SD of 0.129 and p = 0.22, respectively. The results of the measurement of the apex to foramen distances in this study were in close agreement with previous findings. Burch and Hulen (14) found the AF distance to be 0.59 mm in a study of all tooth types and study conducted by Arora and Tewari (15) reported the distance between the AF found to be in a range of 0.052–2.91 mm. A similar study was conducted by Naseri et al. (16) revealed that the mean distance between AF was found to be in the range of 0.3–0.7 mm which is in accordance with the values calculated in the present study. In another study by Martos et al. (17) which was conducted using a stereomicroscope on mandibular molars of a Brazilian population, the mean distance from apex to AF was 0.80 (±0.54) mm. Akhlaghi et al. (18) in an ex vivo study in a local Iranian population using India ink on mandibular second molars showed that the mean (±SD) distance from the apex of the AF was 0.30–0.47mm. India ink was used in this study which makes the evaluation method different than the present study. Study conducted by Cheung et al. (19) indicated that the average distance of AF from the anatomic apex at the C-shaped mandibular second molars in a Chinese population is 0.79–0.89 mm by using micro-CT. These slight variations are to some degree due to the varying methods used to measure the distance as well as to the different reference points that were probably used. Furthermore, the other reason for this difference can be owing to differences in various populations. In a recent study conducted by Reda et al. in 2022, they found that one AF was the most common among all the premolars and that the mean distance of AF from the anatomic apex recorded between 3.40 ± 1.80 and 5.12 ± 1.98 (20). In a study conducted among the Chinese population by Yang et al., 1–2 mm distance was the average among their study sample (21). Variation in the distance of the AF thus shows racial predilection.

Conclusion

Proper evaluation of the apical anatomy by CBCT is crucial in performing root canal treatment, and the most common location for the apical foramina of all premolar teeth was central AF, followed by the distal location. The distance between the AF and the anatomic apex in the mandibular premolars in Kurdistan population was approximately 1 mm, and therefore, the extent of obturation should be 1-mm short of the radiographic apex and the root canal procedure should be terminated at this point.

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Conflict of Interest: None declared.

Ethical Approval: Before commencing the study, permission was obtained from the College of Dentistry at Duhok University. The official paper number was 917, dated 23/11/2021. Approval was also obtained from the Ethics Committee at the Directorate General of Health in Duhok Governorate. The official paper number was 4255 on October 20, 2020.

Informed consent: Written informed consent was obtained from patients who participated in this study.

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