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Proximity of Teeth Roots to Vital Structure: A CBCT Study

Jackson Dipankara[1], Wiwiek Poedjiastoeti[1], Intan Farizka[2], Anggraeny Putri Sekar Palupi[1], Yessy Ariesanti[1], Rachendra Pratama[1], Sarwer Jamal Biplob[3], Aldrich Victor Reiner Sutanto[4]

Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Universitas Trisakti, DKI Jakarta, Indonesia[1]
Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Universitas Trisakti, DKI Jakarta, Indonesia[2]
Department of Oral and Maxillofacial Surgery, Bangladesh Medical University, Dhaka, Bangladesh[3]
Undergraduate Student, Faculty of Dentistry, Universitas Trisakti, DKI Jakarta, Indonesia[4]

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ABSTRACT

To determine the differences in the distance between tooth apices and vital anatomical structures using cone-beam computed tomography (CBCT). Research measuring the distance from the dental apex to vital structures with CBCT remains limited, as most existing studies rely on panoramic radiography and have generally been conducted in populations outside Indonesia. An analytical observational approach with a cross-sectional design was employed to evaluate differences in the distance between tooth apices and the alveolar crest in relation to adjacent vital structures. Interobserver reliability testing demonstrated almost perfect agreement, with kappa coefficient values ranging from 0.823 to 0.862. Independent t-tests were performed to assess differences in apex-to-vital structure distances based on sex. Significant differences were found only in measurements involving the mental foramen and the mandibular canal. One-way ANOVA was used to evaluate apex-to-structure distances across age groups, revealing no statistically significant differences among age categories. The findings indicate that female patients tend to have tooth apices located closer to the mental foramen and mandibular canal compared with male patients. However, no significant differences in apex-to-vital structure distances were observed across different age groups. Therefore, dental treatments involving these vital structures may require procedural modifications in female patients to minimize the risk of postoperative complications.

1. Introduction

The anatomical relationship between vital structures and tooth roots has been extensively studied in recent years. Understanding the relationship between vital structures and tooth roots is essential, especially during extraction procedures, surgical interventions involving vital structures, or implant placement [1].

Radiographic examinations are performed to evaluate procedural risks, determine the relationship between the tooth roots and surrounding tissues or vital structures, and assist in assessing the level of difficulty of the tooth extraction procedure [2]. However, in clinical practice, this does not appear to be a universally applied protocol prior to dental procedures.

Dental radiography can be classified into two main types: intraoral and extraoral radiography. Commonly used extraoral techniques include panoramic radiography for two-dimensional (2D) imaging and Cone-beam Computed Tomography (CBCT) for three-dimensional (3D) imaging [3], [4]. Panoramic radiography provides a 2D representation of complex three-dimensional structures but has limitations such as image magnification, distortion, superimposition, and structural misrepresentation. In contrast, CBCT overcomes these limitations by providing detailed 3D images with a relatively low effective radiation dose [5], [6].

Radiographic examination plays an important role in supporting diagnosis, determining appropriate treatment plans, and ensuring the achievement of treatment goals [7]. Assessment of the distance between the mandibular third molar and the mandibular canal is essential to minimize the risk of preoperative nerve injury [8]. The prevalence of inferior alveolar nerve injury is relatively high, reaching 17.66% [9]. Therefore, when the proximity between the tooth roots and the canal is observed on panoramic radiographs, the use of three-dimensional imaging such as CBCT is recommended, as CBCT provides greater accuracy in evaluating the relationship between the tooth and the mandibular canal [8].

Additionally, the proximity of the maxillary posterior teeth to the maxillary sinus should be assessed to prevent complications such as oroantral communication [10]. The prevalence of oroantral communication has been reported to be 45% in maxillary second molar extractions, 30% in third molars, 27.2% in first molars, and 5.3% in first premolars [11].

The location of the mental foramen is crucial for local anesthesia administration, surgical procedures, and dental implant placement. Variations in its location, morphology, and anatomy must be carefully considered to prevent nerve injury. Cone-Beam Computed Tomography (CBCT) has been shown to be superior to panoramic radiography in detecting anatomical variations among patients. The higher accuracy of CBCT compared to panoramic radiography in identifying the mental foramen is attributed to its ability to overcome the inherent limitations of panoramic imaging [12].

One of the most common complications associated with tooth extraction and dental implant placement in the mandibular region is injury to the inferior alveolar or mental nerves, whereas in the maxillary region, complications often involve the maxillary sinus. Research focusing on the measurement of the distance between the tooth apex and vital structures using CBCT remains limited. Most previous studies have relied on panoramic radiography, and those utilizing CBCT have generally been conducted in populations outside Indonesia. Therefore, the present study aims to determine the differences in the distance between tooth apices and vital structures using CBCT.

2. Material and Method

An analytical observational study with a cross-sectional design conducted to evaluate the differences in the distance between the tooth apex and the alveolar bone crest in relation to vital structures using CBCT. Sixty-four secondary data in the form of CBCT radiographs obtained from the Radiology Department of RSGMP FKG Usakti between 2022 and 2024. The CBCT data must meet the following inclusion criteria: CBCT radiographs of patients aged 17 years and over at the Dental Radiology Unit of RSGM-P FKG Trisakti University, Secondary data of CBCT radiographs of patients from January 2022 to June 2024, Having

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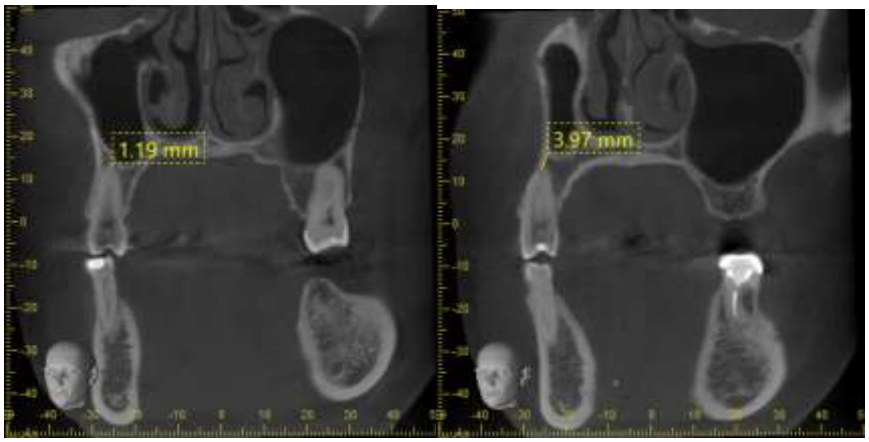
impacted or non-impacted mandibular third molars for measuring the distance between the apex of the third molar and the mandibular canal, Maxillary posterior teeth between premolars/molars, Mandibular posterior teeth between premolars/molars and the exclusion criteria: CBCT radiographs with poor quality, pathological lesion at the apical site of the mandibular third molar, pathological lesion in the maxillary and mandibular posterior teeth, both premolars and molars, pathological lesion in the maxillary sinus area, pathological lesion around the mental foramen, pathological lesion around the mandibular canal.

All CBCT images were obtained from the CBCT machine (J Morita 3D Accuitomo 170, J. Morita Co., Japan) with the exposure parameters at 90 KvP, 5 mA, and images have a voxel size of 80 μm. Cross sectional view with 1.00 mm slice thickness was obtained. All CBCT data were analyzed by general dentist and oral and maxillofacial radiologists using i-Dixel software version 2.2 (Morita, Japan). The shortest distance from root apices of the maxillary premolars/molars to the maxillary sinus were measured by drawing the nearest vertical line from the apex of the buccal and palatal roots in premolars, and from the mesiobuccal, distobuccal, and palatal roots in molars, to the most inferior border of the maxillary sinus floor (Figure 1). The distance between the root apices of mandibular third molar to mandibular canal were measured by drawing a line from lowest point of apex to superior cortical bone of mandibular canal (Figure 2). The distance between root apex of the first or second premolar to the mental foramen was measured by drawing a line from the most superior point of mental foramen (Figure 3). All measurements were conducted on the coronal views. Inter observer agreement was calculated to verify the reliability of measurement (Table 1) [13].

Table 1. interpretation of Cohen's Kappa (κ)

Cohen's Kappa (κ)	Strenght of Agreement
<0.00	Poor
0.01-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect



A B

C

Figure 1. The measurement of distance between maxillary posterior teeth to maxillary sinus from coronal view. First premolar (A) second premolar (B), first molar (C).

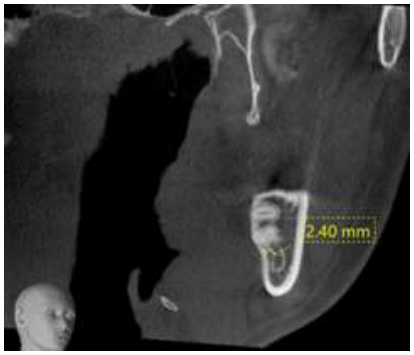


Figure 2. The measurement of distance between mandibular third molar root apex and mandibular canal from coronal view.

Figure 2. The measurement of distance between mandibular premolar root apex and mental foramen from coronal view.

3. Result and Discussion

Evaluation of the distance between the tooth apex and vital structures was performed using cone-beam computed tomography (CBCT). Two examiners independently measured the distances from the tooth apex to the maxillary sinus, mandibular canal, and mental foramen. A total of 30 samples from each measurement were initially tested for interobserver reliability. The results of the reliability analysis are presented in Table 2.

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Table 2. interobserver measurement

	Uji Interobserver	Strength of agreement
P1 – Sinus Maksilaris	0.829	*Almost perfect*
P2 – Sinus Maksilaris	0.828	*Almost perfect*
M1 – Sinus Maksilaris	0.862	*Almost perfect*
M2 – Sinus Maksilaris	0.823	*Almost perfect*
Apeks gigi – foramen mentalis	0.828	*Almost perfect*
M3 – Kanalis Mandibularis	0.857	*Almost perfect*

The reliability test showed kappa coefficient values ranging from 0.823 to 0.862, indicating almost perfect interobserver agreement. Therefore, the measurement method was considered reliable and was subsequently used for data collection in this study.

Measurements of the distances between tooth apices and vital structures (maxillary sinus, mandibular canal, and mental foramen) were compared based on gender. The results showed that the average distance from the first premolar (P1) apex to the maxillary sinus was 3.15 ± 3.35 mm in males and 3.96 ± 3.54 mm in females. For the second premolar (P2), the mean apex-to-sinus distance was 0.29 ± 1.88 mm in males and 0.85 ± 2.60 mm in females.

In the first molar, negative root-to-sinus distance values (–0.85 ± 1.86 mm in males and –0.54 ± 1.80 mm in females) indicated that the root apex was located very close to or within the maxillary sinus. Similarly, the second molar roots also showed negative values (–0.73 ± 1.72 mm in males and –0.75 ± 1.02 mm in females), suggesting close proximity or penetration of the roots into the sinus in both genders.

The mean distance between the mandibular premolar apex and the mental foramen was 3.50 ± 1.68 mm in males and 2.68 ± 1.19 mm in females, indicating a greater distance in males. Meanwhile, the mean distance from the mandibular third molar root apex to the mandibular canal was 2.03 ± 2.76 mm in males and 0.67 ± 1.21 mm in females, showing closer proximity in females. These findings are summarized in Table 3.

Table 3. Measurement Results Based on Gender

		N	Mean±Std (mm)
P1 – Maxillary sinus	Male	22	3.15±3.35
	Female	42	3.96±3.54
P2 – Maxillary sinus	Male	22	0.29±1.88
	Female	42	0.85±2.60
M1 – Maxillary sinus	Male	22	-0.85±1.86
	Female	42	-0.54±1.80
M2 – Maxillary sinus	Male	22	-0.73±1.72
	Female	41	-0.75±1.02

Root apex – foramen mentalis	Male	22	3.50±1.68
	Female	42	2.68±1.19
M3 – Mandibular canalis	Male	22	2.03±2.76
	Female	42	0.67±1.21

An independent t-test was performed to determine whether significant differences existed between male and female subjects in terms of apex-to-vital structure distances. The results showed no significant differences in the root-to-sinus distances for the first premolar (P1), second premolar (P2), first molar (M1), and second molar (M2) ($p > 0.05$). However, significant differences were observed in the distances between the tooth apex and both the mental foramen ($p = 0.03$) and the mandibular canal ($p = 0.01$). These findings indicate that males generally have greater distances from the tooth apex to these vital structures compared with females. The detailed results are presented in Table 4.

Table 4. T-Independent Test Results.

		Sig
P1 – Maxillary sinus	Male	0.38
	Female	
P2 – Maxillary sinus	Male	0.37
	Female	
M1 – Maxillary sinus	Male	0.51
	Female	
M2 – Maxillary sinus	Male	0.95
	Female	
Root apex – foramen mentalis	Male	0.03*
	Female	
M3 – Mandibular canalris	Male	0.01*
	Female	

These findings are consistent with those reported by Yoshimine et al., who observed the shortest root distance at the first molar (M1) to the maxillary sinus (1.67 ± 2.36 mm) in a Japanese population. Similarly, Kilic et al. and Kwak et al. identified the first molar as the tooth closest to the sinus in Turkish and Korean populations, with mean distances of 2.74 ± 3.23 mm and 0.25 ± 2.17 mm, respectively. These results suggest that the present findings are comparable to those reported in Japan, Korea, and Turkey but differ from those in China,

where [14] reported the closest relationship between the sinus and the second molar (M2) root (0.85 ± 2.5 mm).

In this study, the greatest distance was observed at the first premolar (P1) in both males and females, with no significant gender-based differences at most measurement sites. This aligns with the observations of [14], [15] who also reported no significant gender differences in apex-to-maxillary sinus measurements ($p > 0.05$). However, significant gender-related differences were found in the apex-to-mental foramen and third molar-to-mandibular canal distances. The mean distance from the tooth apex to the mental foramen was significantly greater in males (3.50 ± 1.68 mm) than in females (2.68 ± 1.19 mm) ($p = 0.03$). Likewise, the third molar–mandibular canal distance differed significantly between genders ($p = 0.01$), emphasizing the importance of considering gender variations when planning surgical or endodontic procedures in these regions.

The present study also found that the mental foramen (MF) was most located below the second premolar. This observation is in line with [16] in the Egyptian population and [17] in the Polish population, both of whom reported significant gender differences in MF position. Similar patterns were also described by [18], [19] who found that males generally had larger mental foramen dimensions compared to females.

[20] suggested that these gender-related differences may be attributed to larger overall body size in males, potentially increasing the risk of iatrogenic injury in females, particularly during surgical or endodontic procedures involving the mental foramen.

With respect to age, variations in the distances between posterior root apices and adjacent anatomical structures were observed but did not reach statistical significance. For the P1–maxillary sinus distance, the highest mean value occurred in the 36–45-year group (4.74 ± 4.75 mm), and the lowest in the 17–24-year group (3.34 ± 3.42 mm) ($p = 0.53$). Similarly, the P2–maxillary sinus distance peaked in the 36–45-year group (1.24 ± 2.75 mm) without significant intergroup differences ($p = 0.68$). The M1–maxillary sinus distance increased slightly from –0.91 ± 2.02 mm (age 17–24) to 0.14 ± 1.63 mm (age 36–45) ($p = 0.26$), and a similar non-significant pattern was observed for M2 ($p = 0.57$).

The apex-to-mental foramen distance showed a marked increase from 2.63 ± 1.25 mm (age 17–24) to 3.76 ± 1.54 mm (age 36–45), approaching statistical significance ($p = 0.05$), suggesting potential clinical relevance. The third molar–mandibular canal distance also increased from 0.80 ± 1.73 mm (age 17–24) to 1.84 ± 2.04 mm (age 36–45), though this difference was not statistically significant ($p = 0.22$). These findings are summarized in Table 5.

Table 5. Distance Between Dental Apex and Vital Structures Based on Age.

		N	Mean±Sd (mm)	Sig
	17-24	39	3.34±3.42	
P1 – Maxillary sinus	25-35	15	3.78±2.82	0.53
	36-45	9	4.74±4.75	
	17-24	39	0.65±2.67	
P2 – Maxillary sinus	25-35	15	0.22±1.03	0.68
	36-45	9	1.24±2.75	
	17-24	39	-0.91±2.02	
M1 – Maxillary sinus	25-35	15	-0.48±1.23	0.26
	36-45	9	0.14±1.63	
	17-24	39	-0.88±1.47	
M2 – Maxillary sinus	25-35	15	-0.57±0.87	0.57
	36-45	9	-0.46±1.06	
	17-24	39	2.63±1.25	
Root apex – foramen mentalis	25-35	15	3.39±1.58	0.05
	36-45	9	3.76±1.54	
M3 – Mandibular canalris	17-24	39	0.80±1.73	0.22

	25-35	15	1.56±2.49
	36-45	9	1.84±2.04

Based on ANOVA testing, no statistically significant age-related differences were observed in apex-to-vital structure measurements ($p > 0.05$), indicating that aging does not substantially alter the anatomical relationships of posterior teeth to adjacent vital structures. However, the apex-to-mental foramen distance presented a marginal p-value of 0.05, suggesting a trend toward increasing separation with age. The mean distance increased from 2.63 mm in the 17–24-year group to 3.76 mm in the 36–45-year group.

These findings are consistent with those of [21], who reported that the position of the mandibular canal and mental foramen may vary with age and dental health status. Morphological adaptations of the mandible resulting from bone remodeling processes during adulthood may contribute to these differences [22].

For other structures, including posterior tooth apices and the maxillary sinus (P1, P2, M1, and M2), no significant age-related variations were found. This observation supports the results of [23], who noted that following full development in late adolescence, the maxillary sinus generally maintains a stable size and position throughout adulthood. Likewise, [24] reported horizontal stability in mandibular canal positioning relative to the lower molars, although minor vertical variations may occur due to individual anatomical characteristics.

In summary, while minor age-related changes may occur—particularly in the mental foramen region—this study indicates that, within the 17–45-year age range, age does not significantly influence the anatomical relationship between posterior teeth and vital structures.

4. Conclusions

No significant differences were found in the distance between the tooth apex and the maxillary sinus based on gender. However, significant differences were observed in the distances between the tooth apex and both the mandibular canal and the mental foramen. Female patients demonstrated shorter apex-to-structure distances to these two anatomical landmarks compared with male patients. Therefore, dental procedures involving these vital structures may require treatment modifications in female patients to minimize the risk of postoperative complications.

Measurements of the distance between the tooth apex and vital structures across different age groups showed no statistically significant differences. This may be attributed to the fact that anatomical growth generally stabilizes in adulthood. Nonetheless, this study revealed marginally significant differences at the mental foramen and near-significant differences at the mandibular canal. These findings suggest the need for additional caution when performing procedures on posterior teeth adjacent to these structures, considering the potential for anatomical variations due to craniofacial remodeling and age-related changes in bone and dental health.

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