RESEARCH ARTICLE

Proximity of the maxillary dentition to the incisive canal and greater palatine foramen among patients with various vertical and sagittal growth patterns

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Abstract

Objective: To determine the proximity of incisive canal and greater palatine foramen to the maxillary dentition in different vertical and sagittal growth patterns.

Method: The cross-sectional study was conducted at the Department of Orthodontics, Bakhtawar Amin Medical and Dental hospital, Multan, from January 15 to June 15, 2024, and comprised cone-beam computed tomography images of adult patients of either gender aged 16-65 years with natural permanent dentition. The subjects were assessed based on both vertical and sagittal lines based on maxillary mandibular angle and Wits appraisal, respectively. The shortest distance from the incisive canal to maxillary incisors, and greater palatine foramen to the nearest molar was determined on axial cross-section. The mean distances were compared between males and females. The mean distances among the vertical (low, normal and high) and sagittal (Class I, II and III) groups were also compared. Data was analysed using SPSS 25.

Results: Of the 112 patients with mean age 34.7±11.5 years, 59(52.7%) were females and 53(47.3%) were males. In females, the distance from greater palatine foramen to the nearest molar and the distance from incisive canal to the root apex of right maxillary incisors was found to be increased compared to males ($p<0.001$). In the vertical group, subjects with normal angle showed the greatest distance from incisive canal to the root apex of right maxillary incisors ($p=0.03$) and from the right greater palatine foramen to the nearest molar ($p<0.001$). The distance from incisive canal to the root apex of left maxillary incisors was found to be greatest in Class I subjects ($p<0.03$).

Conclusion: Females, normal-angle and Class I subjects showed a trend towards increased distance between the palatine structures and maxillary dentition.

Keywords: Cone-beam computed tomography, Tooth apex, Root resorption, Orthodontic tooth movement, Palatine bone, Mini dental implant. (JPMA 76: 509; 2026) **DOI: https://doi.org/10.47391/JPMA.21598**

Introduction

Absolute anchorage has advanced orthodontic therapy, allowing for the achievement of complicated goals without surgery. Temporary anchorage devices (TADs), such as mini-plates and mini-dental implants, offer stability and expanded treatment possibilities.[1-3] Their major disadvantages include increased failure and damage to roots and vital structures. The palatal sites have shown reduced failure rates due to thick cortical bone, and can be used to provide absolute anchorage for a variety of tooth movements.[4,5] Moreover, most patients in orthodontic practice frequently present with a complaint of protruding maxillary anterior teeth needing significant retraction.[6] This may also lead to root resorption possibly due to the proximity of the maxillary incisal roots with the vital structures.[7]

The palate comprises two extra-dental vital structures, the incisive foramen leading to incisive canal (IC) and greater palatine foramen (GPF). They contain the neurovascular bundles. These regions are commonly used to place mini-implants for incisor intrusion, retraction and other orthodontic tooth movements. The proximity of these anatomical structures to the maxillary dentition can cause iatrogenic side-effects, such as sensory impairment and root resorption, following tooth movements.[7,8] Hence a thorough knowledge about the location of these anatomic structures is of utmost importance to avoid any side-effects or placement within the foramina leading to a failure of the mini-implant. Additionally, variations in craniofacial morphology may be influenced by facial types, which may also affect where anatomical structures are located.[8] Therefore, the incorporation of various facial growth patterns into research is of utmost importance.

The anatomical relationship between the maxillary incisors (U1) and the IC have been reported by prior computed tomography (CT) and cone-beam computed tomography (CBCT) studies, but they had inadequate image resolution for precise evaluation of alveolar bone shape and thickness.[7,9,10] Moreover, orthodontic patients present with various craniofacial morphologies that may affect the

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position of IC and GPF with respect to dentition. Although the anatomy of IC is widely understood, the orthodontic literature does not provide a clear description of the IC's approximate placement in relation to the U1 in various vertical and sagittal malocclusion. Prior studies have evaluated the location of the GPF on dry human skulls.[11] A thorough understanding of the anatomical position of the GPF is essential as this region is regularly utilised for the placement of orthodontic implants for distalisation and intrusion of posterior dentition.[7]

The current study was planned to determine the proximity of IC and GPF to the maxillary dentition in different vertical and sagittal growth patterns.

Materials and Methods

The cross-sectional study was conducted at the Department of Orthodontics, Bakhtawar Amin Medical and Dental Hospital, Multan, from January 15 to June 15, 2024. After approval from the institutional ethics review committee, the sample size was calculated on the basis of a study[10] which reported the mean distance from upper central incisor to IC to be 4.36±1.18mm in average facial height, and 3.83±0.90mm in high-angle patients. The alpha value and power were kept as 0.05 and 80%, respectively. CBCTs were evaluated to match the inclusion criteria of adult patients of either gender aged 16-65 years with natural permanent dentition and good-quality scans. The CBCT scans of patients with facial asymmetry, incisor diastema or shift of the maxillary midline ≥2mm, history of orthodontic or prosthetic treatment, missing teeth except the third molars, and with tooth or bone anomalies in the maxillary midline region were excluded. The study was based on the radiological data of CBCT scans, and patients' identity was kept confidential.

The CBCT scans had been obtained on the institutional equipment (Carestream Dental LLC Atlanta, USA, CBCT 9600 machine), with an exposure time of 3.6s, scanning time of 18s and field of view 20x25cm. The minimal layer thickness of these scans was 0.3mm. The subjects were instructed to sit up, keeping the Frankfort plane parallel to the ground and occluding teeth in maximum intercuspation during the scan. Patients' skeletal vertical and sagittal facial patterns were determined using the maxillo-mandibular plane angle (MMA) and Wits appraisal, respectively.[12] In the vertical group, MMA $<21^0$ was considered low, MMA $21\text{-}28^0$ as normal, and MMA $>28^0$ as high (42). Furthermore, the sample was divided into three sagittal groups using both Wits appraisal and A-Nasion-B (ANB) angle. Class I meant Wits -1 to +1mm and ANB 0-4, Class II meant Wits >+1mm and ANB >4, and Class III meant Wits <-1mm and ANB <0.

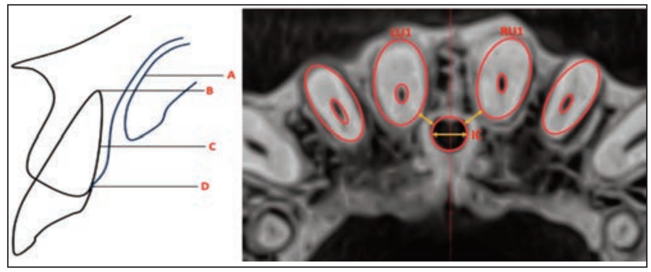

Figure-1: Distance between IC and maxillary incisor at apex, and at the middle root third. A: Incisive canal, B: Root apex of U1, C: Middle of the root of U1, D: Cementoenamel junction (CEJ) of the root of U1, IC: Incisive canal, LU1: Left upper central incisor, RU1: Right upper central incisor.

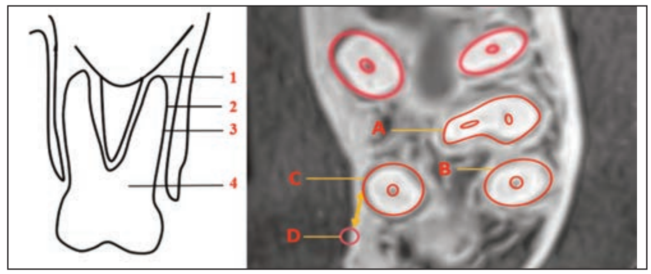

Figure-2: Distance between GPF and 3rd maxillary molar root (middle third) (C). 1: Root apex of the maxillary 2nd molar, 2: Greater palatine foramen, 3: Middle of the root of the maxillary 2nd molar, 4: Cementoenamel junction (CEJ) of the root of the maxillary 2nd molar, A: Mesiobuccal root of maxillary 3rd molar, B: Distobuccal root of maxillary 3rd molar, C: Palatal root of maxillary 3rd molar, D: Greater palatine foramen.

The sagittal section was used to locate the apex and middle of the root of U1. The coronal section was used to locate the middle of the palatal root of the maxillary molars. The axial sections were located on the CBCT scans of each patient, and measurements were taken, including the shortest distance between IC and right U1 (RU1) and left U1 (LU1) (Figure 1). The measurements were taken at the root apex and middle of the root of U1. The distance between the nearest molar (middle of the palatal root) and GPF (right and left) was also determined (Figure 2).

Data was analysed using SPSS 25. Data normality was assessed using the Kolmogorov-Smirnov test, which showed a non-normal distribution of quantitative variables. Thus, non-parametric tests were used for further analyses. The mean distance between IC and U1, and GPF and maxillary molars were compared between males and females using Mann Whitney U test. Kruskal Wallis test was used to compare the mean distance from IC and GPF in vertical and sagittal groups. Dunn's test was used to analyse intergroup differences. P<0.05 was considered statistically significant.

Results

Of the 112 patients with mean age 34.7±11.5 years, 59(52.7%) were females and 53(47.3%) were males. The mean age of the sample was 34.7±11.5 years. In the vertical group, 30(26.8%) subjects had a low MMA, 40(35.7%) had normal, and 42(37.5%) had high MMA. In the sagittal group, 39(34.8%) had Class I, 38(33.9%) had Class II, and 35(31.2%) had Class III.

The females showed an increased distance between the GPF and the nearest molar on both sides compared to the males ($p<0.01$) (Table 1). However, there were no significant differences between males and females for the distance between IC and U1 ($p>0.05$).

Table-1: Gender-based comparison of mean distances between IC and UI, and between GPF and the nearest molar (n=112).

Variables	Males (n=53) (mm±SD)	Female (n=59) (mm±SD)	*p*-value
Root apex of RU1 to IC	3.85±1.62	4.18±1.26	0.324
Root apex of LU1 to IC	3.52±1.52	3.96±1.28	0.131
Middle third of root of RU1 to IC	2.67±1.12	2.99±1.14	0.172
Middle third of root of LU1 to IC	2.61±0.99	2.79±0.93	0.268
Distance between left GPF and nearest molar	3.69±1.51	5.07±1.96	<0.001*
Distance between right GPF and nearest molar	3.63±1.65	5.10±1.83	<0.001*

N*$p<0.05$; IC: Incisive canal, RUI: Right maxillary incisor, LUI: Left maxillary incisor, GPF: Greater palatine foramen.

The distance from IC and root apex of RU1 in vertical subgroups showed significant differences (Table 2). Among the sagittal groups, the distance between IC and root apex of LU1 was significantly increased in skeletal Class I subjects compared to the rest, and all variables showed the least distance in Class III subjects (Table 3).

The distance between the right GPF and the nearest molar was significantly increased in normal-angle group ($p<0.01$).

Discussion

Several studies have evaluated the location of IC and GPF on dry human skulls, two-dimensional (2D) radiographs and CBCT scans.[1-4,7,9,10-18] One benefit of anatomical assessment utilising CBCT scan is the ability to gather additional information on the population under study, including age, gender and any other clinical data that may be accessible. It is a three-dimensional (3D) analysis that enables the observer to evaluate multiple tomographic sections. To the best of our knowledge, the current study is the first on Pakistani subjects taking into consideration various vertical and sagittal growth patterns using CBCT scans.

In the present study, the sagittal distance from the IC to the

Table-2: Comparison of mean distances among vertical facial patterns.

Variables	Vertical Facial Patterns: Low Angle (n=30) Mean±SD	Normal Angle (n=40) Mean±SD	High Angle (n=42) Mean±SD	*p*-value	Low vs Normal Angle *p*-value	Low vs High Angle *p*-value	Normal vs High Angle *p*-value
Mean distances between IC and U1							
Root apex of RU1 to IC	3.61±1.68	4.51 ±1.21	3.85±1.37	0.037*	0.049*	0.894	0.068
Root apex of LU1 to IC	3.64±1.59	3.98±1.25	3.62±1.42	0.482	0.708	1.000	0.532
Middle third of root of RU1 to IC	2.61±1.01	3.20 ±1.22	2.66±1.07	0.080	0.092	0.997	0.105
Middle third of root of LU1 to IC	2.66±0.87	2.96±0.89	2.50±1.05	0.107	0.413	0.873	0.110
Mean distances between GPF and nearest molar							
Left GPF and nearest molar	3.90±1.58	4.84±2.07	4.38 ±1.85	0.080	0.210	0.020*	0.997
Right GPF and nearest molar	3.48 ±1.48	5.32±1.98	4.28±1.75	0.001*	0.010*	<0.001*	1.000

*$p<0.05$, IC: Incisive canal, RUI: Right maxillary incisor, , LUI: Left maxillary incisor, GPF: Greater palatine foramen.

Table-3: Comparison of mean distances among sagittal facial patterns.

Variable	Sagittal Facial Patterns: Class I (n=39) mm±SD	Class II (n=38) mm±SD	Class III (n=35) mm±SD	*p*-value	Class I vs II *p*-value	Class I vs III *p*-value	Class II vs III *p*-value
Mean distances between IC and U1							
Root apex of RU1 to IC	4.25±1.45	3.98±1.33	3.82±1.57	0.781	0.789	0.534	0.948
Root apex of LU1 to IC	4.26±1.24	3.50±1.36	3.46± 1.51	0.032*	0.038*	0.052*	1.000
Middle third of root of RU1 to IC	2.91±1.12	2.88±1.17	2.64±1.13	0.987	0.982	0.506	0.747
Middle third of root of LU1 to IC	2.93±0.95	2.62±1.00	2.54±0.89	0.419	0.419	0.302	0.981
Mean distances between GPF and nearest molar							
Left GPF and nearest molar	4.67±1.91	4.67±2.03	3.86±1.60	0.110	1.000	0.147	0.173
Right GPF and nearest molar	4.71±2.17	4.49±1.68	3.97±1.73	0.342	0.940	0.282	0.483

*$p<0.05$, IC: Incisive canal, RUI: Right maxillary incisor, , LUI: Left maxillary incisor, GPF: Greater palatine foramen.

upper incisors was found to be greater in females compared to males. On the contrary, Al-Rokhami et al.[10] had reported contrasting data. A probable reason for this variation may be the difference in sample population. Khan et al.[19] evaluated buccal bone thickness anterior to nasopalatine canal, and found increased measurements in male subjects. The reason for these opposing findings may be that the variables were differently defined, and the measurements were recorded in the sagittal cross-section on CBCT scans.

Among the vertical malocclusion groups, only the distance between IC and UI root apex showed significant differences. Overall, the subjects with normal angle showed the greatest bone thickness compared to those with low and high angles. In comparison Al-Rokhami et al.[10] and Ishi et al.[20] found that the low-angle facial group showed relatively greater U1-to-IC sagittal distance owing to the decreased IC dimensions in these subjects. On the contrary, Costa et al.[21] reported that the vertical growth pattern did not have any effect. The normal-angle subjects in the current study may be associated with wider palates and reduced IC dimensions, leading to increased sagittal bone thickness in normal-angle subjects. Furthermore, skeletal Class II growth pattern is more common in Pakistani population which may lead to a larger maxillary sagittal dimension and consequently increased bone width between the IC and maxillary incisor roots.[22] Hence, a wider safe zone may be available in normal-angle subjects for the placement of mini-implants. Also, the incisors may be retracted to a greater distance without the risk of root resorption.

In the current study, the sagittal skeletal malocclusion was also taken into consideration to evaluate any variation in bone thickness between IC and UI roots. Only the distance between the IC root apex of RU1 showed significant differences. Overall, skeletal Class III subjects showed a trend towards the least distance between the IC and maxillary dentition. This is in concordance with a study conducted by Ishi et al.[20] Hence, subjects with smaller maxilla (sagittal and transverse) may be associated with reduced distance between the IC and maxillary dentition, leading to extra caution while placing TADs in the anterior palate for skeletal expanders, etc.

The lateral aspect of hard palate comprises thick cortical bone and keratinised mucosa, and is a common site for TAD placement due to improved stability. Usually, the TADs are placed in the posterior part of hard palate for the purpose of intrusion, distalisation and expansion. The GPF comprises greater palatine nerve and vessels, and is located in the same vicinity. Hence, it is vital to determine its exact location to avoid any sensory impairment. In the present study, in around 60% of the subjects, the GPF was mostly located closer to the third molars. The minimum distance was 2.84±1.14mm on the right side. The females showed increased distance between the GPF and the palatal root of the nearest molar compared to males. Low-angle subjects showed the minimum distance, whereas sagittal malocclusion did not influence the bone width.

It is evident that the findings of the current study would be beneficial to clinicians since it is difficult to determine the precise anatomical location of IC and GPF in various surgical procedures in the maxilla.[7] The anatomical localisation of IC and GPF in relation to the dentition is important when planning the placement of mini-implants for the retraction of incisors and intrusion of the anterior/posterior segment, as the location of the IC and GPF can vary in each facial type. Therefore, accurate identification is essential to obtain favourable orthodontic results and guaranteeing patient safety and satisfaction.[7,9] The location of the IC and GPF could be ascertained by using these measurements as a reference value. Moreover, the limit for anterior maxillary retraction as per the envelope of discrepancy has been determined to be 7mm.[23] As per the findings of the current study, the minimum distance between the IC and UI root was 2.70±0.96mm on the left side. Hence, this needs to be taken into consideration when planning anterior retraction to minimise root resorption.

The current study has limitations related to the limited field of view (FOV), and a smaller sample size due to the challenge of locating patients with all the maxillary molars. This resulted in the reduced power pf the study. Furthermore, age-related changes and ethnicity-related differences were not assessed which could be incorporated in future studies to gain impactful insights on the topic. Lastly, future studies should also evaluate variations in IC anatomy and maxillary root angulations.

Conclusion

The females, normal-angle and Class I subjects showed a trend towards increased distance between the palatine structures and maxillary dentition, having an increased margin for placement of mini-implants. Moreover, the minimum distance between the IC and UI root was around one-third of the limits of anterior retraction defined by the envelope of discrepancy. Hence, clinicians should be cautious during retraction of anterior teeth to avoid any fatal consequences.

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Author Contribution:

ZS: Design, data acquisition, analysis, interpretation, drafting, final approval and agreement to be accountable for all aspects of the work.
WJ: Design, data acquisition, analysis, interpretation, final approval and agreement to be accountable for all aspects of the work.
MA: Design, data acquisition, analysis, final approval and agreement to be accountable for all aspects of the work.
AMC: Data analysis, final approval and agreement to be accountable for all aspects of the work.