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Relationship between maxillary central incisors and incisive canal: a cone-beam computed tomography study

A.I. Linjawi, H.Y.A. Marghalani

Orthodontic Department, Faculty of Dentistry King Abdulaziz University, Jeddah, Saudi Arabia

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Background: *This study aimed to assess the relationship between the maxillary incisors and the incisive canal (IC) using cone-beam computed tomography (CBCT).*
Materials and methods: *Archived CBCT scan from 120 subjects (60 males and 60 females, mean age 34.2 ± 13.1 years) were analysed in this cross-sectional study. The following variables were measured: incisor/palatal plane (PP), IC/PP angles, palatal alveolar bone width (PABW) at apex, IC width, inter-root width at apex and IC level to incisor apex. The relationship between the incisors and IC with respect to sex and age was calculated using one-way analysis of variance, independent samples t-test, and regression analysis.*
Results: *The confidence level was set at 95%. Results showed that half of the study population exhibited IC palatal opening at the level of the maxillary incisor apices. Significant associations were observed between IC/PP and incisor/PP angles and between IC width and PABW at the apical level (p < 0.05), and between age and IC width in the sagittal and axial perspectives and age and IC level relative to the incisor apices. A significant association was observed between sex and IC/PP angle, IC width in the sagittal perspective, and PABW at the apical level. The association was found between IC and maxillary incisors angulations but not between IC width and inter-root distance.*
Conclusions: *Age showed varied associations while sex was significantly associated with most variables assessed.* (Folia Morphol 2022; 81, 2: 458–463)

Key words: alveolar bone thickness, cone-beam computed tomography, incisive canal, incisors' characteristics, inter-root distance

INTRODUCTION

Orthodontics focuses on the improvement of facial aesthetics via retraction of the maxillary anterior teeth to provide maximum anchorage [19, 22]. However, complications such as fenestrations, loss of alveolar bone, root resorption, or dehiscence can occur when the teeth are moved out of the cortical bone, which leads us to scrutinize the confines of orthodontic treatment [1, 12, 18, 21, 24].

Recently, research focused on craniofacial anatomy has demonstrated the close proximity between the incisive canal (IC) and the maxillary central incisors, which is closer than that of the cortical plate in the palate [2]. The IC is located behind the maxillary central incisor roots at the middle level of the maxillary palatine process. Therefore, it is considered the most significant anatomical structure in the premaxilla [7]. It links the nasal and the oral cavities by connecting

Address for correspondence: A.I. Linjawi, BDS, MSc, PhD, Ass. Prof., Orthodontic Department, Faculty of Dentistry, King Abdulaziz University, P.O. Box 80209, Jeddah 21589, Saudi Arabia, tel: +966504155573, e-mail: ailinjawi@kau.edu.sa

the incisive foramen and the nasal foramen. It is surrounded by dense cortical bone and the nasopalatine vessels pass through it [7]. These vessels include the incisive nerve and the sphenopalatine artery. The latter is the end branch of the nasopalatine artery [11, 16].

Disparities in incisor angulations, alveolar bone thickness and IC morphology are challenging variables that can affect the movement of the maxillary incisors [12, 13, 20, 26, 28]. The proximity of the maxillary central incisor roots to the walls of the IC cortex might lead to incisor root resorption during maximum orthodontic retraction of incisors [5, 17]. The research conducted by Pan and Chen [19] revealed the risk posed by IC contact with the maxillary central incisors during incisors retraction, leading to external resorption of the root apex [19]. Similarly, Chatriyanuyoke et al. [4] suggested that more caution should be exercised during immediate placement of implants at the mid-root level of the maxillary central incisors in younger and female patients to prevent IC penetration. To prevent this complication, analysis of IC dimensions and morphology should be accurately implemented before any dental procedures within the vicinity of this anatomical structure [5, 17].

Accurate radiographic imaging is essential to obtain the best diagnosis and ideal management as well as to monitor the development and the results of treatment [10, 23]. Cone-beam computed tomography (CBCT) has been considered more accurate in assessing incisor inclinations and the morphology of the alveolar bone [6, 15, 25, 27, 29]. It can be utilised as an adjunct in case analysis and treatment planning as it minimises difficulties in dental procedures [3, 13, 14]. However, the widely used diagnostic radiographs by most orthodontists are cephalometric and panoramic radiographs. Incisors' angulation and inter-root distances can be easily measured using those conventional radiographs. Thus, finding some predictive measures and correlations between the maxillary incisors' roots and the IC that can be assessed by both conventional and three-dimensional radiographs might help the orthodontists to predict the risk of maxillary incisors' root resorption during orthodontic tooth movement using the available radiographs.

The aim of the present study is to assess the association between the IC and the maxillary incisors using different linear and angular CBCT measurements.

MATERIALS AND METHODS

Study design

This cross-sectional study utilized archived CBCT records of adult Saudi patients with middle-eastern ethnic background who were treated at Orthodontic Department, Faculty of Dentistry King Abdulaziz University, Jeddah, Saudi Arabia. This research was approved by the institutional ethical committee (ethical approval no. 100-06-19), and the study procedures were performed in accordance with the principles of the Declaration of Helsinki, 1975 (as revised in 2008).

Sample characteristics

The inclusion criteria were as follows: 1) CBCT images showing the maxilla clearly, 2) no history of orthodontic treatment, 3) presence of the maxillary incisors, 4) no history of dental treatment related to the maxillary incisors, 5) no history of trauma to the incisors, and 6) no congenital or developmental abnormalities such as cleft palate and cleft lip. The sample groups were organized according to age and sex. Patients were divided into four age groups: ≤ 20 years, 21–40 years, 41–60 years, and > 60 years.

CBCT images

The following specifications were used for the CBCT images: field of view: 81 × 74 mm, voxel size: 0.146 mm, slice thickness: 0.147 mm, normal mode: 90 kV, 4 mA, 4.10 mGy, and 16.8 s. Image acquisition was performed by positioning the head such that the Frankfort horizontal plane was parallel to the floor. Images were stored in the digital format as DICOM files. Both sagittal and coronal perspectives were obtained and assessed using OnDemand 3D Imaging software (Seoul, Korea).

Measurements

The following linear and angular measurements on sagittal reconstruction were evaluated in relation to the maxillary central incisors (Fig. 1):

- incisor/palatal plane (PP) angle: the angle between the long axis of each central incisor and the palatal plane;
- palatal alveolar bone width (PABW) at the apical level: the palatal bone width at the level of the central incisor apices.

For IC, the following linear and angular dimensions were determined using sagittal reconstruction (Fig. 1):

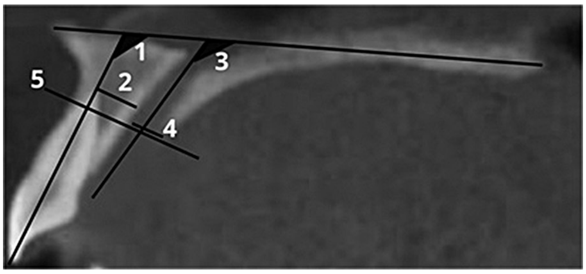

Figure 1. Linear and angular measurements on the sagittal reconstruction; 1 — incisor/palatal plane angle: the angle between the long axis of each central incisor and the palatal plane; 2 — palatal alveolar bone width at apex level: the palatal bone width at apical level of central incisor; 3 — the IC/PP angle: the angle between the long axis of the IC and the palatal plane; 4 — IC width at palatal opening: width of the incisive canal at palatal opening; 5 — the IC palatal opening level relative to the apex of the central incisors: the level was characterised into three types: below apex, at apex and above apex.

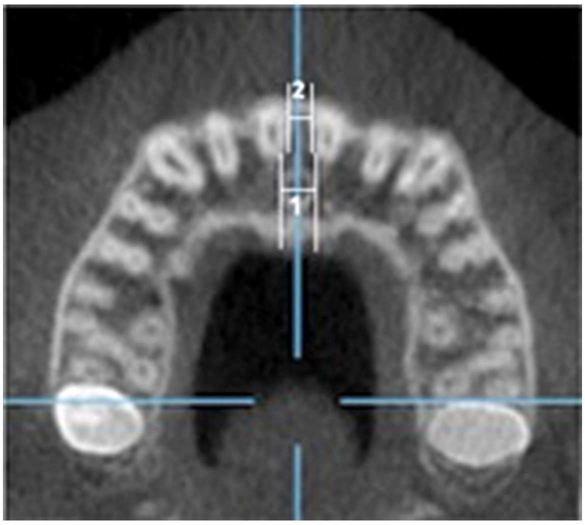

Figure 2. Linear measurements on the axial reconstruction; 1 — incisive canal width at incisor's apical level; 2 — inter-root distance at apex level of incisors: the distance between the two central incisor roots at the apical level.

- — IC/PP angle: the angle between the long axis of the IC and the palatal plane;
- — level of IC palatal opening relative to the apices of the central incisors; the level was classified into three types: below the apex, at the apex, and above the apex;
- — IC width at palatal opening.

On axial reconstruction, the following linear dimensions were assessed (Fig. 2):

- — IC width at the level of incisor apices;
- — inter-root distance at the level of incisor apices: the distance between the two central incisor roots at the apical level.

Measurement error

A single examiner performed all measurements and repeated the measurements after a 2-week interval. The independent t-test showed no substantial deviation between the two sets of measurements ($p < 0.05$). Similarly, an intraclass correlation coefficient of 0.78 indicated good reliability.

Statistical analysis

The evaluated variables are presented as mean values with standard deviations, numbers, and percentages. Comparative data for variables involving the maxillary incisors and the IC were compared using independent samples t-test. Bonferroni correction for multiple comparisons and one-way analysis of variance were used for data related to sex and age, respectively. Regression analysis was used to examine the correlation between the variables. All statistical analyses were performed using IBM SPSS Statistics 22.0 (IBM Corp., Armonk, NY, USA). The confidence level was 95% for all analyses.

RESULTS

Archived CBCT data from 120 subjects (60 males and 60 females, mean age 34.2 ± 13.1 years) were analysed in this study. The mean IC/PP angle was 111.17 ± 8.06°. The mean IC width was 3.82 mm in both sagittal and axial perspectives. The mean incisor/PP angle was 116.88 ± 9.50°, which was higher than the IC/PP angle. The mean PABW and inter-root distance at the apical level were 4.28 mm and 3.66 mm, respectively (Table 1).

Half of the study population exhibited an IC palatal opening at the level of the maxillary incisor apices. In 43.3% of the subjects, the IC palatal opening was below the level of the maxillary incisor apices, and in 6.7% of the participants, it was above the level of the maxillary incisor apices (Table 2).

A significant positive association was observed between IC/PP and incisor/PP angles ($p < 0.01$). Similarly, a significant positive association was observed between IC width in the sagittal perspective and PABW at the apical level ($p < 0.01$). By contrast, there was no significant association between IC width in the axial perspective and the maxillary incisor inter-root distance at the apical level ($p > 0.05$) (Table 3).

Table 1. Mean and standard deviations for the incisive canal (IC) and the maxillary central incisors measurements

	Mean	SD
IC measurements		
IC/PP [°]	111.17	8.06
IC width in sagittal view [mm]	3.82	1.07
IC width in axial view [mm]	3.82	0.91
Maxillary incisors measurements		
Incisor/PP [°]	116.88	9.50
PABW at apex level [mm]	4.28	1.69
Inter-root distance at apex [mm]	3.66	1.53

PP — palatal plane; PABW — palatal alveolar bone width; SD — standard deviation

Table 2. Number and percentages of incisive canal (IC) level to maxillary incisors apex level

IC level to incisors' apex	N (%)
Below apex	52 (43.3%)
At apex	60 (50.0%)
Above apex	8 (6.7%)
Total	120 (100%)

No significant association was observed between age and all measurements used to assess the maxillary incisors ($p > 0.05$) (Table 4). However, a significant negative association was observed between sex and

Table 3. Association between incisive canal (IC) and the maxillary central incisors

	R-squared	CC	P-value
IC/PP Incisor/PP	0.084	0.289	0.001*
IC width at sagittal view PABW at apex level	0.083	0.288	0.001*
IC width at axial view Inter-root distance at apex	0.028	0.166	0.07

Significance level: *$p < 0.01$, CC — correlation coefficient; PP — palatal plane, PABW — palatal alveolar bone width

PABW at the apical level ($p < 0.001$), and males exhibited a stronger association than females (Table 4).

By contrast, age showed a significant positive association with IC width in the sagittal ($p < 0.05$) and axial perspectives ($p < 0.01$) and a negative association with IC level relative to the incisor apices ($p < 0.05$). Sex was significantly associated with the IC/PP angle and IC width in the sagittal perspective ($p < 0.01$), and males exhibited a stronger association than females (Table 5).

DISCUSSION

The present study assessed the relationship between the maxillary incisors and the IC using CBCT. The results revealed a substantial association between the IC/PP and the incisors/PP angles and between IC width in the sagittal perspective and PABW at the

Table 4. Association between the assessed variables for the incisors according to gender and age

	P-value — according to gender			P-value — according to age		
	R-squared	CC	P-value	R-squared	CC	P-value
Incisor/PP	0.010	–0.101	0.136	0.022	0.147	0.054
PABW at apex level	0.115	–0.339	0.000*	0.000	–0.008	0.465
Inter-root distance at apex	0.000	–0.018	0.422	0.015	–0.121	0.094

Significance level: *$p < 0.001$, CC — correlation coefficient; PP — palatal plane, PABW — palatal alveolar bone width

Table 5. Association between the assessed variables for the incisive canal (IC) according to gender and age

	P-value — according to gender			P-value — according to age		
	R-squared	CC	P-value	R-squared	CC	P-value
IC/PP	0.076	–0.276	0.001**	0.001	–0.037	0.343
IC width sagittal view	0.087	–0.295	0.001**	0.027	0.165	0.036*
IC width axial view	0.001	–0.034	0.357	0.086	0.293	0.001**
IC level to incisors' apex	0.003	0.055	0.275	0.023	–0.153	0.047

Significance level: *$p < 0.05$, **$p < 0.01$, CC — correlation coefficient; PP — palatal plane, PABW — palatal alveolar bone width apical level. Age was an influencing factor for the IC dimensions including IC width in the sagittal and axial perspectives and IC level relative to the incisor apices. By contrast, sex was an influencing factor for changes in the IC/PP angle, IC width in the sagittal perspective, and PABW at the apical level.

The morphologic aspects of the maxillary central incisors and their proximity with the IC have been evaluated using CBCT in many studies [4, 8]. Chatriyanuyoke et al. [4] examined the proximity of the IC to the roots of the maxillary central incisors (MCIR) in 120 subjects. They observed that the mean IC-to-MCIR distances were greater at the apex than at the mid-root level and greater in male subjects than in female subjects. They also observed that the IC length was significantly affected by age. Thus, dental procedures at the maxillary central incisor mid-root region require more precautionary measures, especially in younger and female patients, to avoid IC penetration [4].

By contrast, Gull et al. [8] found a significant association between inter-root distance and palatal IC opening. However, the present study did not show any association between the inter-root distance at the apex and IC width, age, or sex. Such variability in the results might indicate that it is important to assess the maxillary incisor roots and their relationship with the surrounding structures using three-dimensional evaluation to avoid probable complications in each case wherein retraction of incisors is considered.

Panda et al. [20] used CBCT to determine the influence of different sociodemographic characteristics such as age, ethnicity, edentulism, and sex on the IC dimensions and anterior maxillary bone width among 300 Indian patients. They reported that age had a significant influence on the mean frontal maxillary bone thickness. Subjects aged 16 to 25 years had greater bone width than those aged above 45 years [20]. By contrast, the present study did not show any association between age and bone thickness. Panda et al. [20] also reported that sex had a pivotal influence on the diameter of the IC foramen. Male subjects exhibited greater foramen diameter than female subjects. Similar findings were observed in the present study.

In a previous study, the association between the frontal IC ridge conformation and incisor implant placement was determined for both dentulous and partially edentulous individuals. Edentulous subjects exhibited lower bone thickness at the level of the IC compared to dentulous subjects [9]. This indicates that the probability of IC damage in elderly patients is greater during implant placement in patients with missing incisors. Although this variable was not assessed in the present study, IC width and length relative to the roots of the maxillary incisors seem to change with age, as confirmed in the present study. Thus, a more cautious and in-depth assessment is important in elderly patients before dental procedures.

CONCLUSIONS

A significant positive association was observed between IC/PP and incisor/PP angles.

A significant positive association was observed between IC width and PABW at the apical level.

No significant association between IC width and the maxillary incisor inter-root distance at the apical level.

No significant association was observed between age and all measurements used to assess the maxillary incisors. By contrast, age showed a significant positive association with IC width and axial perspectives, and a negative association with IC level relative to the incisor apices.

Sex was significantly associated with PABW at the apical level, the IC/PP angle and the IC width.

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Conflict of interest: None declared

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