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Evaluation of Morphologic Features and Proximity of Incisive Canal to the Maxillary Central Incisors Using Cone Beam Computed Tomography

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Abstract
Background: *Spatial position of the maxillary incisor is a critical factor in both facial esthetics and maxillofacial functions. Therefore determination of the three-dimensional (3D) position and inclination of the maxillary incisors is a key issue in orthodontic diagnosis and treatment planning. The objective of this study was to evaluate the morphologic features and the relationship between roots of maxillary incisors and the incisive canal using cone beam computed tomography (CBCT).*
Methodology: *CBCT scans of 32 subjects with skeletal and dental Class I normal occlusion were taken using NewTom GiANO cone beam computed tomography machine. Incisive canal and its relationship with maxillary central incisors were evaluated using CBCT scans. Linear measurements were performed on the axial CBCT scans corresponding to three vertical levels, the palatal opening of the incisive canal (L1), midlevel between the opening level and the root apex of the maxillary central incisors (L2), and the root apex of the maxillary central incisors (L3).*
Results: *Interroot distance significantly increased from 3mm at L1 to 7mm at L3. The anteroposterior distance between the maxillary incisor roots and the incisive canal was approximately 5-6 mm at levels L1 and L2. The average incisive canal width was 3-4 mm and it decreased from L1 to L3.*
Conclusion: *The anteroposterior distance between the maxillary central incisor roots and the incisive canal was approximately 5-6 mm. When maximum retraction of the incisors is planned, three-dimensional evaluation of the dimension and location of the incisive canal and its relationship with maxillary incisor roots would be advantageous in preventing potential complications.*
Keywords: *Canal width, Incisive canal, incisor retraction, maxillary central incisor, proximity*

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I. Introduction

Orthodontic patients not only require improvement of dental and facial esthetics, but also good physiological functions like pronunciation and mastication for which maxillary anterior teeth play an important role. Spatial position of the maxillary incisor is a critical factor in both facial esthetics and maxillofacial functions. Therefore determination of three-dimensional (3D) position and inclination of the maxillary incisors is a key issue in orthodontic diagnosis and treatment planning, and various treatment modalities are employed to achieve an ideal incisor position [1,2,3]. In patients with severe protrusion of anterior teeth, maximum retraction of the anterior teeth after premolar extraction is required for esthetic improvement. In general, the ideal position of the maxillary incisor is determined based on various soft and hard tissue criteria, and orthodontic tooth movement within the biologic limitations is desirable for a successful treatment outcome with long-term stability [4]. According to famous concept of “envelope of discrepancy” by Ackerman and Proffit, which describes the limitations of the range of orthodontic movement of the maxillary incisors, the amount of changes possible for the maxillary incisors with orthodontic treatment alone are approximately 7, 2, 4, and 2 mm for retraction, protraction, extrusion, and intrusion, respectively [5,6]. The range of tooth movement during retraction of the maxillary incisors exceeds the range of movement possible in other directions and/or for other teeth. The hard tissue limitations for retraction in the maxilla are the lingual cortical plate and the incisive canal cortical plates [7, 8]. The incisive canal is an anatomic structure that runs posterior and more close to the roots of the central incisors in the median plane of the palatine process of the maxilla, surrounded by thick cortical bone [9,10]. It connects the floor of the nasal cavity with the palate and opens into the oral cavity as incisive foramen. It runs parallel to the maxillary central incisors and transmits nasopalatine vessels and nerves, branches of the maxillary division of the trigeminal nerve, and the maxillary artery [11]. Because of proximity of incisive canal to the maxillary incisors, the surgical invasion and its complications of the incisive canal during dental procedures in maxillary incisor region can cause nonosseointegration of dental implants or sensory dysfunction [12,13]. The precise location of incisive canal in relation to the maxillary incisors is not well documented in the orthodontic literature because of the difficulties in detecting incisive canal morphology using conventional two-dimensional radiographs. It has been seen that contact with hard tissue structures, such as the labial, palatal, or incisive canal cortical plates, is a risk factor for apical root resorption in the maxillary incisors. As such the root resorption of maxillary central incisor roots after maximum retraction is one of the iatrogenic complications of orthodontic treatment [14]. The objective of this study was to evaluate the morphologic features and the relationship between roots of maxillary incisors and the incisive canal using cone beam computed tomography (CBCT).

II. Materials And Methods

2.1 Subjects

The study was carried out on the patients visiting the out-patient section of the Department of Orthodontics and Dentofacial Orthopaedics, Government Dental College & Hospital, Srinagar. CBCT scans were taken for those who required CBCT for diagnosis and treatment planning. The inclusion criteria include patients having lateral cephalogram, normal anteroposterior skeletal relationship (ANB of 0°- 4°), normal overjet and overbite with Class I molar relationship. The exclusion criteria were history of orthodontic treatment, missing or supernumerary maxillary incisors, prosthesis in relation to maxillary incisors, history of trauma to maxillary incisors, and congenital anomalies like cleft lip and palate. Based on the inclusion and exclusion criteria, 32 subjects (male, 13; female, 19; mean age, 22.3 ± 4.5 years) were selected. The mean ANB angle was 3.3° ± 2.8° (range −5.6° – 7.8°).

2.2 Methods

The data was obtained using NewTom GiANO NNT Scanner with the patient in upright position and head positioned along the Frankfort horizontal plane, running parallel to the floor. All the scans were taken using the same machine by the same operator. The operating parameters were set at 3mA and 90kV, dose of 80-100 µSv and the scan time of 9 seconds. All CBCT images were taken using a limited dentoalveolar field of view (FOV: 8cm×8cm and 8cm ×11cm). It was determined that the sagittal plane was perpendicular to the axial plane and parallel to the plane passing through anterior nasal spine and posterior nasal spine.

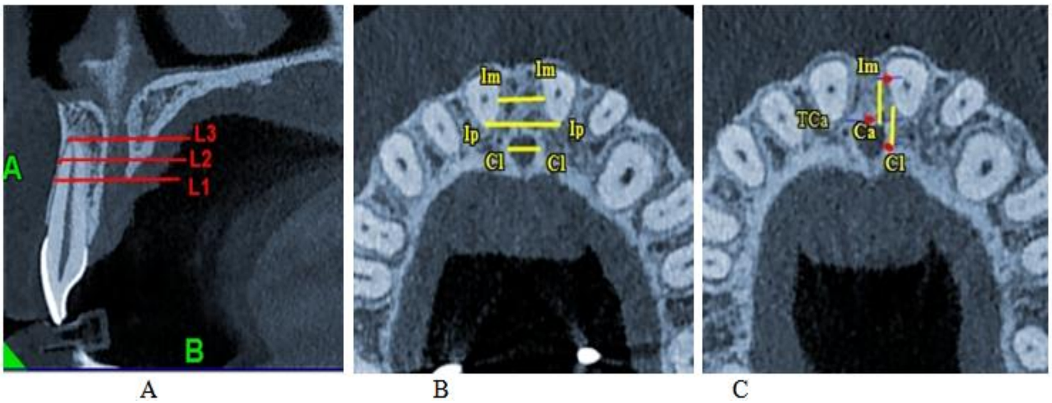

Figure 1. Landmarks and linear measurements. **(A)** Three vertical levels of the incisive canal: palatal opening level (L1), midlevel (L2), and root apex level (L3). **(B)** Landmarks for transverse measurements: Im indicates the most medial point of the maxillary central incisor roots; Ip, the most posterior point of the maxillary central incisor roots; Cl, the most lateral point of the incisive canal; Im-Im, interroot distance; Ip-Ip, posterior interroot distance; Cl-Cl, canal width. **(C)** Landmarks for anteroposterior measurements: Ca indicates the most anterior point of the incisive canal; TCa, the tangent line through Ca; Im-TCa, the distance from Im to TCa; Cl-Root, the distance from Cl to the posterior border of the maxillary central incisor root.

Linear measurements were performed on the axial CBCT scans corresponding to three vertical levels that were determined to exist in the sagittal plane: (1) the palatal opening of the incisive canal (opening level, L1), (2) midlevel between the opening level and the root apex of the maxillary central incisors (midlevel, L2), and (3) the root apex of the maxillary central incisors (root apex level, L3) (Figure 1A). Landmarks and measurements were defined as follows: Im, the most medial point of the maxillary central incisor roots; Ip, the most posterior point of the maxillary central incisor roots; Cl, the most lateral point of the incisive canal; Im-Im, the interroot distance; Ip-Ip, posterior interroot distance; Cl-Cl, canal width (Figure 1B); Ca, the most anterior point of the incisive canal; TCa, the tangent line through Ca; Im-TCa, the distance from Im to TCa; Cl-Root, the distance from Cl to the posterior border of the maxillary central incisor root (Figure 1C). With regard to anteroposterior distances, the smaller value from the bilateral measurements was adopted as a representative value.

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III. Results

3.1 Statistical Analysis

The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Continuous variables were summarized in the form of mean and standard deviations and categorical variables were summarized as percentages. All measurements were repeated after 1 month interval. Dahlberg formula was used to calculate method errors:

Se = $\sqrt{(\sum d^2 \; /2n)}$, where d = the difference between two measurements and n = the number of measurement pairs. The method errors obtained ranged from 0.24 to 0.56 mm. Because the two-sample t-test showed no significant differences between men and women for any of the measurements, measurements were considered as single group. A P-value of less than 0.05 was considered statistically significant.

Interroot distance (Im-Im) was 2.9 ± 0.74, 3.7 ± 0.68, and 7.3 ± 0.64 mm at levels L1, L2, and L3, respectively. Interroot distance significantly increased from L1 to L3 ($P < 0.05$). Posterior interroot distance (Ip-Ip) was 7.9 ± 0.80, 7.6 ± 0.84, and 7.3 ± 0.64 mm at levels L1, L2, and L3, respectively. At L3, Ip and Im represented the same point, and Ip-Ip was equivalent to Im-Im. In contrast to Im-Im, Ip-Ip at L3 was significantly smaller than at L1 ($P < 0.05$) (Table 1). The incisive canal width (Cl-Cl) was 3.9 ± 0.77, 3.6 ± 0.86, and 3.5 ± 0.62 mm at levels L1, L2, and L3, respectively. The incisive canal width at L3 was significantly smaller than at L1 ($P < 0.05$). Im-TCa was 5.4 ± 1.06, 5.2 ± 1.04, and 5.0 ± 1.16 mm at L1, L2, and L3, respectively. The measurements of Cl-Root were 5.5 ± 1.28 and 5.6 ± 1.16 mm at L1 and L2. Cl-Root was not measurable at L3 because the root apex was farther away from the median plane than was the most lateral border of the incisive canal in all subjects. Im-TCa, and Cl-Root measurements did not show significant differences according to the vertical levels (Table 2).

Table 1. Interroot Distance of the Maxillary Central Incisors and Incisive Canal Width at Three Vertical Levels*

Linear Measurements	**Level**		
	Opening Level (L1)	**Midlevel (L2)**	**Root Apex Level (L3)**
	Mean ± SD	Mean ± SD	Mean ± SD
Im-Im (mm)	2.9 ± 0.74	3.7 ± 0.68	7.3 ± 0.64
Ip-Ip (mm)	7.9 ± 0.80	7.6 ± 0.84	7.3 ± 0.64
Cl-Cl (mm)	3.9 ± 0.77	3.6 ± 0.86	3.5 ± 0.62

*Im, the most medial point of the maxillary central incisor roots; Ip, the most posterior point of the maxillary central incisor roots; Im-Im (medial interroot distance), the transverse distance between the bilateral Ims; Ip-Ip (posterior interroot distance), the transverse distance between the bilateral Ips; Cl-Cl (canal width), the transverse distance between the most lateral point of the incisive canal; SD indicates standard deviation

Table 2. Measurement from Anterior Border of the Incisive Canal to the Maxillary Central Incisor Roots at Three Vertical Levels*

Linear Measurements	**Level**		
	Opening Level (L1)	**Midlevel (L2)**	**Root Apex Level (L3)**
	Mean ± SD	Mean ± SD	Mean ± SD
Im-TCa (mm)	5.4 ± 1.06	5.2 ± 1.04	5.0 ± 1.16
Cl-Root (mm)	5.5 ± 1.28	5.6 ± 1.16	NA

* Im, the most medial point of the maxillary central incisor roots; TCa, the tangent line through the most anterior point of the incisive canal; Cl, the most lateral point of the incisive canal; Im-TCa, the anteroposterior distance from Im to TCa; Cl-Root, the anteroposterior distance from Cl to the posterior border of the maxillary central incisor root that meets the tangent line through Cl; SD, standard deviation; N/A, not applicable.

IV. Discussion

According to the concept of "envelope of discrepancy" by Ackerman and Proffit, the clinical guidelines recommend that the maximum amounts of maxillary incisor retraction and intrusion by orthodontics alone are 7 mm and 2 mm, respectively [5]. The development of absolute anchorage with implants has broadened the limits of orthodontic tooth movement [6]. Our study showed that the biological anteroposterior distances between the maxillary central incisor roots and the incisive canal were approximately between 5mm and 6 mm, slightly less than the conventional guidelines for retraction. This 5-6mm distance does not necessarily imply the "safety zone" for retraction because individuals with relatively large interroot distances are not at risk of canal invasion or contact even following maximum retraction. However, a large diversity in anatomy, morphology and size of the incisive canal and incisive foramen in different people are frequently reported with three-dimensional evaluation. The incisive canal, in many circumstances, is deviated toward the right central incisor [10,11,15,16]. The average width of the incisive canal in the axial plane at the level of the apical third of the root is reportedly about 3 to 5 mm, with a large variation ranging from 1.1 to 6.7 mm [10,11]. Our findings were consistent with the findings of previous studies. Since the average interroot distance between the maxillary central incisors at the level of apical third of root is about 3 to 7 mm, root touching or approximation with the incisive canal, especially in the mesiopalatal surface, can be speculated in certain cases after maximum amounts of distal root movement [17,18]. Because of the proximity of maxillary incisors to incisive canal, the possibility of sensory dysfunction in the anterior region and failure of osseointegration has been reported in cases of contact of the incisive canal through surgical interventions such as dental implant placement [19,20]. Recently Chung et al. reported that proximity of maxillary incisal roots to the incisive canal might influence the degree of root resorption after large incisal retraction [4]. Therefore, when planning orthodontic treatment, it is critical to confirm the exact location of maxillary incisors and the incisive canal and determine the morphology of the alveolar bone. It is well documented that remodelling of the surrounding bone is associated with tooth movement. Although remodelling of the incisive canal following orthodontic tooth movement has not been reported much in the literature [4], relative changes in the position of the incisive canal because of changes in the surrounding alveolar bone following tooth loss have been noted in the edentulous dentition [21]. Therefore, to determine the remodelling potential of the incisive canal wall following orthodontic tooth movement, further evaluations are necessary.

V. Conclusion

1. The anteroposterior distance between the maxillary central incisor roots and the incisive canal was approximately 5-6 mm
2. When maximum retraction of the incisors is planned, three-dimensional evaluation of the dimension and location of the incisive canal and its relationship with maxillary incisor roots would be advantageous in preventing potential complications.

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