

Morphologic evaluation of the incisive canal and its proximity to the maxillary central incisors using computed tomography images

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ABSTRACT

Objective: To evaluate the morphologic features and the relative position of the incisive canal with regard to the maxillary incisor roots using computed tomography (CT).

Materials and Methods: Morphologic evaluation of the incisive canal and its proximity to the maxillary central incisors were measured using CT images of 38 adults with skeletal and dental class I normal occlusion. Linear measurements were performed on the axial cross-sectional images 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: The percentage of subjects with an incisive canal width greater than the interroot distance of the central incisors was 86.8% and 63.2% at levels L1 and L2, respectively. The anteroposterior distance between the maxillary incisor roots and the border of the incisive canal was approximately 5–6 mm at levels L1 and L2.

Conclusion: The anteroposterior distance between the maxillary central incisor roots and the incisive canal was approximately 5–6 mm. More than 60% of the subjects had an incisive canal width greater than the interroot distance. Evaluation of the proximity of the incisive canal to the maxillary incisors, along with its dimensional characteristics, may be helpful when a considerable amount of maxillary retraction is planned. (*Angle Orthod.* 2016;86:571–576.)

KEY WORDS: Incisive canal; Tooth movement; Envelope of discrepancy; Maximum retraction; Complication

INTRODUCTION

The maxillary anterior teeth are important not only in achieving pleasing dental and facial esthetics but also

in physiological functions including pronunciation and mastication.^{1–5} Therefore, determination of the three-dimensional (3D) position of the maxillary incisors is an integral part of orthodontic diagnosis and treatment planning, and various biomechanical treatment modalities are employed to achieve the ideal incisor position.

The extent of orthodontic tooth movement is constrained by the periodontal attachment apparatus; adjacent anatomical structures, such as the alveolar bone, tongue, and lips; and the biomechanical limits of anchorage during orthodontic mechanotherapy.^{6–10} Ackerman and Proffit introduced the concept of the “envelope of discrepancy,” which graphically shows the extent of changes possible with orthodontic tooth movement alone, with orthopedic or functional appliance therapy for growth modification, and with orthognathic surgery in combination with orthodontic treatment.^{7,11} Accordingly, it is traditionally thought that 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. Interestingly, the range of tooth movement during retraction of the

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maxillary incisors far exceeds the range of movement possible in other directions and/or for other teeth.

The anatomical limit of maxillary incisor retraction is reportedly the palatal cortical plate.¹²⁻¹⁶ However, another anatomical structure, the incisive canal, runs more closely to the maxillary incisor roots between the central incisor roots in the median plane than does the palatal cortical plate. The incisive canal connects the floor of the nasal cavity with the palate and opens into the oral cavity as the incisive foramen posterior to the maxillary central incisors. It runs parallel to the maxillary central incisors and transmits the nasopalatine vessels and nerves, branches of the maxillary artery, and the trigeminal nerve and is surrounded by a thick layer of cortical bone.¹⁷⁻²² Because of its proximity to the maxillary incisors, the possibility of surgical invasion of the incisive canal during dental procedures has been reported, and this can result in nonosseointegration of dental implants or sensory dysfunction.^{23,24}

Although the overall anatomy of the incisive canal is well defined, its precise location in relation to the maxillary incisors is not well documented in the orthodontic literature. This may be because of the difficulties in detecting incisive canal morphology using conventional orthodontic radiographs. However, with recent advancements in 3D imaging, the approximation of the maxillary incisor roots to the incisive canal can be frequently detected after anterior retraction following orthodontic treatment (Figure 1). Interestingly, the contact of maxillary central incisor root with the incisive canal after maximum retraction was associated with apparent root resorption raising potent complications.²⁵

Therefore, the objective of this study was to evaluate the morphologic features and the relative position of the incisive canal with regard to the maxillary incisor roots using computed tomography (CT).

MATERIALS AND METHODS

Materials

The materials used for the study were retrieved from a preexisting archive of cross-sectional evaluations of adults (aged > 18) with skeletal and dental class I normal occlusion from the Institute of Craniofacial Deformity, Yonsei University (Seoul, Republic of Korea)^{26,27} with the approval of the institutional review board. The retrospectively retrieved materials were selected based on the following inclusion criteria: (1) the presence of clinical, lateral cephalogram, and CT images; (2) normal anteroposterior skeletal relationship (ANB of 0° to 4° and Wits appraisal of -4.0 mm to 0 mm); (3) normal overjet and overbite with class I molar and canine relationship; (4) no history of

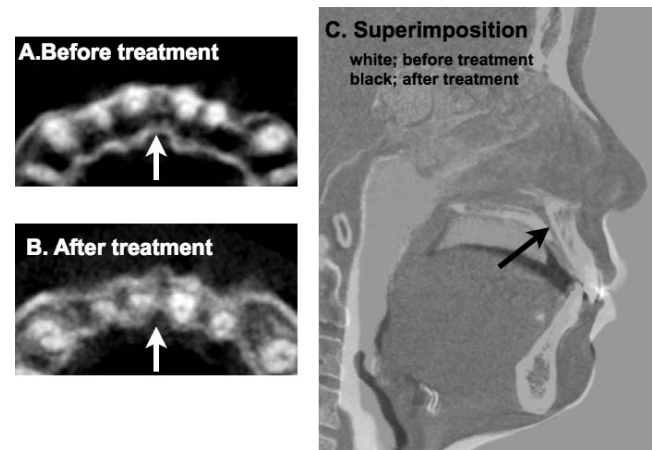


Figure 1. Cone beam computed tomography (CBCT) images of the incisive canal and superimposition before and after anterior retraction. Axial sections of the maxillary anterior region representing the apical one third of the maxillary incisors before (A) and after (B) anterior retraction. Notice the contact of the maxillary right central incisor and the approximation of the maxillary left central incisor roots to the incisive canal (arrow) after treatment. (C) CBCT superimposition on the cranial base before (in white) and after treatment (in black). Notice the changes in tooth position and the lateral profile following orthodontic treatment. No distinct changes were noted in the position of the incisive canal (arrow).

orthodontic or prosthetic treatment; and (5) no missing teeth except the third molars. Of 38 sets of materials (mean age, 21.2 ± 3.17 years), 21 were from men and 17 were from women. The average upper incisal angle to the SN plane (U1 to SN) of the subjects was $104.7^\circ \pm 5.62$, indicating that the upper incisor inclination was within the normal range.

Morphologic Evaluation of the Incisive Canal and Its Proximity to the Maxillary Central Incisors

The CT images were obtained using HiSpeed Advantage (GE Medical Systems, Milwaukee, Wis) with the high-resolution bone algorithm (200 mA, 120 kV, a scanning time of 1 second) using a slice thickness of 1 mm. The CT images saved in Digital Imaging and Communication in Medicine format were analyzed using InVivoDental imaging software (version 5.2, Anatomage, San Jose, Calif). The axial plane was oriented with the Frankfort-horizontal (FH) plane as a horizontal reference plane. 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. Linear measurements were performed on the axial cross-sectional images 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)

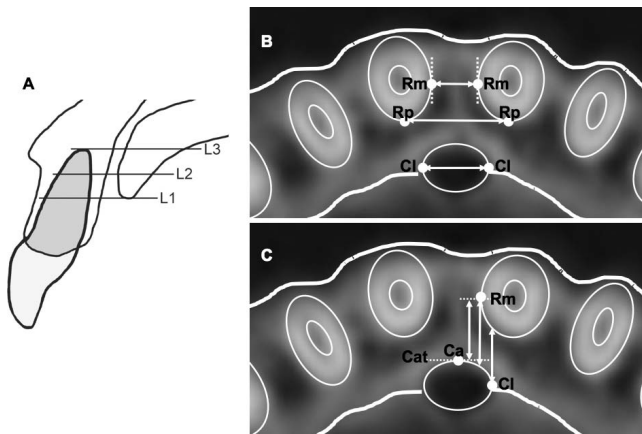


Figure 2. Landmarks and linear measurements. (A) Three vertical levels of the incisive canal: palatal opening level (L1), midlevel (L2), and root apex level (L3). (B) Landmarks for transverse measurements: Rm indicates the most medial point of the maxillary central incisor roots; Rp, the most posterior point of the maxillary central incisor roots; Cl, the most lateral point of the incisive canal; Rm-Rm, interroot distance; Rp-Rp, posterior interroot distance; Cl-Cl, canal width. (C) Landmarks for anteroposterior measurements: Ca indicates the most anterior point of the incisive canal; Cat, the tangent line through Ca; Rm-Cat, the distance from Rm to Cat; Rm-Canal, the distance from Rm to the anterior border of the incisive canal; Cl-Root, the distance from Cl to the posterior border of the maxillary central incisor root.

the root apex of the maxillary central incisors (root apex level, L3) (Figure 2A). Landmarks and measurements are defined as follows: Rm, the most medial point of the maxillary central incisor roots; Rp, the most posterior point of the maxillary central incisor roots; Cl, the most lateral point of the incisive canal; Rm-Rm, interroot distance; Rp-Rp, posterior interroot distance; Cl-Cl, canal width (Figure 2B); Ca, the most anterior point of the incisive canal; Cat, the tangent line through Ca; Rm-Cat, the distance from Rm to Cat; Rm-Canal, the distance from Rm to the anterior border of the incisive canal; Cl-Root, the distance from Cl to the posterior border of the maxillary central incisor root (Figure 2C). With regard to anteroposterior distances, the smaller value from the bilateral measurements was adopted as a representative value.

Statistical Evaluation

All measurements were made by a single examiner, who repeated them after a 2-week interval. The 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.²⁸ The method errors obtained ranged from 0.28 to 0.64 mm. Because the two-sample t -test showed no significant differences between men and women for any of the measurements, measurements

were not divided according to gender. One-way analysis of variance followed by a Tukey test was used to investigate the influence of the differences in vertical levels. The statistical analyses were performed using SPSS 18.0 (IBM, Armonk, N.Y.), with a significance level of $P < .05$.

RESULTS

Incisive Canal Width and Interroot Distance of the Maxillary Central Incisors

The incisive canal width (Cl-Cl) was 4.0 ± 0.73 , 3.7 ± 0.73 , and 3.5 ± 0.94 mm at levels L1, L2, and L3, respectively. The incisive canal width at L1 was significantly smaller than that at L3 ($P < .05$). Interroot distance (Rm-Rm) was 2.8 ± 0.70 , 3.5 ± 0.77 , and 7.1 ± 0.84 mm at levels L1, L2, and L3, respectively. Interroot distance was significantly increased from L1 to L3 ($P < .05$). Posterior interroot distance (Rp-Rp) was 7.8 ± 0.84 , 7.5 ± 0.92 , and 7.1 ± 0.84 mm at levels L1, L2, and L3, respectively. At L3, Rm and Rp represented the same point, and Rm-Rm was consequently equivalent to Rp-Rp. In contrast to Rm-Rm, Rp-Rp at L3 was significantly smaller than at L1 ($P < .05$) (Table 1).

The percentage of subjects with an incisive canal width greater than the interroot distance (Rm-Rm) was 86.8% (33/38), 63.2% (24/38), and 0% (0/38) at levels L1, L2, and L3, respectively. On the other hand, the incisive canal width was smaller than Rp-Rp in all of the subjects at each vertical level (Table 2).

Proximity of the Anterior Border of the Incisive Canal to the Maxillary Central Incisor Root

Rm-Cat was 5.2 ± 1.16 , 5.1 ± 1.09 , and 4.9 ± 1.30 mm at L1, L2, and L3, respectively. The measurements of Rm-Canal and Cl-Root were 5.9 ± 1.07 and 5.5 ± 1.32 mm at L1 and 5.7 ± 1.14 and 5.6 ± 1.19 mm at L2. Rm-Canal and Cl-Root were 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. Rm-Cat, Rm-Canal, and Cl-Root measurements did not show significant differences according to the vertical levels (Table 3).

DISCUSSION

Based on the “envelope of discrepancy,” the maximum amount of maxillary anterior retraction is 7 mm,¹¹ and the recent development of skeletal anchorage has also broadened the limits of orthodontic tooth movement.²⁹ Our results indicate that the biological anteroposterior distances between the maxillary central incisor roots and the incisive canal were approximately 5–6 mm, slightly less than our conventional

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

Measurement	Vertical Level		
	Opening (L1)	Midlevel (L2)	Root Apex (L3)
	Mean ± SD	Mean ± SD	Mean ± SD
Canal width (mm)	4.0 ± 0.73 B	3.7 ± 0.73 AB	3.5 ± 0.94 A
Rm-Rm (mm)	2.8 ± 0.70 A	3.5 ± 0.77 B	7.1 ± 0.84 C
Rp-Rp (mm)	7.8 ± 0.84 B	7.5 ± 0.92 AB	7.1 ± 0.84 A

^a Mean values with the same superscript letters within a row are not significantly different from each other. SD indicates standard deviation; Rm, the most medial point of the maxillary central incisor roots; Rp, the most posterior point of the maxillary central incisor roots; Rm-Rm (interroot distance), the transverse distance between the bilateral Rms; Rp-Rp (posterior interroot distance), the transverse distance between the bilateral Rps. Canal width is the transverse distance between the most lateral point of the incisive canal.

guidelines. This 5- to 6-mm 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, more than 60% of our subject pool had an incisive canal width larger than the interroot distance, and individual variations of canal dimension, especially enlargement and asymmetry of the canal morphology, are frequently reported with 3D evaluation.^{20,21,30,31}

Anatomical features of the incisive canal have been studied in connection with rehabilitation of the maxillary anterior region^{18–24} and the placement of orthodontic mini-implants.^{30,32–34} However, the consequences or the possibilities of incisor roots being in contact with the incisive canal following tooth movement are poorly documented in the orthodontic literature. Similar to the example presented in Figure 1, it was recently noted through 3D evaluation that the maxillary central incisor root in direct contact with the incisive canal following anterior retraction was associated with severe root resorption, but without any neurologic symptoms.²⁵ Given that the incisive canal is surrounded by thick cortical bone, similar reactions may be induced when the roots are in contact with the lingual cortical plate. Contact of tooth roots with the

Table 2. The Percentage of Patients With an Incisive Canal Width Greater Than the Interroot Distances

Canal Width ^a	Vertical Level		
	Opening (L1), %	Midlevel (L2), %	Root Apex (L3), %
> Rm-Rm	86.8	63.2	0
> Rp-Rp	0	0	0

^a Rm-Rm (interroot distance) indicates the transverse distance between the bilateral Rms; Rp-Rp (posterior interroot distance), the transverse distance between the bilateral Rps.

Table 3. Proximity of the Anterior Border of the Incisive Canal to the Maxillary Central Incisor Roots at Three Vertical Levels^a

Measurement	Vertical Level		
	Opening (L1)	Midlevel (L2)	Root Apex (L3)
	Mean ± SD	Mean ± SD	Mean ± SD
Rm-Cat (mm)	5.2 ± 1.16	5.1 ± 1.09	4.9 ± 1.30
Rm-Canal (mm)	5.9 ± 1.07	5.7 ± 1.14	N/A
Cl-Root (mm)	5.5 ± 1.32	5.6 ± 1.19	N/A

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

cortical plate has been addressed as a contributor to root resorption,^{12–14,16} result in delayed tooth movement,¹² and may also cause perforation and dehiscence of the cortical plate.^{6,9,10,12,15} In this context, it is interesting to note that the incidence of orthodontic root resorption is by far more frequent in the maxillary central incisors, even with their larger tooth dimensions, than in the lateral incisors.^{14,35}

Considering the morphologic dimensions of the central incisor roots and the incisive canal, the posterior-median aspect of the apical third (L1 or L2 levels) of the roots rather than the root apex per se is most likely to approximate with the canal following maxillary anterior retraction and root movement. However, in many clinical situations anterior intrusion also occurs during the retraction process, raising the possibility of approximation along the path of tooth movement. It is also noteworthy that in the mandibular canal, temporary paresthesia of the lower lip was reported in association with tooth root when in contact with the canal wall following orthodontic tooth movement.^{36,37} Thus, 3D images may be helpful in estimating the proximity of the incisive canal along with the dimensional characteristics when a considerable amount of maxillary incisor retraction with vertical control is planned.

Tooth movement induces remodeling of the surrounding bone. Although remodeling of the incisive canal following orthodontic tooth movement has not, to our knowledge, been reported,²⁵ 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.^{22,38} Therefore, to determine the remodeling potential of the incisive canal wall following orthodontic tooth movement, further evaluations using comparisons of pre- and posttreatment materials are necessary.

CONCLUSIONS

- The anteroposterior distance between the maxillary central incisor roots and the incisive canal was approximately 5–6 mm.
- More than 60% of subjects had an incisive canal width greater than the interroot distance.
- Evaluation of the proximity of the incisive canal to the maxillary incisors, in addition to its dimensional characteristics, may be helpful when a considerable amount of maxillary retraction is planned.

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