Evaluation of Maxillary Incisive Canal Characteristics Related to Dental Implant Treatment With Computerized Tomography: A Clinical Multicenter Study

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Background: A close anatomic relationship between the incisive canal and the roots of the central maxillary incisors should be kept in mind during dental-implant treatment in the anterior maxilla. The aim of the present study is to analyze incisive canal characteristics on computed tomography (CT) sections and to evaluate its relation to bone anterior to the canal with regard to dental implantation.

Methods: A total of 933 partially edentulous and/or edentulous patients scheduled for implant insertion in four dental clinics enrolled in the present study. The following were measured and recorded from CT sections for analysis: 1) diameter and length of the incisive canal; 2) width and length of the bone anterior to the canal; 3) palatal bone width and length; and 4) root width and length of the central incisor.

Results: Mean canal length was 10.86 ± 2.67 mm, and mean diameter was 2.59 ± 0.91 mm. Canal length was shortened in edentulous anterior maxilla compared to dentate maxilla. However, canal diameter did not show any difference between dentate and edentulous groups. Males had a longer and wider incisive canal than females. Canal shape was mostly cylindrical in 40.73% of images. No correlation was found with mean canal length and mean canal diameter according to age.

Conclusions: Although variations exist in every patient, the findings from this study suggest that sex and dental status are important factors that can affect incisive canal characteristics and amount of bone anterior to the canal. Clinicians should perform careful planning using CT scans before performing dental implant surgeries in premaxillary region. *J Periodontol 2012;83:337-343.*

KEY WORDS

Dental implants; humans; incisor; maxilla; surgical flaps; tomography.

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Implant surgery of the edentulous premaxilla is often challenging because of esthetic, phonetic, and biomechanical needs. The incisive canal (IC), located at the midline, posterior to the central incisor teeth, is an important anatomic structure of this area. The nasopalatine nerve and terminal branch of the nasopalatine artery pass through this canal.[1] The IC has two openings: 1) inferior opening (incisive foramen), and superior opening (nasopalatine foramen).[1] Because the term nasopalatine foramen is used interchangeably with incisive foramen or foramen of Stensen, and nasopalatine canal is used interchangeably with IC, and considering that according to the *Terminologia Anatomica*: *International Anatomical Terminology*,[2] the term incisive canal has officially been accepted. To harmonize concepts in this study, the terminology as defined previously by Song et al. is used.[1] The IC has one to four channels at its middle level.[1,3] The IC has two to four nasopalatine foramina and one incisive foramen. There are morphologic variations of the canal; however, a universal accepted terminology for such is not available. The canal was defined and classified according to several criteria. One study defined the canal shape as Y-morphology or cylindrical[4] and the

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other Y-morphology as one canal or two parallel canals.[5] Moreover, canal shape has also been classified based on the sagittal view direction.[1] Mardinger et al.[6] considered both aspects, making a classification on sagittal plane as well, and named the canal shape cylindrical, funnel-like, hourglass-like, and banana-like.

Careful evaluation is necessary when central incisors are restored with implants. High resorption rates often occurred postextraction.[7,8] This may expose these structures to the alveolar crest. Shortening of canal and enlargement of the IC diameter by tooth loss were also reported.[3,6] Insertion of implants into the IC may lead to contact of implants with nervous tissue and cause non-osseointegration or lead to sensory alteration.[9,10] With increasing demand for rehabilitation of edentulous sites using implants, preoperative evaluation with three-dimensional (3D) imaging gained attention, but studies examining IC anatomy are scarce. Liang et al.[3] examined 163 dry skulls and 120 spiral computerized tomography (CT) scans; and reported average canal diameter was 3.3 mm, and average canal length was 9.9 mm. Song et al.[1] used 3D micro-CT images and detected 11.5-mm mean canal length in 56 cases. They looked at the effect of dental status on canal characteristics and reported shorter IC in edentulous maxilla. However, Liang et al.[3] could not find a difference between the diameter of dentate or edentulous groups. In contrast, Mardinger et al.[6] illustrated an increase in diameter with ridge resorption.

Initial implant stability is the most critical factor in implant osseointegration. Most researchers recommend ≥3 to 5 mm of bone beyond the apex and ≥10-mm implant length when placing immediate implants, so implant stability can be obtained.[11] The height and width of the residual alveolar bone and surrounding anatomic structures can dictate the implant position as well as path of insertion. In a previous study, the width of the the bone anterior to the IC was reported to range from 2.9 to 13.6 mm (mean: 7.4 mm) on 34 spiral CT scans.[4] Another study on sagittal CT images detected a ≈60% buccal bone width reduction and ≈44.4% buccal bone length reduction anterior to the canal between dentate and edentulous patients.[6]

Based on the limited number of publications on human participants, the clarification about the IC seems to be critical before implant surgery. Therefore, the aims of the present study are to determine IC characteristics on CT sections and to evaluate its relationship to anterior maxillary bone with regard to dental implantation.

MATERIALS AND METHODS

A total of 933 partially edentulous and/or edentulous patients (417 males and 516 females, aged 18 to 84 years; mean age: 43.79 ± 16.19 years) scheduled for implant insertion in four dental clinics (171 CTs in Turkey, 310 CTs in Spain, 133 CTs in Saudi Arabia, and 319 CTs in Cyprus) enrolled in the present study. One calibrated investigator (YDY, HGY, MV-T, RA-S) at each center performed all the measurements from November 2010 to January 2011. Spiral** and cone beam†† CT scans achieved in these centers were used in the present study. A detailed research protocol was discussed and agreed before initiation of the study. Measurements were clarified on schematic diagrams between calibrated investigators YDY, HGY, MV-T, RA-S). Patients with evidence of nasopalatine pathology (e.g., nasopalatine duct cyst) and low quality imaging, such as scattering of the bony borders, were excluded. The anatomic variations of the canal were examined on axial sections and classified into four groups:[6] 1) cylindrical; 2) banana-like; 3) hourglass-like; and 4) funnel-like. The dimensions of the IC were measured in millimeters on the axial CT images with software programs. The following landmarks were selected for measurements (Figs. 1 and 2): 1) the diameter of the IC (measurements done at crestal, middle, and the most apical point of the canal)[5,6] (Fig. 1); 2) the length of the IC[5,6] (Fig. 2); 3) the width of the bone anterior to the canal (buccal bone) (measurements done at crestal, middle, and the most apical point of the canal)[5,6] (Fig. 1); 4) the length of the bone anterior to the canal[5,6] (Fig. 2); 5) the palatal bone width (Fig. 1); 6) the palatal bone length (Fig. 2);

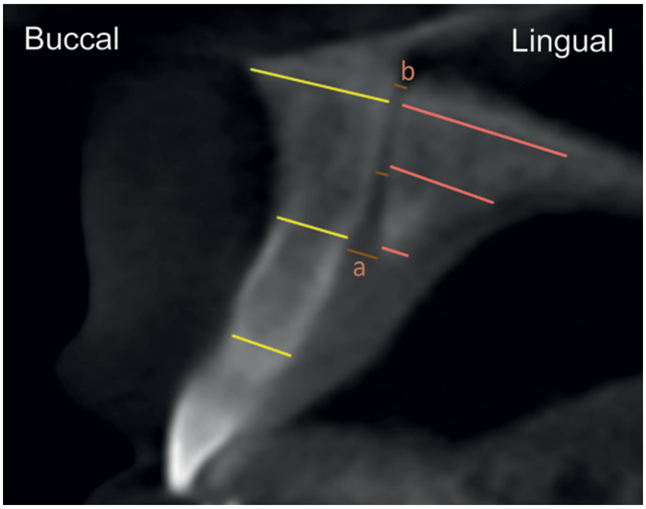

Figure 1.
Example of an examined sagittal CT section. Yellow line = bone width anterior to the canal measured from three points: crestal, middle, and apical. Pink line = palatal bone width measured from three points: crestal, middle, and apical. Brown line = diameter of IC. a = diameter of incisive foramen; b = diameter of nasopalatine foramen.

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and 7) the root length and root width of the central incisor teeth, if present.

Statistical Analyses

Age and sex of the patients were recorded, and the measurements were analyzed according to age and sex. Means ± SDs were calculated. All statistical analyses were performed by the center at Hacettepe University with statistical software.[‡‡] Student *t* test was used to compare data between dentate and edentulous patients as well as male versus female patients. The correlations between parameters were analyzed with Pearson correlation coefficient. $P<0.05$ was considered statistically significant.

RESULTS

This study evaluates CT scans of 933 patients. To our knowledge, it is one of the higher samples used for this kind of analysis reported in the literature. Demographic variables and descriptive statistics of all patients were summarized in Tables 1 and 2. Mean canal length was 10.86 ± 2.67 mm, and mean diameter was 2.59 ± 0.91 mm. Diameter of the superior orifice (nasopalatine foramen/apical canal diameter) and inferior orifice (incisive foramen/crestal canal diameter) were found to be 2.76 ± 1.40 and 2.93 ± 1.01 mm, respectively. Overall, mean length of the bone anterior to the canal was 19.17 ± 3.70 mm, and bone width was 7.17 ± 1.49 mm. Root length, width, and bone length between apex and nasal floor were also calculated in dentate patients (Tables 1 and 2).

A total of 725 patients were dentate and 208 patients were edentulous in the anterior maxilla. Differences between dentate and edentulous patients are given in Table 3. Edentulous patients were older, as expected ($P=0.0001$). Canal length was shortened in edentulous anterior maxilla compared to dentate maxilla, and this difference was statistically significant ($P = 0.0001$). However, canal diameter did not show any difference between groups (Table 3). Bone dimensions anterior to the canal differed according to the presence of teeth. Mean length and width of the bone anterior to the canal were higher in dentate patients, and the differences were statistically significant ($P=0.0001$) (Table 3).

When the effect of the sex was evaluated, significant differences were also detected (Table 4). Males were demonstrated to have a longer and wider IC than females ($P=0.0001$ for both length and width, respectively); moreover, buccal and palatal bone length and bone width were statistically greater in men ($P = 0.0001$) (Table 4). There is no statistical difference between males and females in bone length values from apex to nasal floor (Table 4).

No correlation was found with mean canal length and mean canal diameter according to age. Conversely, there were negative correlations between age and buccal bone dimensions ($P = 0.001$, $r = -0.188$ for length; $P = 0.001$, $r = -0.144$ for width).

In the whole study population, including dentate and edentulous patients, canal shape was cylindrical in 40.73%, funnel-like in 27.65%, hourglass-like in 18.76%, and banana-like in 12.86% images (Table 5). Dentate patients have 41.65% cylindrical, 26.06% funnel-like, 18.89% hourglass-like, and 13.37% banana-like canals. These parameters were 37.5%, 33.17%, 18.26%, and 11.05% canals, respectively, for edentulous patients. Cylindrical canal shape was the

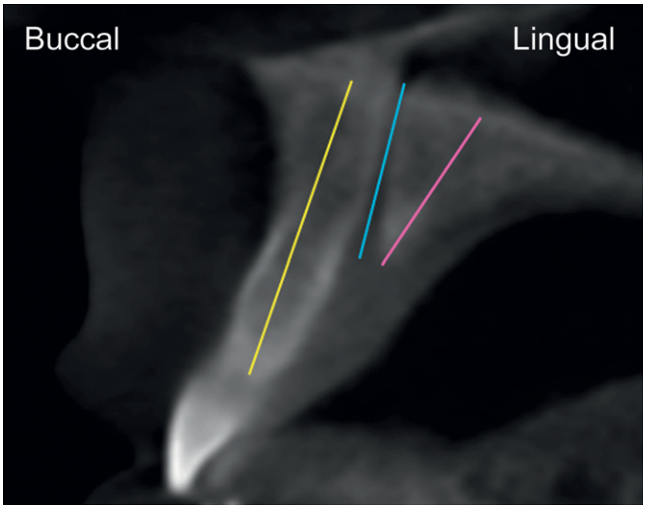

Figure 2.
Example of an examined sagittal CT section. Yellow line = bone length anterior to the canal. Blue line = IC length. Pink line = palatal bone length.

Table 1.

Demographic Variables and Descriptive Statistics of 933 Individuals (mean ± SD)

Descriptive Statistics	Mean ± SD
Age	43.79 ± 16.19
Age of dentate patients	40.67 ± 15.67
Age of edentulous patients	54.67 ± 12.98
Canal length (mm)	10.86 ± 2.67
Buccal length (mm)	19.17 ± 3.70
Palatal length (mm)	11.01 ± 2.76
Root length (mm)	12.65 ± 1.73
Apex to bone (mm)	8.03 ± 3.04

Buccal length = bone length anterior to the canal.

‡‡ SPSS v.11.5.0 software for Windows, IBM, Chicago, IL.

Table 2.

Canal Diameter, Bone Thickness, and Root Width Parameters in the Whole Study Group

Canal Diameter (mm)				Bone Thickness Anterior to the Canal (mm)				Palatal Bone Thickness (mm)				Root Width (mm)			
Crestal	Medial	Apical	Mean	Crestal	Medial	Apical	Mean	Crestal	Medial	Apical	Mean	Crestal	Medial	Apical	Mean
2.93 ± 1.01	2.07 ± 0.92	2.76 ± 1.40	2.59 ± 0.91	5.62 ± 1.56	6.68 ± 1.57	9.19 ± 2.48	7.17 ± 1.49	2.19 ± 0.83	4.79 ± 1.37	7.37 ± 2.16	4.78 ± 1.29	6.08 ± 0.81	4.96 ± 0.71	2.05 ± 0.66	4.37 ± 0.55

Bone Thickness Anterior to the Canal = buccal bone thickness.

most prevalent shape (40.73%), whereas banana-like was the least (12.86%). The presence or absence of teeth did not affect this prevalence (Table 5).

DISCUSSION

Close anatomic relationship between the IC and the roots of the central maxillary incisors may hamper the use of dental implants in the anterior maxilla. Careful radiologic analysis is necessary in treatment planning; however, some studies mentioned the anatomic features of this area.[1,3-6] In the present study, IC features are determined on CT sections, and 10.86 ± 2.67 mm mean canal length is recorded. Present results correlated well with a recent cone-beam CT study where the length measured 10.99 mm.[5] Moreover, Liang et al.[3] and Mraiwa et al.[4] found a mean length of 9.9 ± 2.6 and 8.1 ± 3.4 mm, respectively. However, the samples analyzed by Mraiwa et al.[4] were limited to 34 spiral CT scans. Additionally, Song et al.[1] scanned 56 anterior maxilla cadavers using micro-CT and found a mean length of 11.5 mm, which correlated with the results of the present study.

Mean canal diameter is 2.59 ± 0.91 mm in the present study. Liang et al.[3] measured a mean canal diameter of 3.6 ± 1.0 mm; however, measuring points were unclear in their study. Other studies did not report a mean canal diameter value or measured the diameters of superior and inferior openings.[1,4-6] In the present study, diameter of superior orifice (nasopalatine foramen) is 2.76 ± 1.40 mm, and the diameter of inferior orifice (incisive foramen) is 2.93 ± 1.01 mm. Values were slightly narrow compared to those obtained from other studies.[1,4-6] This difference may be attributable to the large number of samples (933) in the present study and to a higher heterogeneity of our population (four different countries).

Although they can be modified by several existing augmentation techniques,[12,13] bone dimensions anterior to the canal continue to be important in determining proper implant dimensions. In the present study, mean bone length anterior to the canal is 19.17 ± 3.70 mm. There is no comparable data with mean bone length, but one study[14] reported 17.22-mm bone length in class A ridges and decreased to 9.57 mm in class E ridges.[6] In the present study, minimum bone length anterior to the canal was 8 mm, and bone width was 7.17 ± 1.49 mm. Although mean width seems enough for a standard diameter implant, it ranges from 2.8 to 11.8 mm. A similar result was reported by Mraiwa et al.[4] (7.4 mm, ranging from 2.9 to 13.6 mm). Thus, in some maxillary arcades, implant placement seems impossible without augmentation. One study reported that bone anterior to the canal lost 60% of its mean width and decreased from 6.4 mm (dentate bone) to 2.6 mm (class E), and when

Table 3.

Comparative Statistical Analysis of IC Characteristics in Dentate and Edentulous Patients

Parameters	Dentate (n = 725) Mean ± SD	Edentulous (n = 208) Mean ± SD	P
Age	40.67 ± 15.67	54.67 ± 12.98	0.0001*
Canal length (mm)	11.07 ± 2.70	10.16 ± 2.48	0.0001*
Buccal length (mm)	19.97 ± 3.30	16.38 ± 3.68	0.0001*
Palatal length (mm)	11.04 ± 2.76	10.90 ± 2.78	0.507
Canal diameter (mm)			
Crestal	2.90 ± 1.00	3.02 ± 1.05	0.126
Medial	2.08 ± 0.93	2.04 ± 0.89	0.546
Apical	2.77 ± 1.40	2.73 ± 1.37	0.698
Mean	2.59 ± 0.91	2.62 ± 0.94	0.682
Bone thickness anterior to the canal (mm)			
Crestal	6.06 ± 1.24	4.10 ± 1.62	0.0001*
Medial	6.75 ± 1.52	6.44 ± 1.74	0.019*
Apical	9.3 ± 2.52	8.76 ± 2.31	0.005*
Mean	7.38 ± 1.42	6.43 ± 1.49	0.0001*
Palatal bone thickness (mm)			
Crestal	2.26 ± 0.85	1.96 ± 0.72	0.0001*
Medial	4.85 ± 1.36	4.58 ± 1.37	0.012*
Apical	7.53 ± 2.17	6.82 ± 2.03	0.0001*
Mean	4.88 ± 1.29	4.44 ± 1.23	0.0001*

Buccal Length = bone length anterior to the canal.
* $P < 0.05$.

the incisive foramen was on the ridge, it occupied a mean of 36.5% of the area of ridge planned for implant insertion.[6]

Immediate implantation into carefully selected extraction sockets shortens the time of therapy and reduces surgical episodes. Generally, in immediate implant situations, 3 to 5 mm existing bone beyond the apex is needed to achieve initial implant stability. Mean bone length apex to nasal bone was 8.03 ± 3.04 mm in the present study. Bone length apex to nasal bone was <3 mm in only 2.89% of patients; 13.24% of patients had 3 to 5 mm bone length, and 83.87% had >5 mm (unpublished data of present authors of this study). Thus, the present study results reveal that most patients had enough bone at the apex for immediate implantation in the anterior maxillary region.

The presence or absence of anterior incisors affected some dimensions. Canal length, bone length, and width anterior to the canal were greater in dentate patients. Bornstein et al.[5] reported an increase of buccal width in dentate patients compared to edentulous patients. Because of the anterior maxillary bone resorption, there is a reduction in canal length. Other studies found the same results as the present study.[1,3,6] However, mean diameter of the canal did not change according to dental status. This could be attributable to the canal shape. IC was mostly cylindrical or funnel-like (a larger part was directed toward incisive foramen). Bone resorption occurs, but the exposed part of the canal was still at the same diameter or smaller.

Significant differences were also detected in males versus females in terms of IC features. The canal dimension, bone length, and width anterior to the canal were greater in men. Similarly, Bornstein et al.[5] found wider bone length anterior to the canal, and Liang et al.[3] found longer and wider canals in men. However, with a limited sample size (17 males and 17 females), Mraiwa et al.[4] could not find effect of sex on canal dimensions. To the best of our knowledge, there are no comparable data about the sex differences of bone length in the literature. Even bone anterior to the canal was longer in men; bone length apex to bone did not change between sexes. This difference may be related to the longer roots of teeth in men ($P = 0.0001$).

In the present study, no significant correlations are detected between age and canal length diameter. In contrast to these finding, Bornstein et al.[5] reported that the age of the patients had a significant influence on the length of the nasopalatine canal. However, Mraiwa et al.[4] could not find any relationship between age and canal characteristics in their study.

Canal shape or morphology was classified according to several criteria in the literature. Classifications were made according to number of canals, direction, course, or what the image looks like in the CT (e.g., cone-shaped, cylindrical, Y-shaped, hourglass-shaped, etc.) Moreover, these variations were determined on either cross-sectional or axial slices or determined on 3D images. Therefore, neither of these examples were comparable to each other. In this study, canal morphologies are also determined on axial CT slices. Morphologies were classified as defined previously, in which ICs were mostly cylindrical and funnel-like.[6]

In a recent study, Peñarrocha et al.[15] suggested that implants in the IC might be a treatment approach for the rehabilitation of the severely atrophied maxilla. They used the IC as an anatomic buttress for dental implant insertion in seven patients.[15] The nasopalatine neurovascular bundle was removed in all patients, and five patients experienced some sensory loss (minimal or no treatment required). Moreover, quite invasive procedures, such as application of a bone graft and subsequent implant insertion, for rehabilitation of the severely atrophied maxilla have

Table 4.

Comparative Statistical Analysis of Male and Female Patients

Parameters	Male (n = 417) Mean ± SD	Female (n = 516) Mean ± SD	P
Age	44.34 ± 15.94	43.34 ± 16.40	0.347
Canal length (mm)	11.64 ± 2.73	10.23 ± 2.45	0.0001*
Buccal length (mm)	19.67 ± 3.79	18.76 ± 3.57	0.0001*
Palatal length (mm)	11.57 ± 2.71	10.55 ± 2.73	0.0001*
Root length (mm)	13.17 ± 1.76	12.25 ± 1.59	0.0001*
Apex to bone (mm)	8.21 ± 3.21	7.89 ± 2.91	0.159
Canal diameter (mm)			
Crestal	3.21 ± 1.06	2.71 ± 0.91	0.0001*
Medial	2.22 ± 0.96	1.96 ± 0.86	0.0001*
Apical	2.91 ± 1.39	2.65 ± 1.39	0.005*
Mean	2.79 ± 0.95	2.44 ± 0.85	0.0001*
Bone thickness anterior to the canal (mm)			
Crestal	5.85 ± 1.51	5.44 ± 1.58	0.0001*
Medial	7.10 ± 1.59	6.34 ± 1.48	0.0001*
Apical	9.65 ± 2.58	8.82 ± 2.34	0.0001*
Mean	7.54 ± 1.47	6.87 ± 1.43	0.0001*
Palatal bone thickness (mm)			
Crestal	2.42 ± 0.85	2.01 ± 0.78	0.0001*
Medial	5.26 ± 1.38	4.43 ± 1.24	0.0001*
Apical	7.96 ± 2.19	6.91 ± 2.01	0.0001*
Mean	5.21 ± 1.30	4.45 ± 1.18	0.0001*
Root width (mm)			
Crestal	6.25 ± 0.88	5.94 ± 0.72	0.0001*
Medial	5.10 ± 0.79	4.86 ± 0.63	0.0001*
Apical	2.17 ± 0.61	1.97 ± 0.68	0.0001*
Mean	4.50 ± 0.62	4.26 ± 0.47	0.0001*

Buccal Length = bone length anterior to the canal.
* $P<0.05$.

also been presented.[9,16] In the literature, clinical implications of damaging the canal and its neurovascular structures as well as their long-term effects have not been addressed comprehensively. Before starting to apply the above procedures, implant surgeons should know the anatomic structure of IC and analyze CTs for individual differences. In this regard, patients can be properly informed if surgeons elect to place implants in this area.

CONCLUSIONS

The present study is a human study, including a large number of CT images from four different countries. The results from this study suggest that a CT scan is a valuable tool to evaluate anatomic variations, morphology, and dimensions of IC and incisive foramen.

Table 5.

Canal Morphologies of IC in Dentate and Edentulous Patients According to Countries

Canal Morphologies	Turkey	Spain	Saudi Arabia	Cyprus	Total
Cylindrical					
Dentate	75	78	43	106	302
Edentulous	25	43	2	8	78
Total	100	121	45	114	380
Banana-like					
Dentate	5	38	24	30	97
Edentulous	4	12	2	5	23
Total	9	50	26	35	120
Hourglass-like					
Dentate	18	36	16	67	137
Edentulous	4	19	3	12	38
Total	22	55	19	79	175
Funnel-like					
Dentate	27	51	36	75	189
Edentulous	13	33	7	16	69
Total	40	84	43	91	258

Although variations exist in every patient, findings from this study suggest that sex and dental status are important factors that can affect IC characteristics and amount of bone anterior to the canal. Clinicians should perform careful planning using CT scans before performing dental implant surgeries in the premaxillary region.

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