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Radiographic evaluation of the incisive foramen position by Cone-Beam Computed Tomography (CBCT) in edentulous anterior maxilla regions and its relationship to dental implant placement of incisor teeth

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ABSTRACT

Background: The implants with increasing dental implant placement of missing teeth haves already paid attention for its success and popularity of this treatment. However, dental implant placement in the anterior maxilla region regarding anatomic and beauty is limited. One of the main factors is structure limitations in incisive foramen area.

Objective: This study aims to evaluate the position of the incisive foramen by cone-beam computed tomography (CBCT) and its relation to dental implant placement of incisor teeth.

Methods: This case-series study consisted of 64 women and 36 men. CBCT images for edentulous anterior maxilla were conducted by using a limited field of view (FOV) of 4*5. Reformatted sagittal and coronal slices were analyzed for dimensions of the incisive foramen, the incisive canal, and buccal bone wall. There were nine parameters measured regarding incisive foramen including the incisive canal length and buccal bone width (millimeters, [mm]).

Results: The mean length of the incisive canal was 7.905±2.201 mm, width of incisive foramen (coronal view) 3.094±0.922 mm and 2.818±0.828 mm (sagittal view). The mean volume and length of the incisive canal were greater and significant ($p<0.001$) in men than women. However, the mean width of the incisive foramen, Stenson foramen, and incisive foramen distances to alveolar bone crest was greater and significant ($p=0.001$) in women than men.

Conclusion: The width of the incisive foramen in 58% edentulous patients was more than 2.5 mm. In such cases, authors recommend replacing lateral incisors with dental implants instead of central incisors when possible.

Keywords: incisive foramen, cone-beam computed tomography, anterior maxilla, dental implants

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INTRODUCTION

The demand for treatment to replace missing teeth every day is increasingly as a result of the advances in implantology. Tooth loss or missing teeth especially in the anterior region is commonly the result of a traumatic injury or a congenital anomaly. Several options are available for the replacement of missing teeth.[1] These include removable dental prostheses, conventional fixed partial dentures (FPDs), resin-bonded FPDs, implant supported prostheses.[2,3] The implant treatment becomes the first choice for dentists and patients due to the high clinical success of dental implants particularly in anterior teeth region (aesthetics or beauty). But implant surgery, in the anterior maxilla, is often challenging because the biomechanical, aesthetic and phonetic demands need to find a perfect compromise with the anatomical structure limitations.[4]

In fact, the possibility of replacing dental implants is the function of factors such as anatomical factors which alveolar bone thickness in the edentulous region adjacent to the anatomical landmark noted. In the region of aesthetics in the maxilla bone, incisive foramen repositioned as anatomic landmarks after pulling anterior teeth over the time and resorption of alveolar bone, and sometimes even the treatment plan changed. Therefore, the assessment of foramen and incisive Canal seems essential before implantation.[5,6]

There were some studies trying to evaluate this issues. Mardinger et al. (2008) evaluated the radiologic changes of the nasopalatine canal about dental implantation who had maxillary CT scans before dental implantation.[7] The result shows that the canal width was wider along the degree of ridge resorption from classes A to E in all dimensions, mainly in the palatal opening, median area and nasal area. The mean diameter of the enlargement was 1.8 mm, which reached 5.5 ± 1.08 mm in type E bone. In the severely resorbed ridges (classes C through E), when the palatal opening was situated on the ridge, it occupied a mean of 35.6% (13% to 58%) of the area devoted to implant placement.[7]

Song et al. (2009) investigated the microanatomy of the incisive canal (IC) using three-dimensional microCT images in 56 anterior maxillae harvested from human cadavers. They concluded that many incisive canals had one foramen inferiorly (palatal opening) and two foramina superiorly (nasal opening), and the separating level was just beneath the nasal floor. The incisive canals were classified into four types according to the lateral shape of the canal: vertical-straight, vertical-curved, slanted-straight, and slanted-curved.[8]

Then, Penarrocha et al. (2009) selected seven patients as sample using severe resorption of the edentulous maxilla (Class V according to the Cawood and Howell classification), and in each patient, one implant was positioned in the nasopalatine canal. In addition, a total of another 29 implants were also placed in the posterior to this structure. One of the implants in the nasopalatine canal was lost during the osseointegration phase. Five patients experienced minor sensory alterations during the first weeks after surgery. At the final examination, which took place after a mean of 5 years (range, 3 to 7 years) all patients expressed the presence of normal sensation.[9]

Subsequently, Bornstein et al. (2010) examined CBCT images of partially edentulous patients scheduled for dental implantation in the anterior maxilla. In CBCT images, a limited field of view (FOV) of 4 × 4 cm, 6 × 6 cm or 8 × 8 cm was selected. Reformatted sagittal and coronal slices were analyzed about dimensions and anatomic characteristics of the nasopalatine canal as well as the dimensions of the buccal bone wall. The study population comprised 44 men and 56 women with a mean age of 43.09 years. Gender of the included patients had a statistically significant influence on the dimensions of the buccal bone plate, the mean values being higher for men. In the multivariate linear regression model, the status of the central maxillary incisors (both present, one missing, and both missing) and the time elapsed since loss of the central incisors (less than1 year vs. more than1 year) were independently associated with buccal bone wall measurements, adjusted for age and sex.[10]

Last, a study was conducted by Tözüm et al. (2011) toward 933 partially edentulous and edentulous patients scheduled for implant insertion in four dental clinics enrolled in the present study. Canal length was shortened in edentulous anterior maxilla compared to the dentate maxilla. However, canal diameter did not show any difference between dentate and edentulous groups. Men had a longer and wider incisive canal than women. 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.[11]

Accordingly, evaluating the position of the incisive foramen by cone-beam computed tomography (CBCT) and its relation to dental implant placement of incisor teeth is needed in terms of anatomic and beauty.

METHODS

In this case-series study, 100 patients (64 women and 34 men) with edentulous anterior maxilla enrolled. CBCT images using a three-dimensional tomography (Planmeca 3D-Max) were prepared with voxel size maximum of 0.1 mm. Device parameters on eight mA and 80kV and exposure time 12 seconds was set. For all of these images, the field of view (FOV) limited the size of 5 × 4 cm was selected.

Slices in CBCT images were selected to observe canal and incisive foramen in a vertical position of sagittal and coronal slices. Reformatted were analyzed with regard to dimensions of the incisive foramen as well as the dimensions of the incisive canal and buccal bone wall. The nine parameters regarding incisive foramen and the surrounding structures including the incisive canal length and buccal bone width were measured. Canal dimensions and incisive foramen through reconstruction of sagittal and coronal images in mm was measured.

Variable of this study includes canal volume in cubic centimeters, the level of the canal (in coronal sections) in millimeters square. Stanton foramen diameter (sagittal sections), incisive foramen diameter (in sagittal sections). The length of the incisive canal (sagittal sections), the diameter of buccal (sagittal sections), the width of Stanton foramen (coronal sections). The width of incisive foramen (coronal sections), and distance from foramen to crest bone. All variables are defined, was measured according to the Bornstein study.[10]

CBCT images were not involved in the treatment and follow-up process of patients by a qualified professional who has been evaluated as well as Romexis computer software Version 3.2 to evaluate and analysis images was used.

RESULTS

A comparison between women and men

The Table 1 below showing the total number of samples in each group according to mean value, standard deviation, minimum, maximum, and median value. Z-values and T-test for two independent samples are also included.

Table 1 The comparison between women and men according to mean value, standard deviation, minimum, maximum, median, and test results

Variable	Gender	Number	Mean	Standard deviation	Minimum	Maximum	Median	Test result
Volume of canal	Men	35	.051714	.0257871	.0100	.1070	.052000	Z=1.178
	Women	65	.048323	.0335392	.0060	.1680	.039000	P=0.239
Level of canal	Men	35	125.3143	47.30550	54.00	228.00	121.0000	T=2.496
	Women	65	102.0615	42.82810	19.00	220.00	93.0000	P=0.014
Width of Stanton foramen	Men	35	4.2143	1.29232	2.00	8.00	4.4000	T=0.046
	Women	65	4.2015	1.34437	.80	8.40	4.2000	P=0.964
Width of incisive foramen	Men	35	3.0200	.93015	1.20	5.20	3.0000	T=0.477
	Women	65	3.1123	.91899	1.00	5.20	2.9000	P=0.634
Length of canal	Men	35	9.3800	2.56570	4.60	18.00	9.8000	Z=4.432
	Women	65	7.1185	2.02607	2.60	11.80	7.4000	P<0.001
Diameter of buccal	Men	35	7.2571	1.98913	3.00	10.40	7.4000	T=0.543
	Women	65	7.0508	1.43223	3.60	10.00	7.2000	P=0.590
Diameter of Stanton foramen	Men	35	2.4714	.76603	1.20	4.00	2.2000	Z=1.214
	Women	65	2.7631	1.07624	1.20	5.30	2.4000	P=0.225
Diameter of incisive foramen	Men	35	2.9800	.91033	1.00	4.80	2.9000	Z=1.437
	Women	65	2.7292	.78217	1.20	4.80	2.6000	P=0.151
Distance from foramen to crest	Men	35	7.4257	2.83656	1.40	13.20	7.2000	T=3.511
	Women	65	9.3262	2.43582	3.80	14.40	9.0000	P=0.001

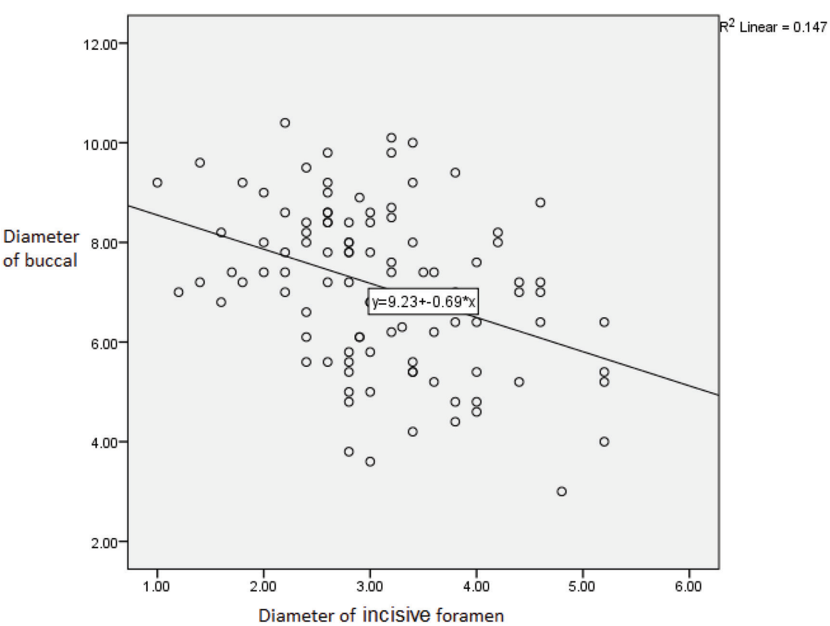

Figure 1 Linear regression graph of two variable diameters for incisive foramen and the diameter of the buccal (mm). The thickness of the buccal cortex is important for implant placement; this graph shows the increasing incisive foramen and diameter of buccal provide reducing the amount of available bone

In Table 1 indicates that the range of canal volume and dispersion around the mean value, in women, is more than men, but mean and median values in the canal volume are more predominant in men, although they were not significant (P = 0.239). The range in canal level in women is more than men. However, the dispersion around the mean and median in canal levels in women is less than men. The mean value in the canal level in men is predominant than women significantly (P = 0.014).

The mean diameter range of Stanton foramen and dispersion is more in women, but median and mean in men is more than women. But the difference was not significant (P = 0.946). The range in diameter of the incisive foramen in women is more than men, dispersion around the median and mean in men is more than women but mean in women is more than men. But the difference was not significant (P = 0.634). The overall indicators for the length of canals such as mean value, standard deviation, and range in men are more than women, and median in men is greater than women significantly (P <0.001).

All the indicators of buccal diameter including median value, standard deviation, and range in men, are more prominent in women. But, the mean value of them in men are more predominant, although this difference was not significant (P = 0.590). The overall indicators for Stanton foramen width including mean value, standard deviation, and range in men are less than women, but the median value in men is lesser, although this difference was not significant (P = 0.225)

Table 2 The correlation coefficient between each variable and the test result

Variable	Correlation coefficient	Volume of canal	Level of canal	Width of Stanton foramen	Width of incisive foramen	Length of canal	Diameter of buccal	Diameter of Stanton foramen	Diameter of incisive foramen	Distance from foramen to crest
Volume of canal	Correlation coefficient	$r_s=1$	$r_s=.794^{**}$	$r_s=.562^{**}$	$r_s=.480^{**}$	$r_s=.173$	$r_s=-.285^{**}$	$r_s=.399^{**}$	$r_s=.426^{**}$	$r_s=-.126$
	p-value		<0.001	<0.001	<0.001	.242	.005	<0.001	<0.001	.288
Level of canal	Correlation coefficient	$r_s=.794^{**}$	r=1	$r=.400^{**}$	$r=.385^{**}$	$r_s=.410^{**}$	r=-.183	$r_s=.261$	$r_s=.396^{**}$	r=-.095
	p-value	<0.001		<0.001	<0.001	<0.001	.069	.076	<0.001	.348
Width of Stanton foramen	Correlation coefficient	$r_s=.562^{**}$	$r=.400^{**}$	r=1	$r=.488^{**}$	$r_s=-.093$	r=-.188	$r_s=.379^{**}$	$r_s=.319^{**}$	r=-.144
	p-value	<0.001	<0.001		<0.001	.175	.061	<0.001	.006	.152
Width of incisive foramen	Correlation coefficient	$r_s=.480^{**}$	$r=.385^{**}$	$r=.488^{**}$	r=1	$r_s=-.248^{*}$	$r=-.384^{**}$	$r_s=.364^{**}$	$r_s=.433^{**}$	r=.016
	p-value	<0.001	<0.001	<0.001		.012	<0.001	<0.001	<0.001	.876
Length of canal	Correlation coefficient	$r_s=.173$	$r_s=.410^{**}$	$r_s=-.093$	$r_s=-.248^{*}$	$r_s=1$	$r_s=.088$	$r_s=-.108$	$r_s=.044$	$r_s=-.211^{*}$
	p-value	.242	<0.001	.175	.012		.324	.139	.928	.038
Diameter of buccal	Correlation coefficient	$r_s=-.285^{**}$	r=-.183	r=-.188	$r=-.384^{**}$	$r_s=.100$	r=1	$r_s=-.273^{**}$	$r_s=-.345^{**}$	$r=.259^{**}$
	p-value	.005	.069	.061	<0.001	.324		.008	<0.001	.009
Diameter of Stanton foramen	Correlation coefficient	$r_s=.399^{**}$	$r_s=.261$	$r_s=.379^{**}$	$r_s=.364^{**}$	$r_s=-.108$	$r_s=-.273^{**}$	$r_s=1$	$r_s=.278^{**}$	$r_s=.052$
	p-value	<0.001	.076	<0.001	<0.001	.139	.008		.002	.747
Diameter of incisive foramen	Correlation coefficient	$r_s=.426^{**}$	$r_s=.396^{**}$	$r_s=.319^{**}$	$r_s=.433^{**}$	$r_s=.044$	$r_s=-.345^{**}$	$r_s=.278^{**}$	$r_s=1$	$r_s=-.093$
	p-value	<0.001	<0.001	.006	<0.001	.928	<0.001	.002		.235
Distance from foramen to crest	Correlation coefficient	$r_s=-.126$	r=-.095	r=-.144	r=.016	$r_s=-.211^{*}$	$r=.259^{**}$	$r_s=.052$	$r_s=-.093$	r=1
	p-value	.288	.348	.152	.876	.038	.009	.747	.235	

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)
r : Spearman correlation coefficients

And the last, overall indicators for incisive foramen including mean value, standard deviation, and range in men are more prominent as well as median value in men is more than women, in spite of the difference was not significant (P = 151). Range and dispersion around the mean value in the variable of distance from foramen to crest in men are predominant. However, the median value in women was more prominent. The mean value was also significantly higher in women than men (P = 0.001).

The correlation between the variables

The following Table 2 shows data about the correlation between two variables r and p in the form of statistics. The number of variables for all was 100 samples equally. So there was no need to include them in the table and due to the high volume of commentaries of following table only meaningful data mentioned in the table was described below the table.

In Table 2 above indicates that by increasing the volume of the canal, the sizes related to the level of the canal, the diameter of Stanton foramen and incisive foramen, the width of Stanton foramen and incisive foramen were increased significantly as well as the diameter of the buccal reduced significantly (P<0.001). Increasing levels of the canal, the sizes related to the volume of the canal, the diameter of Stanton and incisive foramen, also length and width of the incisive foramen were increased significantly (P<0.001). Also, by increasing diameter of Stanton foramen, the size of the volume and levels of the canal, the diameter of the incisive foramen, the width of Stanton and incisive foramen were also significantly increased (P<0.001).

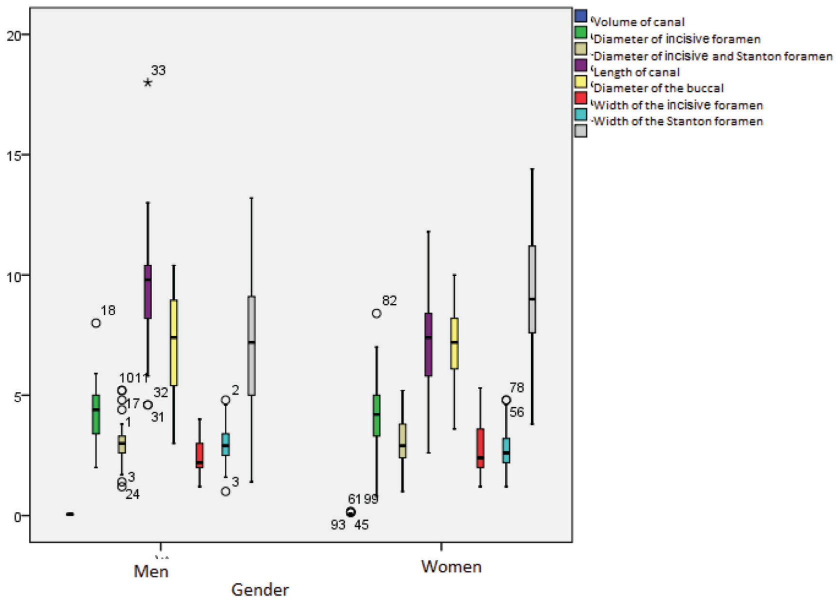

Figure 2 The Bar Graph shows data distribution comparison (except for canal level) between women and men (vertical axis in millimeters). As can be seen above, the overall length in men is more than women recorded. On the other hand, the median distance from foramen to crest in women is more than men

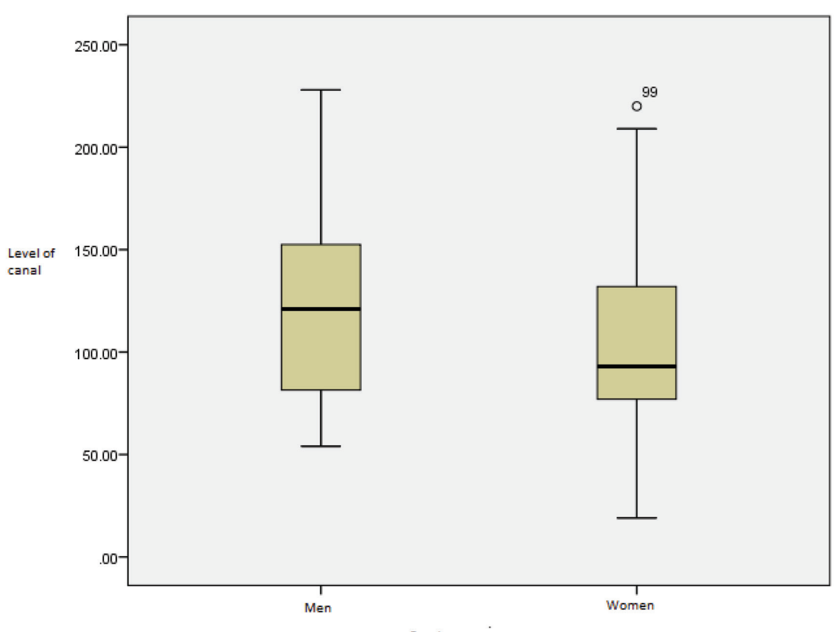

Figure 3 The diagram is comparing canal level between women and men (vertical axis in cubic millimeters). The range of canal level in women is more than men. But the data dispersion around the mean and median value of canal levels in women is less than men. But, the mean value for canal level in men is more than women significantly

Increasing diameter of the incisive foramen, data showed that the sizes related to volume and level of the canal, the diameter of Stanton foramen, the width of Stanton foramen, and width of incisive foramen also increased significantly (P<0.001). But the sizes related to the length of canal and diameter of buccal were reduced significantly. In addition to the increase of the canal length, the sizes related to the level of the canal also increased significantly, and the sizes related to the diameter of incisive foramen as well as the distance from foramen to crest were reduced significantly (P<0.001). Furthermore, increasing the diameter of the buccal just the size related to distance from foramen to crest were increased significantly, and the sizes related to the canal volume also diameter and width of the incisive and Stanton foramen were decreased significantly (P<0.001). In addition to increasing the width of the Stanton foramen, the sizes related to the volume of the canal, the diameter of incisive and Stanton foramen, as well as the width of the incisive foramen, were increased significantly but the diameter of the buccal decreased significantly (P<0.001). And the last, the increasing of width for the incisive foramen, sizes related to the volume of the canal, canal level, the diameter of incisive foramen and width of the Stanton foramen significantly increased and the diameter of the buccal significantly reduced. With increasing distance from foramen to crest, sizes related to the diameter of buccal were increased significantly, but the length of canal declined significantly (P<0.001).

DISCUSSION

The study showed that mean of volume, level and length of the canal in men were different significantly (p=0.239, p=0.014, and p <0.001 respectively). The mean width of the incisive foramen was more significant in men than women (p = 0.015), but despite the higher mean diameter of the Stanton foramen and buccal in men was not statistically significant (p=0.946 and p=0.590, respectively). On the other hand, mean diameter of the incisive foramen, the width of Stanton foramen, and distance of foramen to crest in women is more than in men, the only significant difference was found between the distance of foramen to crest (p=0.634, p=0.225, and p=0.001, respectively). There are some studies comparing this result about incisive canal dimensions between men and women. These studies showed that the overall length and width of the canal in men were more significant than women. Among these studies, a craniometric study by Iordanishvilli showed that the diameter of the nasopalatine canal is higher significantly in men and elderly.[10] In addition, Guler et al. in 2005 by using panoramic X-ray reported that men have great canals significantly.[12] Similarly, Liang et al. in 2009 by using spiral CT reported that the canal diameter was higher significantly in men (p=0.000001) than women.[13]

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Another study which was conducted by Güncü et al. in 2013 examined the influence of gender and tooth loss on incisive canal characteristics and buccal bone dimensions in the anterior maxilla.[14] There were 417 male and 516 female patients who using Computed tomographies (CTs) already evaluated. Mean incisive canal length was 11.96 ± 2.73 mm and 10.39 ± 2.47 mm in men and women, respectively. The mean canal diameters were 2.79 ± 0.94 mm and 2.43 ± 0.85 mm, in men and women respectively (P< 0.05).[14] The result repeated in other studies via CBCT. This study also similar with study by Fernández-Alonso et al. in 2014 showed that there were significant differences between the genders regarding length of canal in men than women (P<0.001).[9]

Based on morphology and nasopalatine canal size, a study was conducted by Bornstein et al. which analyzed IC in 100 CBCTs suggested that they were highly variable. The variability was related to some factors such as genders, ages, and central incisors as well as time since teeth loss.[7] Among them, the causes which could be effective besides to gender dimensions and canal features were the age factor. The relationship of age and an increased diameter IC was noteworthy that with increasing age, increases the number of cases and may be due to the increased diameter in older people due to bone loss.

In this context, the study of Mardinger et al. observed that subsequent of teeth loss, Nazvpalatyn diameter of the nasopalatine canal had been increased significantly.[4] After tooth loss, atrophy from lack of use may be influenced by the surrounding structures. The nasopalatine canal may be broader and may eventually nerve-vascular bundle inside it, come out from the crest ridge. However, in contrast to those observations, the study of Güncü et al. have been reported although tooth loss decreased length of IC and size of buccal bone. However, it didn't change the diameter of canal.[14]

And the last, other factors in studies were considered as an influencing factor on nasopalatine canal dimensions, whether they had or had not dentition. Some studies showed that there were significant differences of canal dimensions between patients with dentition and without teeth reported.[13,14] These results also similar with a study by Liang et al. which observed that canal dimensions were significant with age, as well as by increased of IC diameter IC (P=0.04).[14] In this study, there was no significant relationship between the diameter of the edentulous group and dental groups (respectively 3.6 and 3.5 mm, p = 0.7). However nasopalatine canal in dental groups significantly longer in the edentulous group reported (respectively 10.6 and 9.2 mm, p = 0.003).[13]

CONCLUSION

In this study was trying to examine the dimensions of the incisive foramen position in patients with edentulous anterior maxilla using cone-beam computed tomography (CBCT). It was found that the mean volume, level, and length of the canal is greater in men. However, the difference was only significant in the level and length. On the other hand, the mean of the incisive foramen diameter, the width of Stanton foramen, and also the distance of foramen to crest is prominent in women. Most of the edentulous patients showing that the width of incisive foramen (measured in the coronal sections) and more than half of foramen diameter (measured in sagittal sections) were more than 2.5 millimeters. Therefore, in such cases, it is recommended that instead of replacing one or both central incisors, by using lateral incisors for the implant to build bridges based on dental implantations were better for aesthetic considerations and patient satisfaction as well.

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