Relationship of central incisor implant to the ridge configuration anterior to the nasopalatine canal in dentulous and partial edentulous individuals: A comparative study

Xueting Jia, Wenjie Hu, Huanxin Meng

Background: The aims of this study were to investigate the contour alteration of the ridge anterior to the nasopalatine canal after tooth loss and the difference between the incidences of the nasopalatine canal perforation in dentulous and edentulous patients by cone-beam computed tomography. Methods: 72 cone-beam computed tomography scans were selected from database. In 36 subjects of them, both maxillary central incisor were present, while the rest were edentulous ridges missing one maxillary central incisor. The configuration of the ridge anterior to the canal were recorded, including lingual concavity depth, lingual concavity height, lingual concavity angle, bone height coronal to the incisive foramen, and bone width anterior to the canal. The incidence of perforation were evaluated after implant placement in the cingulum position with the long axis following that of its restoration on images. Results: Comparing with variable values in dentulous patients, the lingual concavity depth and angle were greater by 0.9 mm and 4°, and bone height was shorter by 1.1 mm in edentulous patients, respectively. Besides, bone width in edentulous patients was narrower than in dentulous patients by 1.2 mm at incisive foramen level and 0.9 mm at 8 mm subcrestal level, respectively. After 72 virtual cylindric Implants (4.1 × 12 mm) were placed, a total of 12 sites (16.7%) showed a perforation and three-fourths occurred in edentulous patients. After replacing with 72 tapered implants (4.3 × 13 mm), a total of 6 implants (8.3%) broke into the canal, which all belonged to edentulous patients. Conclusions: The nasopalatine canal may get close to the implant region after the central incisor extraction, and the bone width anterior to the canal may also reduce. The perforations may occur more commonly in edentulous patients.

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Abstract

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Methods: 72 cone-beam computed tomography scans were selected from database. In 36 subjects of them, both maxillary central incisor were present, while the rest were edentulous ridges missing one maxillary central incisor. The configuration of the ridge anterior to the canal were recorded, including lingual concavity depth, lingual concavity height, lingual concavity angle, bone height coronal to the incisive foramen, and bone width anterior to the canal. The incidence of perforation were evaluated after implant placement in the cingulum position with the long axis following that of its restoration on images.

Results: Comparing with variable values in dentulous patients, the lingual concavity depth and angle were greater by 0.9 mm and 4°, and bone height was shorter by 1.1 mm in edentulous patients, respectively. Besides, bone width in edentulous patients was narrower than in dentulous patients by 1.2 mm at incisive foramen level and 0.9 mm at 8 mm subcrestal level, respectively. After 72 virtual cylindric Implants (4.1 × 12 mm) were placed, a total of 12 sites (16.7%) showed a perforation and three-fourths occurred in edentulous patients. After replacing with 72 tapered implants (4.3 × 13 mm), a total of 6 implants (8.3%) broke into the canal, which all belonged to edentulous patients.

Conclusions: The nasopalatine canal may get close to the implant region after the central incisor extraction, and the bone width anterior to the canal may also reduce. The perforations may occur more commonly in edentulous patients.

Keywords: alveolar bone, anterior maxilla, cone-beam computed tomography, dental implants, nasopalatine canal

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Introduction

Dental implant restoration has become a very common treatment in dental practices.[1-3] In the esthetic zone, the primary goal of implant treatment is to re-establish both esthetics and function.[4] As generally accepted, the implant placement is supposed to be based on a restorative-driven philosophy.[5] According to this concept, the three-dimensional ideal implant position has been described.[6-10] Mesiodistally, a single implant should be no closer than 1.5 mm away from adjacent root surface. Apicocoronally, the implant platform is supposed to be placed 2 to 4 mm apical to the expected midfacial gingival margin. Buccolingually, the implant should be positioned slightly palatal to the incisal edge and 2 mm of buccal bone is recommended. With regard to the implant axis, in order to use a prefabricated abutment and a screw-retained crown, and to avoid excessive off-axis loading, placement of an implant axis in alignment with the crown is recommended.[11]

However, in both implant and delayed implant therapy, the nasopalatine canal (NPC) is often an anatomical limitation for a maxillary central incisor implant placement in an ideal position according to the restorative-driven philosophy. The NPC is a bony channel located posterior to the maxillary central incisors and connects the nasal floor with the oral cavity. The NPC contains the nasopalatine nerve and the terminal branch of descending nasopalatine artery, as well as fibrous connective tissue, fat, and even small salivary glands.[12,13] The relative location of NPC in the maxilla was usually described by assessing the dimension of the buccal bone plate anterior to this canal in many studies, and a closer proximity of NPC to the implant surgical site after tooth extraction has been reported.[14-16] Insertion of implants into the NPC may lead to contact of implants with connective tissue and cause non-osseointegration[17] or nasopalatine duct cyst.[18-20]

Kraut & Boyden reported that the likelihood of finding a nasopalatine canal of a size that will be detrimental to the placement of dental implants was approximately 4% by evaluating the volumes of the NPC and bone anterior to the canal in CBCT images of 30 American patients.[21] However, the incidence of perforation into the NPC is associated with not only the anatomic morphology, but also the feature of the implant and the three-dimensional implant position. Although the relative location of the central incisor implant and the NPC was very important, the incidence of perforation into the NPC when a central incisor implant is placed in an ideal position following an optimal axis was not well known yet. In addition, whether the change of the ridge morphology caused by tooth loss will increase the incidence of perforation has not been assessed. Besides, the feature of the exposure and the risk factors of the perforation have never been analyzed. Whether a tapered implant or a minor adjustment of implant angulation could be beneficial for avoidance of perforation was also not well known.

Cone-beam computed tomography (CBCT) has been widely used in clinical evaluation before implant surgery because of the capability of accurate three-dimension imaging.[22] Moreover, virtual implant placement in CBCT images could provide an overall evaluation of implant position, as well as the proximity of the implant to the anatomic structure.[23,24] Therefore, the aims of this study are to investigate the contour alteration of the ridge anterior to the nasopalatine canal after tooth loss and the difference between the incidences of the nasopalatine canal perforation in dentulous and edentulous patients by cone-beam computed tomography.

Materials and Methods

Patient Selection

This study was approved by the Biomedical Ethics Committee of Peking University School of Stomatology (approval ID PKUSSIRB-201519006). The pre-existing CBCT data (Vatech CT, Korea) selected for this study were performed from January 2011 to July 2014 for treatment planning of implant procedures. Appropriate methodology and sample size were determined by a pilot study and power analysis. It was determined that a sample of 36 specimens per group (for a total sample of 72) was needed to represent a clinically significant difference in bone width anterior to the nasopalatine canal. The sample size was calculated with $\alpha = 0.05$ and power = 0.90.

Images selected for this study had to fulfill the following inclusion criteria: (1) Chinese adults; (2) clear view without scattering artifacts; (3) complete image of the NPC; (4) all six maxillary anterior teeth were present or only one maxillary central incisor and at least one pair of maxillary lateral incisors or one pair of maxillary canines were present; (5) the present maxillary anterior teeth without obvious crowding or spacing; (6) no deep overbite or deep overjet in the anterior teeth area; (7) at least two pairs of posterior teeth which could be retained with occlusal contact on each side. Images were excluded if: (1) both maxillary central incisor were present but the amount of alveolar bone loss exceeded one third of root length; (2) unhealed extraction sockets; (3) bone graft material was present in the images; (4) both maxillary central incisors were missing; (5) alveolar ridge height of implant region was less than 14 mm or the ridge width was less than 3.5 mm at the level of 2 mm below the bone crest. Images were categorized into two groups according to dental status. That all maxillary anterior teeth were present was classified as dentulous group, while the edentulous ridge missing one maxillary central incisor was classified as edentulous group. The distributions of age, gender, NPC shape[15] on sagittal slice and implant site were well matched between two groups, respectively.

Data Reconstruction

All images were obtained using a CBCT machine (Vatech CT, Korea) in the Peking University School of Stomatology by experienced radiologists. The imaging parameters were set at 90 kVp, 7.0 mAs, scan time 24 seconds, resolution 0.15 mm and a field of view that varied based on the region scanned. The scans included in this study were selected from the database and processed with a measurement software program (Ez3D2009 Premium Ver. 1.2.1.0) in a password-protected computer. The observer filtered CBCT images using Liquid Crystal Display at a 1,280 × 1,024 screen resolution under room lighting. The distance between display and the observer was 30 cm approximately. The scans were reoriented so that the maxilla was bilaterally symmetric and the long axis of the sagittal CBCT slice was determined following the long axis of the crown (connecting the buccolingual midpoint at the cementoenamel junction and the point at the incisal edge) of the maxillary central incisor. The data were reconstructed with slices at an interval of 0.5 mm. The luminance and grayscale were adjusted to obtain clear CBCT views.

Configuration of Ridge Anterior to the NPC

The lingual concavity of the alveolar ridge anterior to the NPC was analyzed by observing the sagittal slices (Fig 1 A) and measuring:

(1) The lingual concavity depth (LCD), the distance between the deepest point of the buccal plate on the lingual side and a reference line parallel to the sagittal long axis of the central incisor crown and passing through the labial opening of incisive foramen.

(2) The lingual concavity height (LCH), the distance between the deepest point of the buccal plate on the lingual side and a reference line perpendicular to the sagittal long axis of the central incisor crown and passing through the alveolar bone crest.

(3) The lingual concavity angulation (LCA), the angulation between the line connecting the deepest point of the lingual concavity and the labial opening of incisive foramen and the line parallel to the long axis of the central incisor crown and passing through the deepest point of the lingual concavity.

Subsequently, the height of the alveolar bone coronal to the NPC (BH) was also recorded by measuring the vertical distance between the alveolar bone crest and the line perpendicular to the sagittal long axis of the central incisor crown and passing through the labial opening of incisive foramen in the midsagittal plane of the NPC (Fig 1 A).

In addition, the minimum width of buccal bone plate anterior to the NPC (BW) was measured in the axial view images at three levels: incisive foramen level, 8 mm subcrestal level and 14 mm subcrestal level (Fig 1 B).

Relative Location of the NPC and the Virtual Implant

72 Cylindric implants (Straumann Bone-Level Implant, 4.1 × 12 mm) and 72 tapered implants (Nobel Replace Select Tapered Implant 4.3 × 13 mm) were placed virtually in the selected

maxillary central incisor sites sequentially.

In the dentulous group, each implant was placed in the midsagittal plane of selected maxillary central incisor mesiodistally. Buccolingually, the most lingual point of the implant platform was located at that of the cingulum of this central incisor. Apicocoronally, the implant platform was placed 2 mm below the crestal level. The sagittal long axis of the implant was parallel to that of the central incisor crown (Fig 2 A-C).

In the edentulous group, each implant was placed in the center of the edentulous site mesiodistally. Buccolingually, the implant platform was also placed at the cingulum position.[11] The details were present as follows: connecting the most prominent points of the two lateral incisors or the two canines on their lingual side to draw a reference line and measuring the distance between the cingulum of the natural contralateral central incisor at its most lingual point and the reference line, and then the most lingual point of the implant platform was placed labial to the reference line by the same distance. Apicocoronally, the location of the implant platform was the same as that of the dentulous group. The sagittal long axis of the implant was parallel to that of the contralateral central incisor crown (Fig 2 D-F).

After each virtual implant was placed, whether the implant broke through the interior wall of the NPC was assessed in the sagittal and axial views slice by slice. For the NPC perforation cases caused by cylindric implants, the position of the implant platform was kept unchanged and the embedded direction was rotated distally and labially by a minor angulation (5° and 10°), respectively. The size and the location of each perforation were measured in the sagittal and axial view images, which included its length, depth, area and the distance between the most coronal point of the perforation and the alveolar bone crest.

All measurements were conducted by two examiners. The inter- and intraexaminer agreement was determined by comparing two repeated measurements at 20 randomly chosen sites taken 1 week apart.

Statistical Analysis

All statistical analysis was performed using a statistical package (IBM, SPSS Statistics 19.0). The inter- and intraexaminer agreement was determined using a t test. All measurements were presented as means ± standard deviations (SDs). The occurrence of the NPC perforation was expressed as the number of sites and the percentage of the number of sites divided by the total number of sites. The LCD, LCH, LCA, BH and BW were compared between dentulous group and edentulous group by Mann-Whitney U test. The chi-square test was used to compare the incidences of perforation between groups, genders and sides. Univariate and multivariate logistic regression analyses were performed to identify risk factors associated with the NPC perforation. The significance level (P value) was set at 0.05.

Results

A total of 703 subjects were screened and 72 subjects (54 males and 18 females) were selected for this study. The mean age was 45.6 years, with a range of 28 to 64. Each group consisted of 36 subjects. The age, gender and implant site were well matched between the dentulous group and the edentulous group, respectively. The distribution of NPC shape recorded on sagittal plane did not show statistically significant differences between groups (Table 1). The intraexaminer and interexaminer agreements were 0.94 and 0.87, respectively.

Table 2 illustrated the measuring results of configuration of ridge anterior to the NPC. A total of 54 ridges (75.0%) showed a lingual concavity in sagittal views. The mean LCD, LCH and LCA values were 1.8 ± 1.7 mm, 14.3 ± 7.3 mm and 8.6 ± 6.5°, respectively. On average, the incisive foramen was located at 5.9 ± 2.3 mm below the alveolar bone crest. The mean BWs at the incisive foramen level, 8 mm and 14 mm subcrestal level were 6.0 ± 1.7 mm, 6.3 ± 1.5 mm and 6.9 ± 1.9 mm, respectively.

Results of comparisons of ridge configuration between the dentulous group and the edentulous group were also present in Table 2 and Fig 4. With respect to the lingual concavity, the mean LCD was statistically significantly different between the dentulous group and the edentulous group (1.4 ± 1.4 mm vs. 2.3 ± 1.9 mm, $p = 0.036$). In addition, the mean LCA values of the dentulous group and the edentulous group were 6.6° and 10.6° respectively, which was also statistically significantly different ($p = 0.022$). The distance between the incisive foramen and the bone crest was closer in the edentulous group than that in the dentulous group by 1.1 mm approximately ($p = 0.022$). At the incisive foramen level, the mean BW was statistically significantly thinner in the edentulous group than the dentulous group by 1.2 mm approximately (5.4 ± 2.5 mm vs. 6.6 ± 1.1 mm, $p = 0.013$). Furthermore, the mean BWs measured at 8 mm subcrestal level of the dentulous group and the edentulous group were 6.7 mm and 5.8 mm respectively, which was also statistically significantly different ($p = 0.028$). The LCH and BW measured at 14 mm subcrestal level did not show statistically significant differences between the two groups.

After 72 virtual cylindric implants (4.1 × 12 mm) were placed, a total of 12 sites (16.7%) showed a perforation (Table 3). Three cases of them occurred in the dentulous group (8.3%) while other nine cases occurred in the edentulous group (25.0%). The incidence of perforation was much higher in the edentulous group, although the statistically significant difference did not exist ($p = 0.058$). With respect to the implant site, the incidence of perforation was statistically significantly higher in the right central incisor site than in the left central incisor site (33.3% vs. 4.8%, $p = 0.001$). The occurrence of perforation did not show statistically significant differences between genders. In the axial view images, all the perforations were located at the mesiolingual site of the virtual implant. Furthermore, the depth and the area of exposure were 0.7 ± 0.6 mm (range = 0.2 - 2.1 mm) and 1.0 ± 1.3 mm^2 (range = 0.2 - 4.7 mm^2), respectively. In the sagittal view images, the exposure located at 8.5 ± 3.5 mm below the alveolar bone crest, with a range of 2.3 mm to 12.1 mm, and the length of the exposure was 5.1 ± 3.4 mm, with a range of 1.6 mm to 12.0 mm.

After replacing the cylindric implants with the tapered implants (4.3 × 13 mm), a total of 6 implants (8.3%) broke into the NPC, which all belonged to the edentulous group (Table 3). The incidence of perforation with the selected tapered implant was statistically significantly different between the dentulous and edentulous groups ($p = 0.011$). Besides, five out of six perforations occurred in the right central incisor sites, and the statistically significant difference existed between different sides ($p = 0.031$). The location of the exposure was at the 6.2 ± 3.2 mm below the alveolar bone crest. The length, depth and area of the exposure were 5.4 ± 3.1 mm, 0.8 ± 0.6 mm and 1.3 ±

1.7 mm^2, respectively.

The numbers of perforation sites was reduced to 4 (5.6%) and 2 (2.8%) by rotating the embedded direction of the cylindric implant distally by 5° and 10°, respectively. After the embedded direction was rotated labially by the same degrees (5° and 10°), the incidence of perforation decreased to 8.3% and 4.2%, respectively. The changes of incidences of perforation, as well as the features of exposure after a minor adjustment of cylindric implant angulation, were present in Table 4.

The multivariate logistic regression analysis revealed that the LCD was a statistically significant risk factor of perforation (OR 4.332; 95% CI 1.596 – 11.760; p = 0.004). Implant placement in the left central incisor site (OR 0.087; 95% CI 0.010 – 0.783; p = 0.029) and BW measured at 8 mm below the alveolar bone crest (OR 0.273; 95% CI 0.111 – 0.671; p = 0.005) were two protective factors appeared in the last model.

Discussion

In 2014, Chan et al. found that a buccal concavity of ridge existed anterior to the maxillary central incisor.[11] The mean buccal concavity depth was 3.42 mm, and it was associated with the occurrence of buccal plate fenestration. However, few studies have provided information regarding the lingual concavity and its relationship with the NPC perforation. In the present study, all the virtual implant were located at the labial-distal side of the NPC. Therefore, an obvious lingual concavity, which means the NPC is located labially relatively, may increase the risk of contact of implant and the neurovascular bundles in the NPC. In our study, 75% of ridges were present with a lingual concavity. More importantly, the lingual concavity depth was a statistically significant risk factor of NPC perforation. Therefore, not merely the incisive foramen, but also the trend of the NPC direction should be carefully evaluated by CBCT to estimate whether the implant will break into the interior wall of the NPC.

Bone dimensions anterior to the NPC is important for implant placement. In most studies, the width of the bone anterior to the canal was measured at crestal, middle, and (or) the most apical point of the canal in the midsagittal plane of the NPC, and the reference line was perpendicular to the maxillary plane or the sagittal long axis of the canal.[14,16] A mean bone width of 7.17 ± 1.49 mm has been reported in a multicenter study.[14] However, the implant is rarely placed in the midsagittal plane of the NPC, and also not involving the nasal part of the canal. In addition, the embedded direction may be different from the direction of measurement mentioned above. As a result, the data obtained by this measuring method might not reflect the implant condition accurately. In this study, the bone width anterior to the NPC was first measured in the axial view images at three levels: the incisive foramen level, 8 mm below the alveolar bone crestal level, and 14 mm below the crestal level. The incisive foramen level is where the NPC might start to hamper the implant placement. The 8 mm and 14 mm below the bone crestal levels may stand for the middle level and the apex level of the virtual implant selected in this study, respectively. In addition, the measuring direction was perpendicular to embedded direction of implant, that is, the sagittal long axis of the restoration. As a result, the measuring results of the present study may reflect the real implant condition more accurately. In the present study, the mean bone width anterior to the NPC was 6.0 and 6.3 mm at the incisive foramen level and 8 mm below the alveolar crest level, respectively, much narrower than the bone width (7.17 mm) reported by Tözüm et al.[14]

In the present study, the incidence of NPC perforation during the maxillary central incisor implant procedure was evaluated by placing a virtual implant in CBCT images. After a cylindric central incisor implant (4.1 × 12 mm) was placed in the cingulum position with the long axis following that of its restoration, the incidence of NPC perforation was 16.7%. In 1998, Kraut & Boyden reported that the likelihood of finding a nasopalatine canal of a size that will be detrimental to the placement of dental implants was approximately 4%, much lower than the likelihood present in our study, by evaluating the volumes of the NPC and bone anterior to the canal in CBCT images of 30 American patients.[21] The difference of incidence was probably due to two reasons. The first reason was totally different measurements. Considering that the incidence of NPC perforation is associated with not only the anatomic morphology, but also the feature of implant and the three-dimensional implant position, the results present in our study may reflect the clinical implant condition more accurately. The second reason was different sample races. Another study of our research team showed that the mean closest distance between the NPC and the apex of the central incisor root were 3.88 mm in axial CBCT images (unpublished data, Jia X et al.), much closer than the mean distance of 5.22 mm reported by Chatriyanuyoke et al.[25] The comparison of the closest distances implied that insertion of implants into the NPC might be more likely to occur in Chinese patients.

The absence of maxillary central incisors affected some dimensions and incidence of NPC perforation. The results of comparison between the dentulous and edentulous group revealed that, the LCD and LCA were statistically significantly greater in the edentulous group by 0.9 mm and

4°, respectively, although the distribution of NPC shape recorded on sagittal plane did not show statistically significant differences between groups. Mardinger et al. also found that the bucco-lingual NPC diameter was wider along the degree of ridge resorption.[15] In the present study, it is implied that a closer proximity of NPC and implant region might be present after tooth loss. In addition, bone width anterior to the canal and the bone height coronal to the canal were greater in dentate subjects in the present study by 1.2 mm and 1.1 mm respectively, mainly due to the alveolar bone remodeling after tooth loss.[26,27] Other studies found the same results about change of bone width after tooth loss as the present study.[14,15] Considering the ridge modeling after tooth loss, including the change of LCD, LCA, BH and BW as mentioned before, it would be no surprise that the incidence of NPC perforation was higher in the edentulous group than the dentulous group (25.0% vs. 8.3% after cylindric implant placement; 16.7% vs. 0.0% after taper implant placement). Delayed implant placement in the maxillary central incisor site may require more care to avoid NPC perforation.

Another interesting finding was that the perforation usually occurred in the right central incisor site. The multivariate logistic regression analysis also revealed that the implant site was associated with the occurrence of NPC perforation. This may be due to another finding of our research team that the NPC was located on the right side at both the incisive foramen level and the apex level slightly (unpublished data, Jia X et al.).

Regarding clinical practice, the location, length, depth, and area of perforation were described in detail. In the axial view images, all the perforations were located at the mesio-lingual side of the implant. However, in the sagittal view images, the perforation could occur at any part of implant (2.3 – 12.1 mm below the bone crest). The mean distance between the exposure and the crest was 8.5 mm in the present study, which meant that the perforation usually occurred at the midroot level of the implant. In the cases of perforation, a mean length of exposure of 4.53 mm predicted that the NPC perforation could not be ignored. However, on the other hand, the depth of exposure was only 0.7 mm on average, which meant that a tapered implant or a minor adjustment of implant angulation might be beneficial for avoiding NPC perforation.

The results of this study were consistent with this hypothesis. In this study, the diameter of the selected tapered implant platform (4.3 × 13 mm) was a little greater than the cylindric implant by 0.2 mm, but the diameter of the tapered implant narrowed to 4.1 mm at about 3.4 mm below the implant platform level, and was only 2.58 mm at the implant apex level, narrower than the cylindric implant by 1.5 mm approximately. Considering the relative shallow depth of exposure after cylindric implant placement, replacing the cylindric implants with the tapered implants (4.3 × 13 mm) significantly decreased the incidence of perforation, from 16.7% to 8.3%. A minor change of embedded direction was also beneficial for avoiding NPC perforation, reducing the incidence to 2.8% - 4.2%. Certain considerations have to be borne in mind before the adjustment of implant angulation, including the proximity of adjacent lateral incisor to the implant site and the existing buccal concavity. The distance between the implant apex and the adjacent root surface should not be closer than 1.5 mm after rotating the implant to the distal, while the buccal plate fenestration is supposed to be avoided during rotating the implant to the labial.

However, neither the selected tapered implant nor a minor adjustment (less than 10°) of implant angulation could avoid NPC perforation thoroughly. Therefore, it is recommended to take full analysis of the NPC using CBCT at the time of implant treatment planning with consideration of individual differences. The results in this study suggested that other appropriate features of implant (e.g. a shorter implant or a narrower implant) or a greater embedded angle that departs from the axis of the restoration might be selected to avoid perforation in some cases.

Conclusions

Within the limits of this study, it can be concluded that the NPC may get close to the implant region after the central incisor extraction, and the bone width anterior to the canal may also reduce. The NPC perforations may occur more commonly in edentulous patients and in the right central incisor site. The right central incisor site, narrow bone width measured at 8 mm below the crest and a deep lingual concavity are associated with the occurrence of NPC perforation. A minor adjustment of implant angulation or a tapered implant may be beneficial for avoidance of perforation.

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Table 1 General characteristics of 72 subjects included in the study

	Total （n=72）	Dentulous group（n=36）	edentulous group（n=36）	p value
Age（mean ± SD）	45.6±8.8	45.5 ± 9.0	45.6 ± 8.8	0.906
Gender（n）				
male	54	27	27	
female	18	9	9	1.000
Implant site（n）				
Right central incisor	30	15	15	
Left central incisor	42	21	21	1.000
Canal shapes (n)				
cylindrical	29	17	12	
funnel-like	17	6	11	
hourglass-like	15	9	6	
banana-like	11	4	7	0.290

Table 2 Ridge configuration and comparison results according to dental status (mean ± SD)

Variable	Total (n=72)	Dentulous group (n=36)	Edentulous group (n=36)	p value
Lingual Concavity				
LCD（mm）	1.8 ± 1.7	1.4 ± 1.4	2.3 ± 1.9	0.036
LCH（mm）	14.3 ± 7.3	13.9 ± 7.8	14.8 ± 6.8	0.539
LCA（°）	8.6 ± 6.5	6.6 ± 5.9	10.6 ± 6.5	0.022
BH (mm)	5.9 ± 2.3	6.5 ± 1.9	5.4 ± 2.5	0.022
BW (mm)				
incisive foramen level	6.0 ± 1.7	6.6 ± 1.1	5.4 ± 2.0	0.013
8 mm subcrestal level	6.3 ± 1.5	6.7 ± 1.2	5.8 ± 1.6	0.028
14 mm subcrestal level	6.9 ± 1.9	7.0 ± 1.6	6.7 ± 2.1	0.401

LCD: lingual concavity depth; LCH: lingual concavity height; LCA: lingual concavity angulation; BH: bone height coronal to the canal; BW: bone width anterior to the canal

Table 3 Frequency distribution of perforation with different implant type

Group	Implants (number)	Number of Perforations (number and percent)	
		Cylindric 4.1 × 12 mm	Tapered 4.3 × 13 mm
Dental Status			
dentulous group	36	3 (8.3%)	0 (0.0%) [**]
edentulous group	36	9 (25.0%)	6 (16.7%) [**]
Implant Site			
right central incisor site	30	10 (33.3%) [*]	5 (16.7%) [***]
left central incisor site	42	2 (4.8%) [*]	1 (2.4%) [***]
Gender			
male	54	7 (13.0%)	3 (5.6%)
female	18	5 (27.8%)	3 (16.7%)
Total	72	12 (16.7%)	6 (8.3%)

[*] Statistically significant difference exists between implant sites with cylindric implant (p = 0.001).

[**] Statistically significant difference exists between dentulous and edentulous groups with tapered implant (p = 0.011) .

[***] Statistically significant difference exists between implant sites with tapered implant (p = 0.031).

Table 4 Change of perforation after a minor adjustment of implant angulation

Embedded Direction	Number (Percent)	Location (mm)	Length (mm)	Depth (mm)	Area (mm^2)
Axis of Restoration	12 (16.7%)	8.5 ± 3.5	5.1 ± 3.4	0.7 ± 0.6	1.0 ± 1.3
Distal by 5°	4 (5.6%)	5.4 ± 3.7	5.5 ± 2.0	0.8 ± 0.4	3.9 ± 4.9
Distal by 10°	2 (2.8%)	2.4 ± 0.1	6.6 ± 2.1	1.1 ± 0.2	2.3 ± 0.7
Labial by 5°	6 (8.3%)	6.8 ± 3.7	5.9 ± 3.9	0.9 ± 0.7	1.5 ± 1.9
Labial by 10°	3 (4.2%)	5.3 ± 4.9	8.2 ± 5.1	1.2 ± 0.9	2.4 ± 2.4

Table 5 Multivariate logistic regression of factors affecting the NPC perforation

Variables	β	OR	95% CI	P Value
Left central incisor site	-2.446	0.087	0.010 - 0.783	0.029
BW measured at 8 mm below crest	-1.299	0.273	0.111 - 0.671	0.005
LCD	1.466	4.332	1.596 - 11.760	0.004
Constant	1.974	7.200		0.329

NPC: nasopalatine canal; BW: bone weight anterior to the canal; LCD: lingual concavity depth.

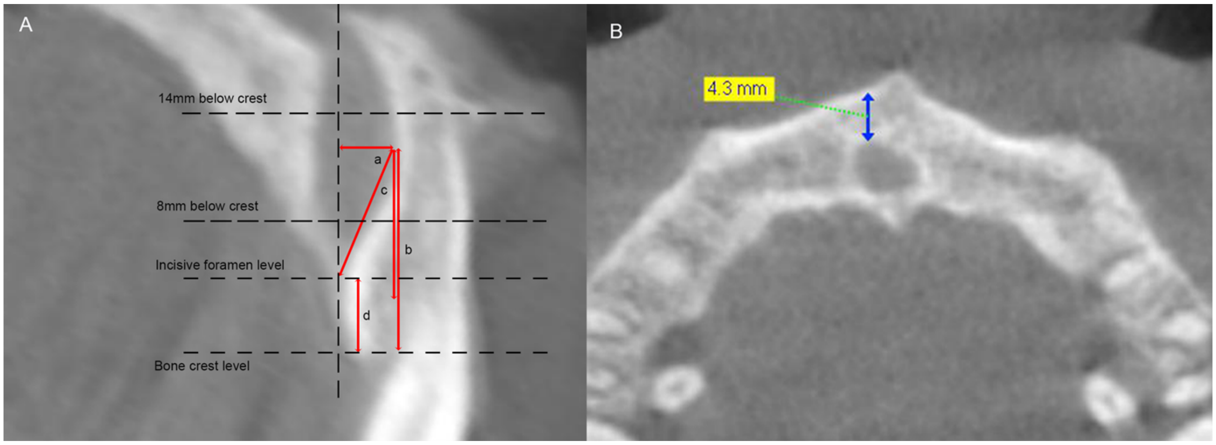

Figure 1 Configuration of Ridge Anterior to the NPC. A, a = the lingual concavity depth (LCD); b = the lingual concavity height (LCH); c = the lingual concavity angulation (LCA); d = the height of the alveolar bone coronal to the NPC (BH). B, the arrow stands for minimum bone width anterior to the NPC (BW), measured at incisive foramen level, 8 mm and 14 mm below bone crest level, respectively.

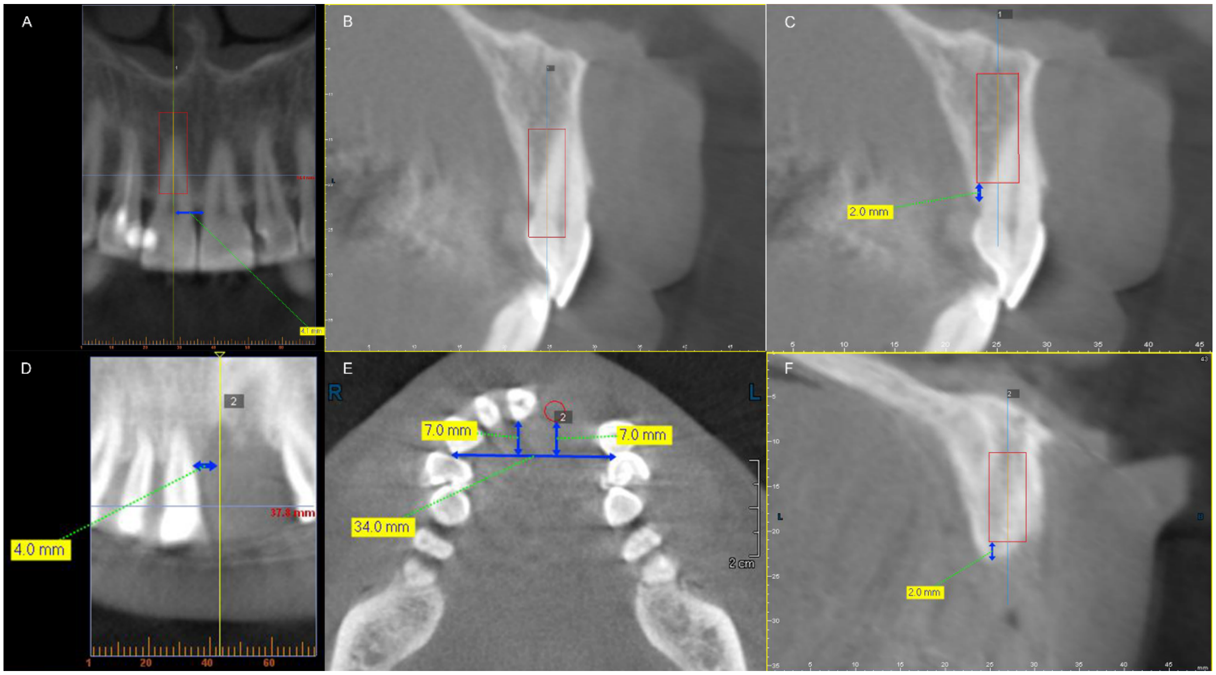

Figure 2 three-dimensional location of virtual implant in dentulous patients (A, B, C) and edentulous patients (D, E, F). A and D, mesiodistal location in dentulous and edentulous group; B and E, buccolingually, the implant platform was placed at the cingulum of the future restoration in both dentulous and edentulous group; C and F, apicocoronally, the implant platform was located 2 mm below the alveolar bone crest in both groups.

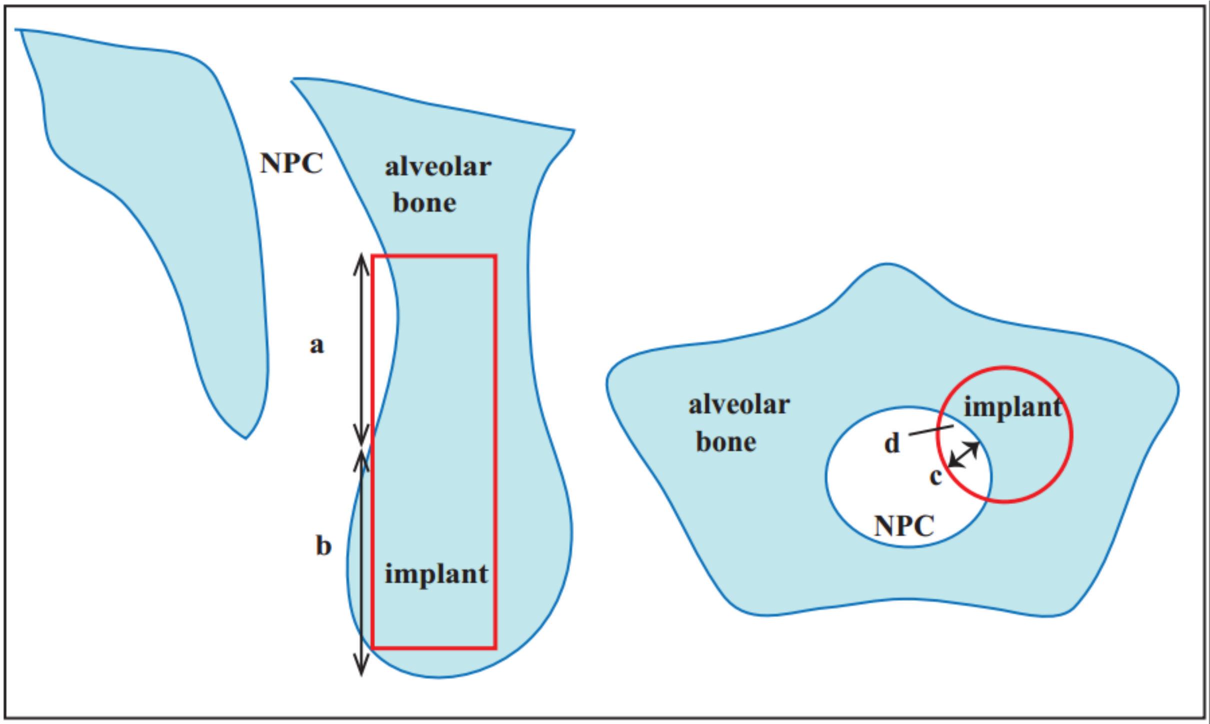

Figure 3 Description of nasopalatine canal (NPC) perforation in both sagittal slice and axial slice.

a = length of exposure; b = distance between the alveolar crest and the perforation (location of perforation); c = the depth of the exposure; d = the area of the exposure.

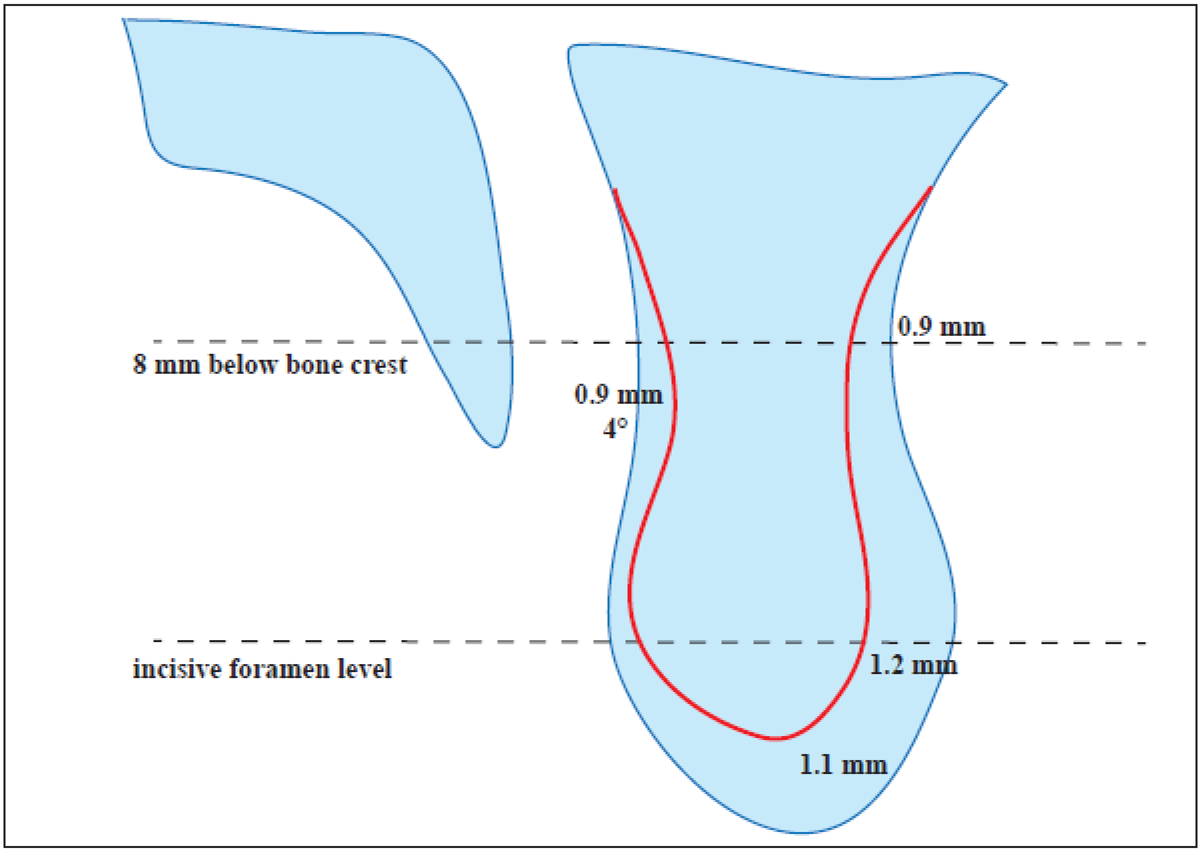

Figure 4 Comparison of ridge configuration anterior to the NPC between dentulous and edentulous patients. The red line stands for the ridge contour of edentulous patients.