Three-Dimensional Analysis of the Anatomical Characteristics and Dimensions of the Nasopalatine Canal Using Cone Beam Computed Tomography

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Abstract

Aim Placement of implants in the maxillary anterior region needs to be preceded by careful analysis of the area as in addition to the functional aspect the esthetic outcome is of prime importance. This descriptive study evaluated anatomical characteristics and dimensions of the nasopalatine canal (NC) from coronal, sagittal and axial aspects using cone beam computed tomography (CBCT) giving it a three dimensional analytical approach. Also the dimensions of the corresponding buccal bone plate (BBP) of the alveolar process were evaluated. Additionally, the influence of age and gender on these characteristics was also analyzed.

Methods A total of 81-CBCT scans of patients with one or no upper central incisors present were selected. Sagittal slices were used for measurements of the NC and BBP and to evaluate shape of the NC. Coronal slices were used to assess NC shape and axial slices to assess number of incisive foramina and foramina of Stenson.

Results The most prevalent canal shape was: cylindrical (48.14 %) in sagittal aspect; Y-type (49.38 %) in coronal aspect; and one incisive foramen with two Stenson's foramina [1–(2–5)] (60.49 %) in axial aspect. Mean NC

length was 11.13 ± 3.23 mm; statistically significant differences were detected between genders ($p < 0.001$). Mean nasopalatine angle was $69.32^\circ \pm 7.70$. Mean BBP length was 17.12 ± 3.97 mm and mean BBP width was 5.71 ± 1.29 mm, significant differences were detected between genders ($p < 0.001$).

Conclusion The current study demonstrates variability of the NC in terms of anatomical characteristics and dimensions; hence, a thorough CBCT analysis is highly recommended for better surgical outcomes and to reduce the post-operative complications in implant dentistry.

Keywords Anterior maxilla · Cone beam computed tomography · Dental implants · Nasopalatine canal · Buccal bone plate

Abbreviations

NC	Nasopalatine canal
BBP	Buccal bone plate
CBCT	Cone beam computed tomography
ANOVA	Analysis of variance
MLRM	Multivariate linear regression model

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Introduction

Rehabilitation of the anterior maxilla with osseointegrated dental implants has become a common treatment protocol over the last few years. In this region, patients often ascribe more importance to the esthetic outcome over the functional aspects of the implant restoration [1].

Failure of implant treatment generally leads to removal of the implant followed by complex tissue and bone augmentation procedures [2]. Contact of implant with the

surrounding neural tissue results in the failure of osseointegration and can also cause some sensory dysfunctions [3].

The pattern of buccal bone plate (BBP) resorption after tooth extraction has been studied by many authors [4–6]. Cawood and Howell [4] observed that the pattern of bone loss in the maxilla varies from that in the mandible. The pattern of bone resorption in the anterior maxilla is generally horizontal, from the buccal surface to the palatal surface [4]. The volume and anatomical characteristics of the bone in anterior maxilla generally poses an anatomical constraint while restoring with implants. Keeping these complications in mind, the anatomic morphology and dimensions of the nasopalatine canal (NC) and corresponding BBP should be carefully evaluated before implant placement in its vicinity.

The NC is generally located in the midline of the palate, posterior to the maxillary central incisors [7]. The NC has an oral opening in the midline of the anterior palate and is known as the incisive foramen, and is located immediately below the incisive papilla. The canal divides into two canaliculi on its way towards the nasal cavity, and terminates at the nasal floor with an opening, known as the foramina of Stenson, at either side of the septum [8]. The canal consists of the incisive nerve and the terminal branch of the descending nasopalatine artery, fibrous connective tissue, fat and even small salivary glands [9]. There are numerous anatomical variations of the NC which are not very well documented in the literature and are often only presented as case reports [3, 7, 10].

Traditionally, two-dimensional methods like intra-oral radiography and panoramic imaging have been recommended in the literature for diagnostic imaging of the anterior maxilla. However, the introduction of cone beam computed tomography (CBCT) has created new diagnostic possibilities in dentistry. CBCT scans have made it possible to analyze anatomical variations of the NC [11, 12] and to determine the degree of BBP resorption in the anterior maxillary region after tooth loss [4–6, 13, 14]. Keeping in mind that the NC may occupy up to 58 % of the BBP width [15], a precise 3-dimensional (3D) anatomic description of the NC to enable safe and accurate surgical planning and placement of dental implants is necessary [16]. To the best of our knowledge, there is no scientific evidence to correlate the tridimensional NC shapes.

The aim of this study was to conduct three-dimensional analysis of the anatomical characteristics and dimensions of the NC and the corresponding BBP using CBCT. Additionally, the influence of age and gender on these findings was also evaluated.

Materials and Methods

Patient Selection

A total of 81-CBCT scans of patients with one or no upper central incisors present were selected. All scans were of patients referred to an imaging center (Insight CBCT, Mumbai, India) by private dentists for treatment planning of various oral surgical procedures. Written informed consent was obtained from all the patients who participated in this study. The institutional review board and ethics committee approved the research.

The inclusion criteria were as follows: (1) patients above 18 years of age; (2) CBCT with a voxel size of 0.125 mm; (3) one or no upper central incisors present. The exclusion criteria were: (1) impacted teeth in the area of interest; (2) presence of any lesion; (3) root pieces present; (4) dental implants in the region of interest; (5) any suspected NC pathology (cyst); (6) bone grafts.

Imaging Procedures

The CBCT images were obtained using an iCAT 17-19 CBCT scanner (Hatfield, Pennsylvania, USA) with a voxel size of 0.125 mm and a beam diameter of 16 × 13 cm. Operating parameters were set at 3 mA and 80 kV and exposure time was 17.5 s. The data was reconstructed with slices at an interval of 0.25 mm, positioned parallel to the horizontal axis of the alveolar bone. The slices were reformatted to place the NC in a vertical position in the coronal view, and the palate/floor of the nose in a horizontal position in the sagittal view.

Image Evaluation

The data was analyzed using i-CAT Vision software (i-CATVision 1.9, Imaging Sciences International, Inc., Hatfield, Pennsylvania, USA).

Images were evaluated from the sagittal, coronal and axial aspects to give it a three-dimensional analytical approach. All dimensional measurements of NC and BBP were made on sagittal slices. The shape of the NC was evaluated from the sagittal and coronal aspects. Axial slices were used to assess the number of incisive foramina (oral/palatal openings) and foramina of Stenson (nasal openings).

Evaluation from the Sagittal Aspect

The following landmarks were selected for standardized measurements of NC and BBP (Fig. 1)

Fig. 1 Diagram showing the landmarks selected for evaluation of the different anatomical characteristics of NC and BBP from the sagittal aspect (1 NC length, 2 nasopalatine angle, 3 BBP length and 4 BBP width)

1. NC length was defined as the distance from the incisive foramina to foramina of Stenson. If the canal was of anatomic type B or C, the length was calculated as a mean value of the different canal measurements.
2. Nasopalatine angle was defined as the intersection of the NC length (1) and tangent line crossing the nasal floor to the anterior nasal spine.
3. The diameter of the nasal foramen. If the NC was of anatomic type B or C, the diameters of all visible nasal foramina were added together, and a mean value was calculated.
4. The diameter of the incisive foramen. If the NC was of anatomic type B, the diameters of the palatal openings were added together, and a mean value was calculated.

5. BBP length was calculated by joining midpoints of coronal bone ridge width (as a line joining the buccal cortical and palatal cortical at cortical level of BBP) and apical ridge width (was a line joining the buccal cortical and palatal cortical at apical level of BBP).
6. BBP width was calculated by plotting a perpendicular line to BBP length at one-third of the coronal BBP length.

In sagittal slices, the anatomic variants of the NC shape were classified into four groups: (1) funnel-like, (2) cylindrical, (3) hourglass-like and (4) banana-like (Fig. 2).

Evaluation from the Coronal Aspect (Fig. 3)

In coronal slices, the anatomic variants of the NC shape were classified into three groups: (1) a single canal, (2) two parallel canals and (3) variations of the Y-type canal with one incisive foramen and two or more foramina of Stenson.

Evaluation from the Axial Aspect (Fig. 4)

In axial slices, the anatomic variants of the NC were classified according to the number of incisive foramina and the number of foramina of Stenson. The groups were identified with two or three digits, the first digit corresponds to the number of openings in the incisive foramina and the second and third digits correspond to the number of openings in the foramina of Stenson. The axial groups were: (1–1), [1–(2–5)], [2–(2–4)] and [3–(1 and 3)].

Fig. 2 Anatomic variants of the NC shape in the sagittal slices (a cylindrical, b funnel-like and c hourglass-like)

Fig. 3 Anatomic variants of the NC shape in the coronal slices (a single canal, b two parallel canals, c Y-type canal with one incisive foramen and two or more foramina of Stenson)

Fig. 4 Axial classification of NC (**a** one incisive foramina, **b** one foramina of Stenson and **c** three foramina of Stenson)

Statistical Analysis

The data collected was analyzed using descriptive statistics and also the 95 % confidence intervals of the mean outcome measures for each patient subgroup were calculated. The *t* test or one-way ANOVA, was appropriately selected for comparison of differences in CBCT measurements (NC and BBP) between patient subgroups.

Pearson's correlation was used to evaluate the association between measurements and patient age. A multivariate linear regression model (MLRM) was used to predict the relation between measurements, age and gender.

The significance level chosen for all statistical tests was $p \leq 0.05$. All analyses were performed using a software package (S-Plus Professional Version 6.2, Insightful Software, Palo Alto, CA, USA).

Results

A total of 81 CBCTs were evaluated in this study. The study group comprised of 35 males (43.2 %) and 46 females (56.8 %) with a mean age of 44.37 ± 14.78 years (Table 1). The mean NC length was 11.13 ± 3.23 mm; mean nasopalatine angle was $69.32^\circ \pm 7.70^\circ$; mean incisive foramina diameter was 4.23 ± 1.89 ; mean nasal foramina diameter was 3.41 ± 1.47 ; mean BBP length was 17.12 ± 3.97 mm and mean BBP width was 5.71 ± 1.29 mm (Table 1).

With respect to sagittal shape, the most prevalent canal shape was cylindrical in 39 cases (48.15 %) (Table 2), followed by hourglass-like in 25 cases (30.9 %) and funnel-like in 17 cases (20.9 %) (Table 2).

Anatomic variations in the coronal slice were the following: Y-type canal was the most frequent with 40 cases (49.4 %) (Table 2), a single canal was observed in 33 cases (40.7 %), two parallel canals in 8 cases (9.9 %).

Regarding the number of foramina in the axial slice, the more frequent finding was one foramen incisive with two to five foramina of Stenson {1–(2–5)} in 49 cases (60.5 %) (Table 2). Other categories were (1–1) in 19 cases

Table 1 Descriptive results

Parameters	Range	Mean	SD
Age	18.00–77.00	44.37	14.78
NC length (mm)	5.18–22.18	11.13	3.23
Nasopalatine angle ($^\circ$)	44.00–87.00	69.32	7.70
Incisive foramina diameter (mm)	2.88–6.86	4.23	1.89
Nasal foramina diameter (mm)	2.16–5.14	3.41	1.47
BBP length (mm)	6.12–27.79	17.12	3.97
BBP width (mm)	2.84–8.12	5.71	1.29

Table 2 The highest frequency observed in each NC classification

NC classification	Frequency	Percentage
Sagittal shape—cylindrical	39	48.14
Coronal shape—'Y' type canal	40	49.38
Axial classification 1–(2–5)	49	60.49

(23.4 %), followed by {2–(2–4)} in 8 cases (9.9 %) and {3–(1 and 3)} in 5 cases (6.2 %).

With respect to gender, the NC length for males (mean 11.87 mm) presented a longer canal than females (mean 10.53 mm) and this difference was statistically significant ($p = 0.013$). Males presented a wider angle (mean 73.45°) than females (mean 67.98°), although no statistically significant differences were found ($p = 0.327$). Males had a wider incisive foramina diameter (mean 4.53 mm) as compared to females (mean 3.98 mm), but this difference was statistically insignificant ($p = 0.457$). Males also had a wider nasal foramina diameter (mean 3.63 mm) as compared to females (mean 3.19 mm), but this difference was also statistically insignificant ($p = 0.362$). The BBP length for males presented a higher mean value (17.72 mm) than females (16.68 mm), but this difference was not statistically significant ($p = 0.121$). The BBP width was significantly different ($p = 0.009$) between males (mean 6.38 mm) and females (5.21 mm) (Table 3).

No statistically significant differences were found with respect to the sagittal shape of the canal and the dimensions of NC and BBP (Table 4).

Table 3 Effect of gender on the NC and BBP dimensions

Dimensions	Male	Female	<i>p</i> value
NC length (mm)	11.87	10.53	0.013*
Nasopalatine angle (°)	73.45	67.98	0.327
Incisive foramina diameter (mm)	4.53	3.98	0.457
Nasal foramina diameter (mm)	3.63	3.19	0.362
BBP length (mm)	17.72	16.68	0.121
BBP width (mm)	6.38	5.21	0.009*

* Statistically significant differences ($p \leq 0.05$)

Regarding coronal slice, the NC length was significantly different between the single and two parallel canal groups and between the two parallel and Y-type canal groups ($p = 0.002$). There was a significant difference between the NC angle between single and Y type canal ($p = 0.037$). The difference between the incisive foramina diameter of two parallel canal and Y-type canals was also statistically significant ($p = 0.002$) (Table 5).

Regarding axial slice, number of oral/nasal foramina of the NC had no significant influence on NC length, NC angle, incisive and nasal foramina diameter, BBP length and width (Table 6).

The current study clearly indicates that there exists a high variability in NC morphology and that gender has an influence on the dimensions and morphology of the NC and BBP. Male patients generally exhibited higher mean values

as compared to female patients. The age of the patients had a significant influence only on the length of the NC, with the mean values generally decreasing with increasing age.

Based on the results of the current study, CBCT imaging is a vital tool in determining the dimensions and morphology of the NC before dental implant surgery, especially when one or both of the maxillary central incisors have been lost over a longer period of time.

Discussion

Implant therapy in the maxillary central incisor region should always be preceded by careful radiographic analysis as there is a close anatomical approximation between the NC and the roots of these teeth. However, there is a scarcity of data regarding the typical morphology, dimensions and anatomical variations of the NC [3]. Also, the clinical implications and risks of damaging the NC and its neurovascular structures have not been adequately addressed in the literature.

Several invasive procedures have been presented for rehabilitation of the atrophied maxilla like guided bone regeneration and subsequent implant placement [17], application of a block graft, enucleation and placement of dental implants directly into the NC [18]. Several authors have presented different surgical techniques to manage

Table 4 Effect of sagittal shape of the canal on NC and BBP dimensions

Parameters	Sagittal shape	<i>N</i>	Mean	SD	<i>F</i>	<i>p</i>
Age	Cylindrical	39	45.22	12.38	2.957	0.051
	Hourglass like	25	46.76	15.78		
	Funnel like	17	41.22	14.67		
NC length (mm)	Cylindrical	39	11.86	2.34	1.465	0.218
	Hourglass like	25	10.22	3.14		
	Funnel like	17	11.43	1.98		
Nasopalatine angle (°)	Cylindrical	39	64.28	8.85	0.143	0.857
	Hourglass like	25	70.47	7.27		
	Funnel like	17	73.21	9.42		
Incisive foramina diameter (mm)	Cylindrical	39	4.56	0.98	0.254	0.769
	Hourglass like	25	4.78	1.12		
	Funnel like	17	4.28	0.78		
Nasal foramina diameter (mm)	Cylindrical	39	3.47	0.67	0.312	0.674
	Hourglass like	25	3.89	0.88		
	Funnel like	17	2.99	0.58		
BBP length (mm)	Cylindrical	39	17.28	4.56	0.311	0.746
	Hourglass like	25	16.57	3.98		
	Funnel like	17	17.47	4.63		
BBP width (mm)	Cylindrical	39	5.45	1.21	0.159	0.858
	Hourglass like	25	5.88	1.47		
	Funnel like	17	5.84	1.48		

Table 5 Effect of coronal shape of the canal on NC and BBP dimensions

Parameters	Coronal shape	N	Mean	SD	F	p
Age	Single canal	33	45.68	11.17	0.792	0.418
	Two parallel canals	8	42.56	16.68		
	Y-type canal	40	44.35	13.07		
NC length (mm)	Single canal	33	12.47	1.67	5.678	0.002*
	Two parallel canals	8	10.31	2.14		
	Y-type canal	40	12.32	3.57		
Nasopalatine angle (°)	Single canal	33	71.23	7.24	3.443	0.037*
	Two parallel canals	8	69.66	8.52		
	Y-type canal	40	67.57	8.42		
Incisive foramina diameter (mm)	Single canal	33	4.15	0.48	5.328	0.002*
	Two parallel canals	8	3.78	1.10		
	Y-type canal	40	4.28	0.74		
Nasal foramina diameter (mm)	Single canal	33	3.42	0.62	1.769	0.271
	Two parallel canals	8	3.49	0.18		
	Y-type canal	40	3.09	0.58		
BBP length (mm)	Single canal	33	18.12	4.13	0.983	0.371
	Two parallel canals	8	16.45	4.46		
	Y-type canal	40	16.79	3.76		
BBP width (mm)	Single canal	33	6.04	1.34	0.846	0.416
	Two parallel canals	8	5.89	1.68		
	Y-type canal	40	5.20	1.28		

* Statistically significant differences ($p \leq 0.05$)

perforation of the NC following implant osteotomies [17, 19, 20].

CT scans [3, 9, 15], micro CT images [16] or high-resolution magnetic resonance imaging [7] have been used in the past to analyze the macro and microanatomy of the maxillary anterior region and also the course of the nasopalatine nerve and its accompanying vessels. In the present study, the maxillary anterior region was evaluated using CBCT for cross-sectional imaging. CBCT administers less radiation dose to the patients as compared to the conventional CT scans and also has many other advantages [21]. CBCT is gradually replacing CT scans for the purpose of diagnosis and evaluation of the bone and neurovascular structures in the maxillary anterior region.

In the present study, gender significantly influences the NC and BBP dimensions with male patients reporting higher values as compared to females. These findings were in accordance with a study conducted by Mardinger et al. [15].

With respect to three-dimensional analysis in sagittal slice, a cylindrical canal was diagnosed in 39 cases, leaving almost 50 % of the cases with hourglass-like or funnel-like variations. These results were similar to the findings of Bornstein et al. [10], Mardinger et al. [15] and Tözüm et al. [22]. Almost significant differences were found in terms of age between hourglass-like and funnel-like shapes.

With respect to analysis from the coronal aspect, Y-type canal was observed more frequently followed by single canal and two parallel canals. Other studies [10, 16] in the past have observed single canal to be the most frequent.

For the purpose of three dimensional analysis from the axial aspect, we established the following groups: (1–1), [1–(2–5)], [2–(2–4)] and [3–(1 and 3)]. The most frequent axial group observed in our study was [1–(2–5)], with the (1–2) group accounting for 75.6 % of the 49 cases. However, Liang et al. [9] observed (1–1) in 44 % of cases, followed by (1–2) in 39 % of cases.

Bornstein et al. [10] reported a mean NC length of 10.99 mm, which is similar to the findings of the present study, in which the mean value was 11.13 mm. The greatest NC length was observed in cylindrical canals, single canals and group (1–1) from sagittal, coronal and axial aspects respectively.

The mean value observed for nasopalatine angle was similar to that reported by Liang et al. [9]. Liang et al. [9] used horizontal plate of palate as a reference point while we used the nasal floor, but both these planes are parallel and hence comparisons can be drawn. Song et al. [16] evaluated the angle formed by the vertical line perpendicular to nasal floor and the NC, which is complementary to the nasopalatine angle used in the current study. When Song et al. [16] obtained a value of 0°, it indicated that

Table 6 Effect of number of oral/nasal foramina of the canal on NC and BBP dimensions

Parameters	Axial classification	N	Mean	SD	F	p
Age	1–1	19	47.24	11.12	2.158	0.091
	1–(2–5)	49	39.93	15.18		
	2–(2–4)	8	45.68	11.07		
	3–(1 and 3)	5	44.12	9.65		
NC length (mm)	1–1	19	10.31	2.17	3.441	0.018*
	1–(2–5)	49	10.98	1.12		
	2–(2–4)	8	11.16	3.17		
	3–(1 and 3)	5	11.47	2.78		
Nasopalatine angle (°)	1–1	19	71.23	6.78	1.882	0.116
	1–(2–5)	49	69.47	8.22		
	2–(2–4)	8	71.11	7.12		
	3–(1 and 3)	5	65.28	8.12		
Incisive foramina diameter (mm)	1–1	19	3.85	0.48	3.468	0.237
	1–(2–5)	49	3.38	0.79		
	2–(2–4)	8	4.21	0.44		
	3–(1 and 3)	5	3.97	1.10		
Nasal foramina diameter (mm)	1–1	19	3.42	0.62	2.689	0.463
	1–(2–5)	49	3.49	0.28		
	2–(2–4)	8	3.09	0.48		
	3–(1 and 3)	5	3.23	0.65		
BBP length (mm)	1–1	19	18.02	2.23	0.434	0.716
	1–(2–5)	49	19.23	3.26		
	2–(2–4)	8	16.19	5.22		
	3–(1 and 3)	5	14.43	4.66		
BBP width (mm)	1–1	19	5.20	0.87	1.110	0.343
	1–(2–5)	49	6.04	1.84		
	2–(2–4)	8	5.89	0.98		
	3–(1 and 3)	5	5.71	1.28		

* Statistically significant differences ($p \leq 0.05$)

there was no separation between NC and the vertical line and this corresponds to a 90° angle in our study. Hence the angle values observed by Song et al. [16] are similar to the ones reported in our study.

In their study, Song et al. [16] reported that the incisive foramina always comprised of only a single foramen and the foramina of Stenson always had two openings. However, these findings are in contradiction with our study, which sometimes observed two parallel canals. In fact, our study reported 2 % of cases that had three openings at the incisive foramina, which coalesced to form one foramen of Stenson or continued to three [3–(1 and 3)]. Recent studies by von Arx et al. [23] and Neves et al. [24] are in accordance with our findings. Von Arx et al. [23] reported 27.8 % of accessory canals, confirming the presence of bone channels within the anterior maxilla. Also, Neves et al. [24] reported a case of a complete additional NC, in which each channel extended from independent foramina of Stenson to independent incisive foramens.

The present study showed BBP dimensions similar to those reported by Tözüm et al. [22] and Bornstein et al. [10]. Also, in terms of gender, our findings are similar to these authors [10], where male patients presented greater values in both, BBP height and width dimensions.

A thorough analysis of the NC and BBP dimensions with CBCT images is necessary in order to obtain the best prognosis for any surgical treatment in the maxillary anterior region.

Most nerves, arteries and veins contained in the NC nourish the premaxillary region. However, in this study analysis from the axial aspect shows that the NC can be formed by several canaliculi, as reflected by the different axial groups. Therefore, it is important to assess the content of NC to avoid any neurovascular or anesthetic complications. Placement and angulation of dental implants in the maxillary central incisor region should be preceded by careful analysis of the nasopalatine angle.

Conclusion

In terms of esthetic and functional rehabilitation, the maxillary anterior region is an area with a significant clinical relevance. The current study demonstrates variability of the NC in terms of shape and number; hence, a thorough CBCT analysis is highly recommended for better surgical outcomes and to reduce the post-operative complications in implant dentistry.

Compliance with Ethical Standards

Conflict of interest None.

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