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ORIGINAL ARTICLE

Three-dimensional study of nasopalatine canal morphology: a descriptive retrospective analysis using cone-beam computed tomography

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Abstract
Purpose For dental implant treatment planning and placement, a precise anatomic description of the nasopalatine canal (NC) is necessary. This descriptive retrospective study evaluated dimensions of the NC and buccal bone plate (BBP) and the tridimensional association of the anatomic variants of NC, using cone-beam computed tomography (CBCT).
Methods This study included 230 CBCTs. Sagittal slices were used for measurements of the NC and BBP and to evaluate shape and direction-course 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 Mean NC length was 12.34 ± 2.79 mm, statistically significant differences were detected between genders ($p < 0.001$). Mean BBP length was 20.87 ± 3.68 mm, statistically significant differences were found for the dental status ($p < 0.001$) and mean BBP width was 6.83 ± 1.28 mm, significant differences were detected between genders ($p < 0.001$). Mean nasopalatine angle was 73.33° ± 8.11°, significant differences were found in sagittal and coronal classifications. The most prevalent canal was: cylindrical sagittal shape (48.2 %); slanted-straight direction-course (57.6 %); Ya-type coronal shape (42.4 %); and one foramen incisive with two Stenson's foramina (1–2) (50.9 %). Sagittal shape was associated with sagittal direction-course ($p < 0.001$). Coronal shape was associated with axial classification ($p < 0.001$).
Conclusions The NC anatomy is highly variable. Gender is related to the NC length and BBP width, while dental status is related to BBP length. There was an association between the different sagittal classifications of the NC and between the coronal shape and axial classification.

Keywords Cone-beam computed tomography · Nasopalatine canal · Buccal bone plate · Dental implant

Introduction

Rehabilitation with osseointegrated dental implants in the anterior maxilla has become a very common treatment in dental practices. However, the nasopalatine canal (NC) is an anatomical limitation for implant placement [2, 16, 19, 20]. The BBP resorption occurs after tooth extractions, dento-alveolar trauma, periradicular and periodontal pathology, or because of tumors or cysts. The pattern of bone resorption has been studied by many authors [1, 3–5, 8, 9, 17, 23]. Cawood et al. [8] studied the type of resorption in 300 dissected skulls and observed that the pattern of bone loss varies in the maxilla and mandible. The pattern of resorption in the anterior maxilla bone is generally horizontal, from the buccal surface of BBP to the palatal surface of BBP [8].

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Williams et al. [27] describe the NC as being located in the midline of the palate, posterior to the roots of the central maxillary incisors. The oral opening of the canal (or incisive foramen) is underneath the incisive papilla and the nasal opening is known as foramina of Stenson [27]. On its way to the nasal cavity the canal divides into two canaliculi, and terminates at the nasal floor at either side of the septum [18]. The NC contains the nasopalatine nerve and the terminal branch of descending nasopalatine artery, as well fibrous connective tissue, fat, and small salivary glands [12].

Knowing the dimensions of NC and the buccal bone plate (BBP) of this canal is very important for carrying out adequate implant treatment planning and insertion of dental implants, both in terms of function and esthetic rehabilitation [6, 7, 11–13, 21, 22]. Radiological studies with cone-beam computed tomography (CBCT) make it possible to analyze anatomical variations of the NC [10, 24], and to determine the degree of BBP resorption in the anterior maxilla region after tooth loss [1, 3–5, 8, 9, 17, 23, 25]. Keeping in mind that the NC may occupy up to 58 % of the BBP width in the area of the future dental implants in the region of the central incisors [13], a precise 3-dimensional (3D) anatomic description of the NC to enable safe and accurate surgical planning and placement of dental implants is necessary [21]. To the best of our knowledge, there is no scientific evidence to correlate the tridimensional NC shapes.

The aim of this descriptive retrospective study was first to evaluate the radiological data of the NC and BBP dimensions in relation to dental status and gender using CBCT imaging, and second to correlate all anatomic variants of the NC in three dimensions.

Materials and methods

Our overall sample consisted of 1,551 consecutive CBCT of patients referred to the Radiology Unit of the Medicine and Dentistry School at the University of Santiago de Compostela. These CBCTs were performed from July 2008 to March 2012 for treatment planning of various oral surgical procedures. A total of 230 CBCT were selected randomly with both, one or no upper central incisors present (−/+, +/+, −/−) and were included in this study from March 2012 to December 2012. This study was approved by the Galician Ethics Committee of Clinical Research (Ref: 2012/272). Written informed consent was obtained from all patients to participate in the study.

The inclusion criteria were the following: (1) patients aged 18 years or older; (2) CBCT with voxel size of 0.3 mm or less. The exclusion criteria were: (1) impacted teeth in the anatomical area of interest; (2) presence of a radiolucent or radiopaque lesion; (3) root fragments present; (4) dental implants in the region of interest; (5) suspected NC pathology (cyst); (6) bone grafts; and (7) presence of orthodontic expanders.

Image evaluation

These CBCT were done using a 17-19 i-CAT scanner (Imaging Sciences International, Inc., Hatfield, Pennsylvania, USA) (5 mA, 120 kVp, 14.7 s) and evaluated by an experienced graduate student. Analysis was carried out using i-CATVision software (i-CATVision 1.9, Imaging Sciences International, Inc., Hatfield, Pennsylvania, USA). The CBCT slice thickness was 0.25 mm.

All measurements of NC and BBP dimensions were made on sagittal CBCT slices. Sagittal slices were also used to evaluate the shape and sagittal direction-course of the canal. Coronal slices were used to assess the shape of NC. Axial slices were used to assess the number of incisive foramina (=oral/palatal openings) and foramina of Stenson (=nasal openings).

Measurements to determine the dimensions of NC and BBP

The following landmarks were selected for standardized measurements (Figs. 1, 2a): (1) NC length was defined as the distance from the incisive foramina to foramina of Stenson; (2) BBP length was calculated by joining midpoints of coronal bone ridge width (it was a line which joining the buccal cortical and palatinal cortical at cortical level of BBP) and apical ridge width (it was a line which joining the buccal cortical and palatinal cortical at apical level of BBP); (3) BBP width was calculated by plotting a perpendicular line to BBP length at one-third of the coronal BBP length; and (4–5) the nasopalatine angle (5) was defined as the intersection of the NC length (1) and tangent line crossing the nasal floor to the anterior nasal spine (4).

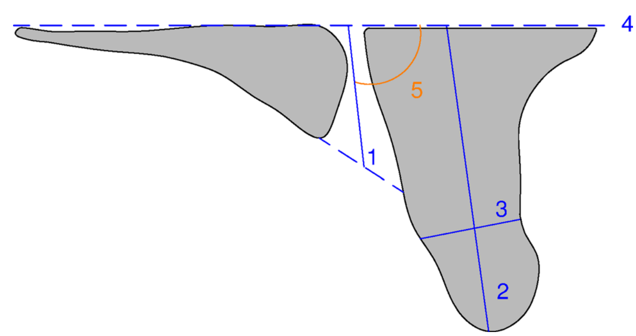

Fig. 1 Sagittal shapes of NC. Measurements in sagittal slice of funnel-like NC: *1* NC length, *2* BBP length, *3* BBP width, *4* tangent line to nasal floor, and *5* nasopalatine angle

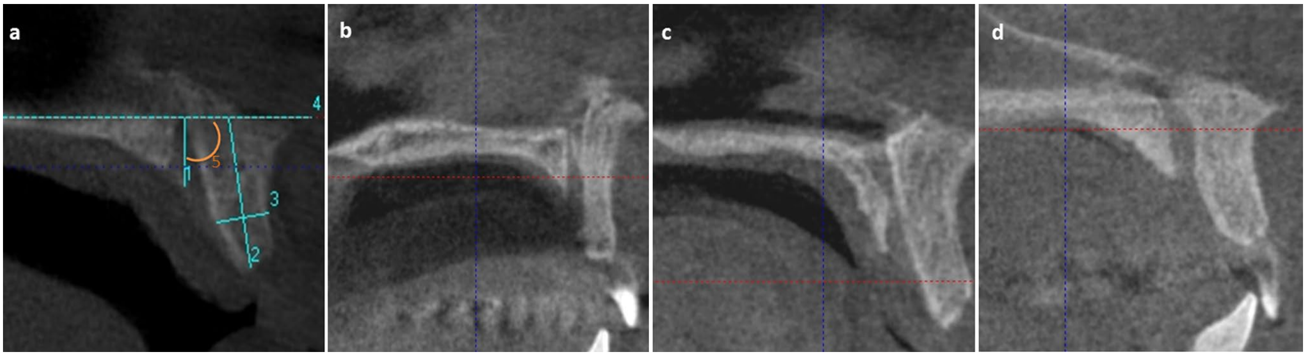

Fig. 2 Sagittal shapes of NC. **a** Measurements in sagittal slice of funnel-like NC: *1* NC length, *2* BBP length, *3* BBP width, *4* tangent line to nasal floor, and *5* nasopalatine angle. **b** Cylindrical NC. **c** Hourglass-like NC. **d** Banana-like NC

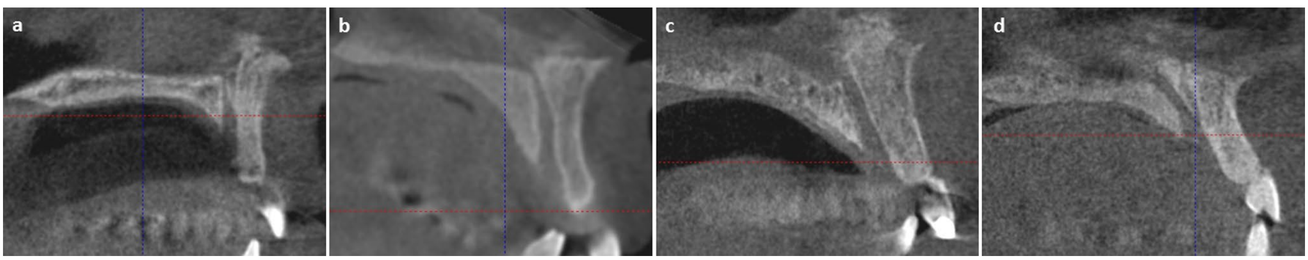

Fig. 3 Direction-course of NC in sagittal slice. **a** Vertical-straight canal (Ia). **b** Vertical-curved canal (Ib). **c** Slanted-straight canal (IIa). **d** slanted-curved canal (IIb)

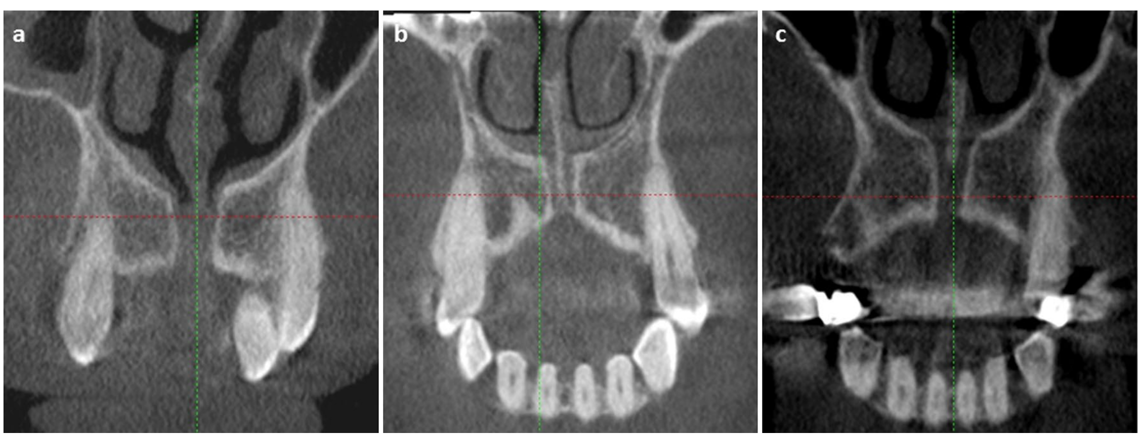

Fig. 4 **a** A single canal. **b** Two parallel canals. **c** Y-type canal

Classifications of the anatomic variants of NC in the three dimensions

In sagittal slices, the anatomic variants of the NC were classified into four groups [13]: (1) funnel-like, (2) cylindrical, (3) hourglass-like and (4) banana-like (Fig. 2). The NC was also classified according to its sagittal direction-course [21]: (1) vertical-straight (Ia), (2) vertical-curved (Ib), (3) slanted-straight (IIa), (4) slanted-curved (IIb) (Fig. 3).

In coronal slices, the anatomic variants of the NC were classified into three groups [6]: (1) a single canal; (2) two parallel canals; (3) variations of the Y-type canal with one incisive foramen and two foramina of Stenson (Ya), Y-type canal with one incisive foramen and three foramina of Stenson (Yb), and Y-type canal with one incisive foramen and more than three foramina of Stenson (Yc) (Fig. 4). Additionally, a single patient could have a combination of NC coronal shapes, due to all NC slices were analyzed travelling from the anterior to the posterior view (Fig. 5).

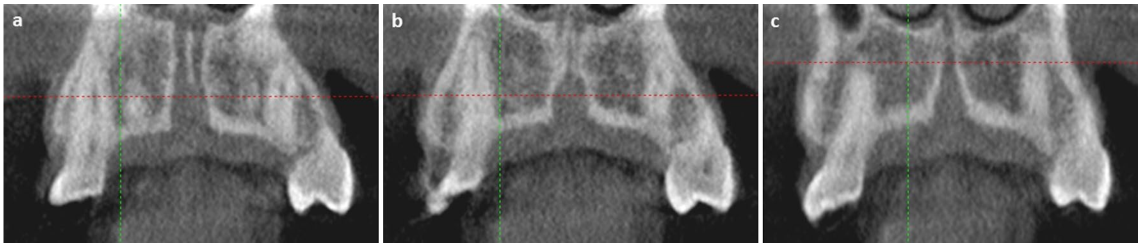

Fig. 5 A single patient with a combination of coronal shapes travelling from the anterior to the posterior slices of NC. **a** Anterior view of NC with two canals. **b** Medial view of NC with a medial single canal. **c** Posterior view of NC with a posterior single canal

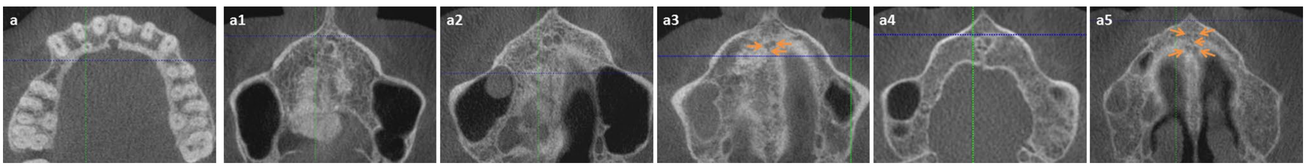

Fig. 6 Axial classification of NC. The (1-1) group correspond to **a** and **a1**. The (1-(2 to 5)) group correspond to **a** and **a2**–**a5**. **a** One incisive foramen. **a1** One Stenson's foramen. **a2** Two Stenson's foramina. **a3** Three Stenson's foramina. **a4** Four Stenson's foramina. **a5** Five Stenson's foramina

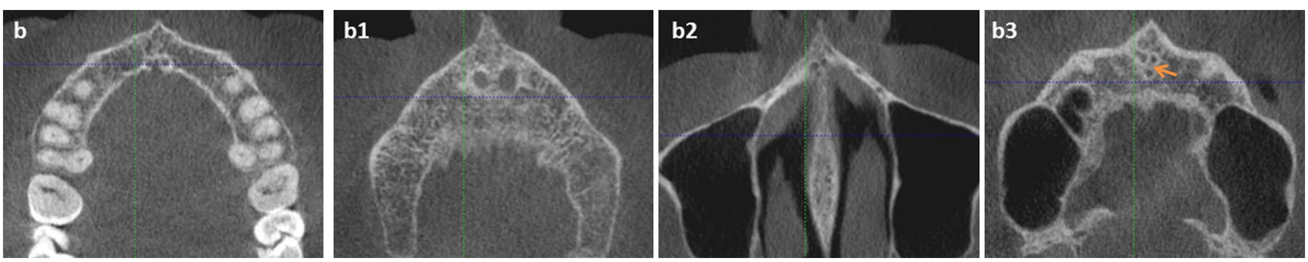

Fig. 7 Axial classification of NC. The (2-(2 to 4)) group correspond to **b** and **b1**–**b3**. **b** Two incisive foramina. **b1** Two Stenson's foramina. **b2** Three Stenson's foramina. **b3** Four Stenson's foramina

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) (Fig. 6a, a1), (1-(2 to 5)) (Fig. 6 a, a2 to a5), (2-(2 to 3)) (Fig. 7) and (3-(1 and 3)) (Fig. 8).

One month later, the same observer assessed the anatomic NC variants in the three slices and the NC measurements in 20 CBCTs to check the intraobserver variability, using Kappa test for the anatomic NC variants and the intraclass correlation coefficient for the NC measurements.

Statistical analysis

All data were first analyzed using descriptive statistics. Differences in CBCT measurements were compared according to dental status (−/+, +/+, −/−) by ANOVA with a post hoc Bonferroni test, Scheffe test and Tukey *b* test; and according to gender by Student's *t* test. Pearson's correlation was used to evaluate the association between measurements and patient age. A multivariant linear regression model (MLRM) was used to predict the relation between measurements, dental status, and gender. The Chi-squared test was used to determine the relation between NC classifications, dental status and gender. Statistical significant was set at $p \leq 0.05$. Analyses were performed using SPSS 15.0 software for Windows (SPSS, Chicago, IL, USA).

Results

A total of 224 CBCT were included in the study. Six CBCTs (out of 230) were not included due to the following reasons: implant placed or bone grafting in the anterior maxilla, poor image quality, presence of maxillary

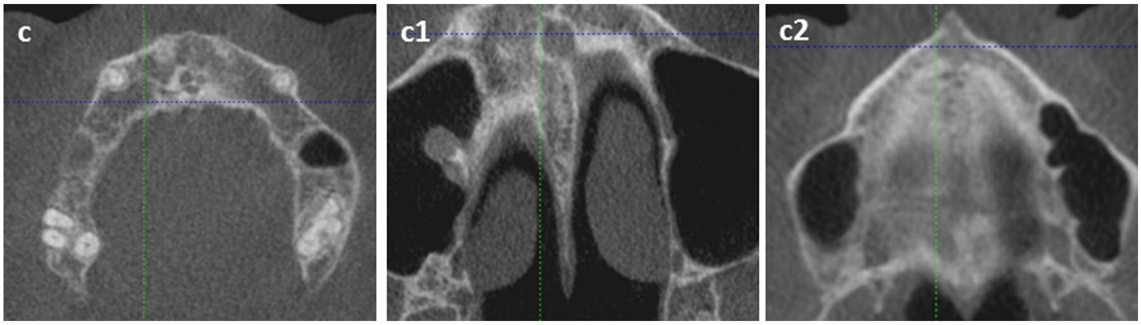

Fig. 8 Axial classification of NC. The (3-(1 and 3)) group correspond to **c** and **c1** and **c2**. **c** Three incisive foramina. **c1** One Stenson's foramina. **c2** Three Stenson's foramina

Table 1 Descriptive results

Parameters	Range	Mean	SD
Age	18.00–84.00	47.28	15.41
BBP length (mm)	7.25–29.80	20.87	3.68
BBP width (mm)	3.23–9.92	6,083	1.28
Nasopalatine angle (°)	52.00–94.00	73.36	8.11
NC length (mm)	4.35–23.57	12.34	2.79

SD standard deviation

Table 2 The highest frequency observed of each NC classification

NC classifications	Frequency	Percentage (%)
Sagittal shape		
Cylindrical	108	48.2
Sagittal direction-course		
Slanted-straight	129	57.6
Coronal shape		
Y-type canal	103	46.0
Axial classification		
1-(2 to 5)	142	63.4

expander, or a nasopalatine duct cyst. The study group comprised 108 males (48.2 %) and 116 females (51.8 %) with a mean age of 47.28 years (Table 1). The mean NC length was 12.34 ± 2.79 mm; mean BBP length was 20.87 ± 3.68 mm; mean BBP width was 6.83 ± 1.28 mm; and, mean nasopalatine angle was 73.33° ± 8.11° (Table 1).

With respect to sagittal shape, the most prevalent canal shape was cylindrical in 108 cases (48.2 %), followed by hourglass-like in 69 cases (30.8 %), funnel-like in 46 cases (20.5 %), and banana-like in one case (0.4 %) (Table 2). With respect to sagittal direction-course of the NC, the most common type was slanted-straight (IIa) in 129 cases (57.6 %), followed by vertical-straight (Ia) which appear in 53 cases (23.7 %), vertical-curved (Ib) in 23 cases (10.3 %), and slanted-curve (IIb) in 19 cases (8.5 %) (Table 2). In general, the slanted type occurred more frequently (IIa + IIb, 66.07 %) than the vertical type (Ia + Ib, 33.93 %).

Anatomic variations in the coronal slice were the following: Ya-type canal was the most frequent with 95 cases (42.4 %), a single canal was observed in 92 cases (41.1 %), two parallel canals in 23 cases (10.3 %), and Yb-type in 7 cases (3.1 %). A combination of two anterior parallel canals with a posterior single canal was found in only 3 cases (1.3 %), and the following types were found in only 1 case each (0.4 %): Yc-type canal; combination of a single anterior canal with two posterior canals; a combination of anterior Ya with a single posterior canal; and the combination of two anterior with a single medial and a single posterior canal.

Regarding the number of foramina in the axial slice, the more frequent finding was one foramen incisive with two foramina of Stenson (1-2) in 114 cases (50.9 %). Other categories were (1-1) in 57 cases (25.4 %), followed by (1-3) in 21 cases (9.4 %), (2-2) in 17 cases (7.6 %), (1-4) in 6 cases (2.7 %), (2-3) and (3-3) in 3 cases (1.3 %), and (1-5), (2-4) and (3-1) in 1 case (0.4 %).

With respect to gender, the NC length for males (mean 13.16 ± 2.72 mm) presented a longer canal than females (mean 11.58 ± 2.64 mm) ($p < 0.001$). The BBP length for males presented a higher mean value (21.27 ± 3.73 mm) than females (20.50 ± 3.60 mm), but this difference was not statistically significant ($p = 0.121$). The BBP width was significantly different ($p < 0.001$) between males (mean 7.28 ± 1.28 mm) and females (6.41 ± 1.14 mm). Males presented a wider angle (mean 73.88° ± 7.66°) than females (mean 72.87° ± 8.51°), although no statistically significant differences were found ($p = 0.353$).

Regarding the dental status, a total of 183 patients were +/+ (81.7 %), 26 were −/− (11.6 %) and 15 were +/− (6.7 %). The age of −/− group was higher than for the +/+ group ($p = 0.001$) (Table 3). The BBP length, was statistically different between −/− and +/+ groups ($p < 0.001$) and between −/− and +/− groups ($p = 0.002$).

Table 3 Effect of dental status on BBP dimensions, nasopalatine angle and NC length

Parameters	Dental status	Range	Mean	SD	*F*	*p*
Age	+/+	18.00–82.00	45.41	15.76	7.956	<0.001*
	−/−	37.00–84.00	56.62	10.93		
	+/−	35.00–66.00	53.87	9.28		
BBP length	+/+	12.69–29.80	21.34	3.35	15.143	<0.001*
	−/−	7.25–25.65	17.36	4.32		
	+/−	17.06–27.35	21.26	3.15		
BBP width	+/+	3.40–9.52	6.91	1.18	2.223	0.111
	−/−	3.23–9.92	6.36	1.92		
	+/−	5.03–8.98	6.67	1.08		
Nasopalatine angle	+/+	52.00–94.00	73.28	8.14	0.048	0.953
	−/−	55.00–86.00	73.65	9.24		
	+/−	64.00–83.00	73.80	5.77		
NC length	+/+	5.42–23.57	12.43	2.65	2.607	0.076
	−/−	4.35–16.96	11.27	3.17		
	+/−	6.76–18.58	13.10	3.47		

+/+, Dentate group; −/−, edentulous group; and +/−, partial edentulous group. *SD* standard deviation

* Statistically significant differences $p < 0.05$

Table 4 Effect of sagittal shape of the NC on BBP dimensions, nasopalatine angle and NC length

Parameters	Sagittal shape	*N*	Mean	SD	*F*	*p*
Age	Cylindrical	109	46.64	14.62	2.968	0.053
	Funnel-like	46	43.76	14.97		
	Hourglass-like	69	50.62	16.45		
BBP length	Cylindrical	109	20.96	3.65	0.304	0.739
	Funnel-like	46	20.49	3.87		
	Hourglass-like	69	20.99	3.63		
BBP width	Cylindrical	109	6.88	1.28	0.162	0.851
	Funnel-like	46	6.77	1.17		
	Hourglass-like	69	6.80	1.37		
Nasopalatine angle	Cylindrical	109	73.29	8.46	0.141	0.868
	Funnel-like	46	72.93	8.59		
	Hourglass-like	69	73.74	7.27		
NC length	Cylindrical	109	12.07	2.92	1.486	0.228
	Funnel-like	46	12.30	2.67		
	Hourglass-like	69	12.80	2.64		

For statistical reason, the single case of banana-like shape was included into the cylindrical group, due to its similarity in other slices

SD standard deviation

No statistically significant differences were found for BBP width, NC length and nasopalatine angle (Table 3).

Direct correlation was found between NC length and the following variables: BBP length ($p < 0.001$, $r^2 = 0.60$), and BBP width ($p = 0.001$, $r^2 = 0.23$). Direct correlation was found between the BBP length and the following variables: BBP width ($p < 0.001$, $r^2 = 0.26$), and nasopalatine angle ($p = 0.002$, $r^2 = 0.21$). No correlation was found with age and the following variables: NC length ($p = 0.961$), BBP length ($p = 0.241$), BBP width ($p = 0.614$), and nasopalatine angle ($p = 0.636$).

No statistically significant differences were found with respect to the NC length and the sagittal shape (Table 4). There were statistically significant differences in NC length between the vertical-straight (Ia) and the vertical-curved canal groups (Ib) ($p = 0.024$), and between the vertical-curved (Ib) and the slanted-straight canal groups (IIa) ($p = 0.017$) (Table 5). Regarding coronal slice, the NC length was significantly different between the single and two parallel canal groups ($p = 0.001$), and between the two parallel and Y-type canal groups ($p = 0.041$) (Table 6).

Regarding the BBP length, no statistically significant differences were found with the following variables: sagittal shape, sagittal direction-course, coronal shape, and axial classification (Tables 4, 5, 6, 7). With respect to BBP width, no statistically significant differences were found with the following variables: sagittal shape, sagittal direction-course, the coronal shape, and axial classification (Tables 4, 5, 6, 7). The nasopalatine angle was significantly different between vertical-straight (Ia) and the slanted-curved canal

Table 5 Effect of sagittal direction-course of the NC on BBP dimensions, nasopalatine angle and NC length

Parameters	Sagittal direction-course	*N*	Mean	SD	*F*	*p*
Age	Vertical-straight	53	48.47	13.83	0.256	0.857
	Vertical-curved	23	47.87	12.95		
	Slanted-straight	129	46.51	16.30		
	Slanted-curved	19	48.42	16.87		
BBP length	Vertical-straight	53	21.48	3.73	1.252	0.292
	Vertical-curved	23	21.42	3.71		
	Slanted-straight	129	20.47	3.71		
	Slanted-curved	19	21.28	3.16		
BBP width	Vertical-straight	53	6.82	1.29	0.761	0.517
	Vertical-curved	23	7.07	1.21		
	Slanted-straight	129	6.85	1.32		
	Slanted-curved	19	6.47	1.10		
Nasopalatine angle	Vertical-straight	53	78.51	6.63	22.208	<0.001*
	Vertical-curved	23	79.04	5.59		
	Slanted-straight	129	71.02	7.83		
	Slanted-curved	19	67.95	4.87		
NC length	Vertical-straight	53	11.94	2.68	4.624	0.004*
	Vertical-curved	23	13.92	3.29		
	Slanted-straight	129	12.05	2.65		
	Slanted-curved	19	13.52	2.64		

SD standard deviation

* Statistically significant differences $p < 0.05$

Table 6 Effect of coronal shape of the NC on BBP dimensions, nasopalatine angle and NC length

Parameters	Coronal shape	*N*	Mean	SD	*F*	*p*
Age	Single canal	92	47.03	16.56	0.852	0.428
	Two parallel canals	23	43.91	17.81		
	Y-type canal	103	48.46	13.99		
BBP length	Single canal	92	21.29	3.42	0.993	0.372
	Two parallel canals	23	20.51	3.85		
	Y-type canal	103	20.59	3.89		
BBP width	Single canal	92	6.81	1.15	0.956	0.386
	Two parallel canals	23	6.49	1.31		
	Y-type canal	103	6.90	1.37		
Nasopalatine angle	Single canal	92	71.71	8.31	3.459	0.033*
	Two parallel canals	23	73.61	8.65		
	Y-type canal	103	74.65	7.17		
NC length	Single canal	92	12.91	2.87	6.678	0.002*
	Two parallel canals	23	10.64	2.84		
	Y-type canal	103	12.20	2.57		

SD standard deviation

* Statistically significant differences $p < 0.05$

groups (Ib) ($p < 0.001$); vertical-straight and slanted-curved canal groups (IIb) ($p < 0.001$); vertical-curved (Ib) and slanted-straight canal groups (IIa) ($p < 0.001$); and vertical-curved and slanted-curved canal groups ($p < 0.001$) in the sagittal slice (Table 5). There were significant differences in the nasopalatine angle between the single canal and the Y-type canal groups ($p = 0.028$) in the coronal slice (Table 6). No statistically significant differences were found with respect to nasopalatine angle with sagittal shape and axial classification (Tables 4, 7).

Sagittal shape and sagittal direction-course were associated ($\chi^2 = 28.293$; $p < 0.001$) following two distributions, firstly, gathering sagittal shapes as follows: 66.10 % of the cylindrical canals, 47.80 % of the hourglass-like canals, and 52.20 % of the funnel-like were slanted-straight (IIa). Secondly, gathering sagittal direction-course as follows: 54.70 % of Ia canals were cylindrical; 43.50 % of Ib canals were funnel-like; 55.80 % of IIa canals were cylindrical; and 47.40 % of IIb canals were hourglass-like. Coronal shape and axial

Table 7 Effect of number of oral/nasal foramina of the NC on BBP dimensions, nasopalatine angle and NC length

Parameters	Axial classification	N	Mean	SD	F	p
Age	3-(1 and 3)	4	55.50	9.15	2.167	0.093
	1-1	57	44.91	16.82		
	1-(2 to 5)	142	48.79	14.37		
	2-(2 to 4)	21	41.90	17.63		
BBP length	3-(1 and 3)	4	19.20	3.57	0.446	0.720
	1-1	57	21.18	3.67		
	1-(2 to 5)	142	20.76	3.69		
	2-(2 to 4)	21	21.00	3.81		
BBP width	3-(1 and 3)	4	5.73	0.71	1.110	0.346
	1-1	57	6.84	1.19		
	1-(2 to 5)	142	6.88	1.34		
	2-(2 to 4)	21	6.71	1.21		
Nasopalatine angle	3-(1 and 3)	4	70.00	12.52	1.983	0.117
	1-1	57	71.32	8.85		
	1-(2 to 5)	142	74.14	7.26		
	2-(2 to 4)	21	74.24	9.99		
NC length	3-(1 and 3)	4	9.20	3.21	3.384	0.019*
	1-1	57	12.83	2.83		
	1-(2 to 5)	142	12.39	2.71		
	2-(2 to 4)	21	11.28	2.69		

Number of incisive foramina—number of Stenson's foramina

SD standard deviation

* Statistically significant differences $p < 0.05$

classification were associated ($\chi^2 = 308.078$; $p < 0.001$) following two distributions, firstly, gathering coronal shapes as follows: 62 % of single canals were (1-1) axial group; 82.60 % of two parallel canals were (2-(2 to 4)); and 100 % of Y-type canals were (1-(2 to 5)) axial group. Secondly, gathering axial groups as follows: 100 % of (1-1) were a single canal; 74.10 % of (1-(2 to 5)) were Y-type canal; 100 % of (2-(2 to 4)) were two parallel canals; and 100 % of (3-(1 and 3)) were two parallel canals. Sagittal shape was not associated with coronal shape and axial classification.

The NC length was dependently associated with BBP length and gender. The effect of BBP length in NC length was the same for males and females. The NC length for males presented 1.176 mm more than females, yielding the following MLRM function for males: NC length = 3.851 + 0.435 · BBP length ($R^2 = 0.407$). The BBP length was dependently associated with NC length and the dental status. The effect of NC length was the same for +/+ and −/−. The BBP length for +/+ presented 3.087 mm more than −/−, yielding the following MLRM function for +/+: BBP Length = 8.680 + 0.770 · NC Length ($R^2 = 0.435$). The BBP width was dependently associated with gender and BBP length. The effect of BBP length was the same for males and females. The BBP width for males presented 0.854 mm more than females, yielding the following MLRM function for males: BBP Width = 4.858 + 0.076 · BBP Length ($R^2 = 0.157$).

Intraobserver variability

With respect to anatomic NC variants, the intraobserver variability was a Kappa value ranging from 0.44 to 0.57 ($p \leq 0.001$). And regarding the NC measurements, the intraobserver variability was an intraclass correlation coefficient value ranging from 0.80 to 0.86 (confidence interval of 95 % ranging from 0.57 to 0.94).

Discussion

A recent study has described the NC as a duct from the oral cavity, which divides into two canaliculi, and terminates at the nasal floor at either side of nasal septum [18]. Others studies have classified the canal based on symmetry, the number of canaliculi into the NC, and shape [6, 13, 21]. However, to the best of our knowledge, this is the first study to analyze the relation of NC morphology in three dimensions. We found statistical differences in NC length according to shape in each anatomic plane. Moreover, the present study contributes an MLRM with a high predictive value for NC length and BBP length.

Our findings regarding NC length are in line with other authors [6, 22]. However, Liang et al. [12] and Mraiwa et al. [14] found a lower mean value. We should note that the sample size in these studies was considerably smaller than the sample size in the present study. Regarding the influence of gender on NC length, like previous studies [6, 11, 21, 22], we found significantly greater values for males. However, the present results with respect to dental status are different from previous studies that report significantly greater NC length in the dentulous group [12, 22]. Other studies report an approximately 2-mm decrease in NC length in the edentulous group, though no mention is made as to whether this value was significant [13, 21]. There is an indirect correlation between age and NC length in the studies by Bornstein et al. [6] and Tözüm et al. [22], who observed a decrease in length as age increased, but we found no such correlation. With respect to the length and width of the BBP, we observed a direct correlation with NC length. This correlation was not analyzed in previous studies. With respect to NC length in the sagittal slice, we found slanted-curved type canals to have greater length than straight type canals. Although Song et al. [21] determined the direction-course of the NC, these authors did not analyze its relation with NC length. In the coronal slice, we observed the greatest length in single canals. In axial slice, group (1-1) canals were longer than group (3-(1 and 3)) canals.

The BBP dimensions in the present study were similar to those reported by Tözüm et al. [22]. The BBP width values obtained by Bornstein et al. [6] in the medial zone of the ridge were also similar to the present results. In addition, our findings are similar to these authors [6] in terms of gender, where males presented greater values in both BBP dimensions, but only BBP width values were statistically significant. Other studies found significant differences not only in BBP width but also in length, which were greater in males [11, 22]. With respect to dental status, BBP length was greatest in the +/+ group, followed by +/− and −/− groups. Mardinger et al. [13] found the edentulous group to have a 44.4 % lower BBP length than the dentulous group. As in ours and other studies [22], these differences were statistically significant. With respect to the correlation of age and BBP dimensions, previous studies [13] found an indirect correlation between width and length, which was not found for the present study. With respect to the findings of this study we found a direct correlation when considering only BBP width and BBP length, yet this was not analyzed in previous studies.

For their part, Bornstein et al. [6] described an MLRM of BBP width which was independently associated with dental status and time elapsed after central incisor loss. However, we have developed an MLRM to explain BBP width using gender and BBP length. Notably, we obtained an MLRM with a value >40 % for predicting NC length and BBP length.

We obtained a mean value for nasopalatine angle that was similar to Liang et al. [12]. Although one of the reference points used by these authors [12] was different from our own (they used the horizontal plate of palate, while we used the nasal floor), both planes are parallel and comparisons can be established. Song et al. [21] analyzed the angle formed by NC and the vertical line perpendicular to nasal floor which is complementary to the nasopalatine angle used by us. In other words, a value of 0° obtained by Song et al. [21] indicates that the NC has no separation from the vertical line, and this corresponds to a 90° angle in our study. Taking this into consideration, the angle values obtained by Song et al. [21], are similar to our own. With respect to the correlations of nasopalatine angle with BBP length and NC length, we have found no support data in the literature.

While not analyzed by previous studies, we found differences in nasopalatine angle with respect to the direction-course. We found that the angle values pertaining to the vertical type canal (Ia + Ib) were greater than those for the slanted type canal (IIa + IIb). Regarding the coronal slice, the Y-type canal presented an almost 3° greater mean angle than the single canal, which was statistically significant.

With respect to three-dimensional analysis in sagittal slice, like Mardinger et al. [13] and Tözüm et al. [22], we found cylindrical shape to be the most frequent and banana-like shape the least. Also like Tözüm et al. [22], we found no association between dental status and sagittal shape. For all of the sagittal shapes, the most frequent direction-course was slanted-curved (IIb). Almost significant differences were found in terms of age between funnel-like and hourglass-like shapes.

With respect to analysis of sagittal direction-course, like Song et al. [21], the present study found that a straight canal (Ia + IIa) were more frequent than curved canal (Ib + IIb). However, the present results for vertical type versus slanted type canal groups were different from these authors [21]. This may be due to the small sample size in their study [21].

With respect to analysis of coronal shape, like other authors [14], we found Y-type canal to be more frequent followed by single canal and two parallel canals. Other studies [6, 21] found single canal to be the most frequent, although the percentages are closer to our frequency. To the best of our knowledge, this is the first study to describe a significant association between coronal shape and axial classification.

With respect to axial classification, Liang et al. [12] established the following groups: one canal, two canals and three or four canals, which correspond to the present study (1-1), (1-2), and (1-(3-4)) groups, respectively. Keeping this in mind, the most frequent axial group in our study was (1-(2-5)), with the (1-2) group accounting for 80.3 %. However, Liang et al. [12] found (1-1) to be the most frequent group, accounting for 44 % of cases, followed by (1-2) in 39 % of cases.

In the study by Song et al. [21], the incisive foramina were found to always comprise only a single foramen and the foramina of Stenson always had two openings. However, this finding is not in accordance with Bornstein et al. [6] or the present study, which both sometimes found two parallel canals. In fact, the present study found that about 2 % of cases had three openings at the incisive foramina, which recombined to one foramen of Stenson or continued to three (3-(1 and 3)). In addition, two other recent studies [15, 26] are in line with our findings. Firstly, von Arx et al. [26] found 27.8 % of accessory canals ≥1.00 mm. This finding confirms the presence of bone channels within the anterior maxilla. In addition, Neves et al. [15] described a case report of a complete additional NC, in which each channel extended from independent foramina of Stenson to independent incisive foramens.

A precise descriptive anatomic analysis with CBCT images is necessary for NC and BBP dimensions before any surgical treatment in the anterior maxilla for best surgical results. For the placement of dental implants in this region, an exhaustive assessment of bone is necessary due to centripetal bone resorption after tooth in −/− group and frequently requires ridge augmentation procedures.

The NC contains the most nerves, arteries and veins that nourish the premaxilla region. However, this study shows that NC can be formed by several *canaliculi*, this corresponds to the different axial groups. Therefore, the content of NC must be assessed to avoid neurovascular and anesthetic complications. The direction-course of NC and the nasopalatine angle must be assessed for the placement and angulation of future dental implants in this area.

Based on the above, the anterior maxilla region is an area with a high clinical relevance in terms of function and esthetic rehabilitation. The present results demonstrate NC variability in terms of shape and number; therefore, we recommend performing an accurate CBCT study for better surgical anesthesia and reduce surgical complications in implant dentistry.

Conclusions

The NC anatomy is highly variable. Gender is related to the NC length and BBP width, while dental status (presence or absence of maxillary central incisors) is related to the BBP length. There was an association between different sagittal classifications of the NC and between coronal shape and axial classification. The CBCT is a useful device for studying the anatomical variations of the NC and the BBP in three dimensions, prior to dental implant placement.

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Conflict of interest The authors declare that they have no conflict of interest.

Ethical standards This study complies with the current laws of Galicia (Spain) and it was approved by the Galician Ethics Committee of Clinical Research (Ref: 2012/272). Written informed consent was obtained from all patients to participate in the study.

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