

Retrospective Assessment of the Anatomy and Dimensions of Nasopalatine Canal with Cone-Beam Computed Tomography

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ABSTRACT

Objectives: The objective of this retrospective study was to evaluate the anatomy and morphology of the nasopalatine canal in axial, sagittal, and coronal sections with cone-beam computed tomography and to appraise the effect of gender, age, and dental status on the nasopalatine canal.

Material and Methods: Overall 1000 patients with cone-beam computed tomography (CBCT) images were analysed retrospectively. The morphology of the nasopalatine canal (NPC) was classified according to sections. Its sizes were measured, and variations were evaluated. The variables obtained were statistically analysed.

Results: It was observed that the most common NPC shape was the cylindrical type (47.1%) in sagittal sections, and the C-shaped canal (51.1%) in coronal sections. In the axial section, two Stenson foramen (45.2%) were observed most frequently, and the most common form was found as oval (60.7%). In sagittal sections, statistically significant differences were obtained between all morphometric measurements and shapes of the NPC except the angle of the canal. It was found that all morphometric measurements in sagittal and coronal sections were higher in men. Also, it was found that the NPC angle and NPC length decreased with tooth loss.

Conclusions: The nasopalatine canal shows many variations, and its dimensions differ according to gender, age, and dental status. For this reason, before the surgical procedures are applied to the maxilla, it should be evaluated radiologically to prevent complications.

Keywords: anatomy; cone-beam computed tomography; maxilla; radiology.

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INTRODUCTION

The nasopalatine canal (NPC), also known as the incisive canal, is an important anatomical structure located in the middle of the premaxillary region. The NPC opens into the oral cavity with the incisive foramen (IF). The opening of the canal to the nasal cavity has been named as Stenson foramen (SF). The NPC includes fibrous connective tissue, adipose tissue, minor salivary glands, and terminal branches of the nasopalatine artery and nerve [1].

Assessment of the sizes and variations of the NPC is particularly substantial for planning surgical procedures on the maxilla, such as cyst enucleation, extraction of impacted teeth, apical resection of central incisors, rapid palatal enlargement with surgical support, and LeFort I osteotomy procedures [2,3]. In addition, the maxillary anterior region is one of the important regions where trauma and related tooth loss frequently occur [4]. This region has a strong effect on tooth-facial aesthetics and function. For this reason, there is a need for prosthetic rehabilitation with implants in the treatment of tooth loss. Anatomical variations of the NPC should be recognized to prevent complications during implant surgery, such as pain, bleeding, sensory defects, and failures in the osseointegration process [5,6].

Various radiographic methods have been used to determine the localization of NPC [7]. While two-dimensional radiographs are frequently used for implant planning, magnification and distortion of the images may occur [8]. Traditional radiographic techniques do not provide clear information about the buccolingual width and three-dimensional structure of the bone in the selected implant site. Preoperative radiographic evaluation is a useful guide for determining the bone quality and quantity in the selected region and choosing the appropriate location, size, and angle of the dental implants [9]. Implants may be placed in soft tissues, including the neurovascular bundle of the NPC, which can lead to loss of osseointegration. To avoid these complications, it is necessary to evaluate the NPC and the surrounding bone correctly. Cone-beam computed tomography (CBCT) is recommended for the detection and evaluation of various structures that are difficult to detect with two-dimensional radiographs. On the other hand, it has been reported that there is no significant difference between linear measurements in CBCT and direct measurements of the jaw and facial structures [10]. Therefore, the assessment of anatomical structures using CBCT has a crucial factor to prevent complications and to make accurate measurements in the relevant region.

This retrospective study aimed to evaluate the anatomical and morphological dimensions of the nasopalatine canal using cone-beam computed tomography images and to investigate the effect of gender, age, and dental status on the nasopalatine canal.

MATERIAL AND METHODS

Ethical approval

Ethical approval was obtained from Izmir Katip Celebi University Non-Interventional Clinical Studies Ethical Committee (23.01.2019, IRB: 14). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all patients for being included in the study.

Subjects

This retrospective study was performed using the CBCT records which were obtained from the archive of Izmir Katip Celebi University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology between January 2012 and December 2018. CBCT recordings taken for various diagnostic purposes such as examination of impacted or supernumerary teeth, detection and diagnosis of oral pathologies, orthognathic surgery or dental implant planning were evaluated, retrospectively. Records of 316 patients were excluded from the CBCT records of 1316 patients examined. Images with the following exclusion criteria were removed from the study:

- Fracture, unerupted tooth, a pathological lesion, root remnant, severe atrophy, dental implant, bone graft, or lip-palate cleft in the maxillary anterior region.
- Surgical procedures such as orthognathic surgery, cyst enucleation, or apical resection have been previously applied to the relevant area.
- The presence of an artifact that prevents interpretation of the image.
- Images with poor image quality.

The ages of the individuals in the sample group were determined according to the date of the CBCT scan. The determined ages were classified as:

- Group 1 between the ages of 9 to 18.
- Group 2 between the ages of 19 to 30.
- Group 3 between the ages of 31 to 45.
- Group 4 between the ages of 46 to 60.
- Group 5 between the ages of 61 and over.

Individuals were classified into four groups according to dental status:

1. Individuals with maxillary central teeth.
2. Individuals with one of the maxillary central teeth missing.
3. Individuals without maxillary central teeth.
4. Edentulous individuals.

CBCT imaging

All the patient records used in the study were obtained by using the CBCT (NewTom 5G® - Quantitative Radiology; Verona, Italy) device operating at 110 kVp. Images taken in the range of 15 × 12 cm FOV were used. All images were evaluated in the voxel size of 0.200 mm. Digital images were evaluated under dim lighting conditions using a 27-inch screen size monitor (Eizo Radiforce MX270W - EIZO Corp.; Ishikawa, Japan) at a 2560 x 1440 resolution and NNT Viewer version 8.0 (NewTom - Quantitative Radiology; Verona, Italy) computer software.

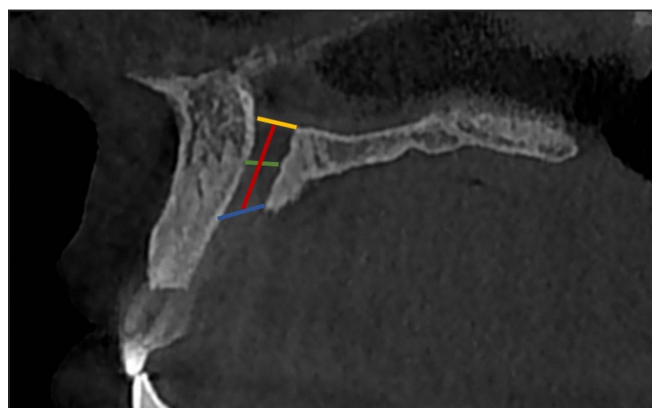


Figure 1. The measurements of the nasopalatine canal (NPC) in sagittal section. Yellow line = Stenson foramen width; green line = mid-level point width; blue line = incisive foramen width; red line = the length of the NPC.

Assessment of CBCT images

The axial, sagittal, and coronal sections were examined in CBCT images. SF, IF, and mid-level point (MP) widths were measured in sagittal sections. If the canal was of type B = or (C), the mean value was recorded. The distance between the midpoint of SF and the midpoint of IF was taken as the NPC length. If the canal was of type B = or (C), their averages were recorded (Figure 1). The angle of the NPC was determined by drawing a line that connects the anterior nasal spina (ANS) and the posterior nasal spina (PNS). The anterior angle between this line and the course of the canal was measured (Figure 2).

In sagittal sections, the shapes of NPC were classified under six groups by adding cone and reverse funnel shapes to the classification of Mardinger et al. [11]. Cylindrical, hourglass, cone, funnel, banana, and reverse funnel shapes are shown in Figure 3A-F.

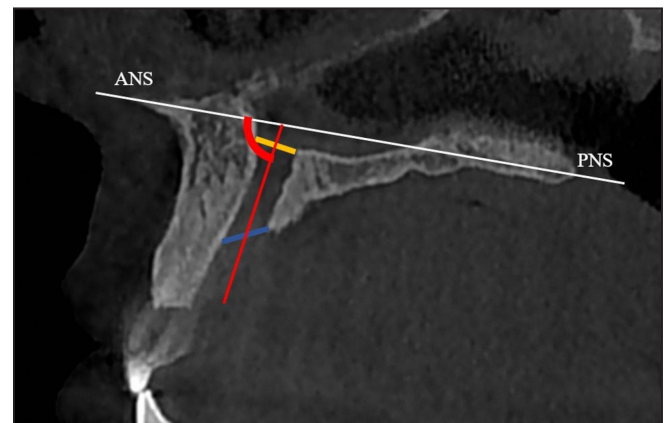


Figure 2. The measurement of the nasopalatine canal angle in sagittal section. Yellow line = Stenson foramen (SF) width; blue line = incisive foramen (IF) width; white line = the line connecting anterior nasal spina (ANS) and posterior nasal spina (PNS); red line = the line passing through the midpoints of the widths of IF and SF.

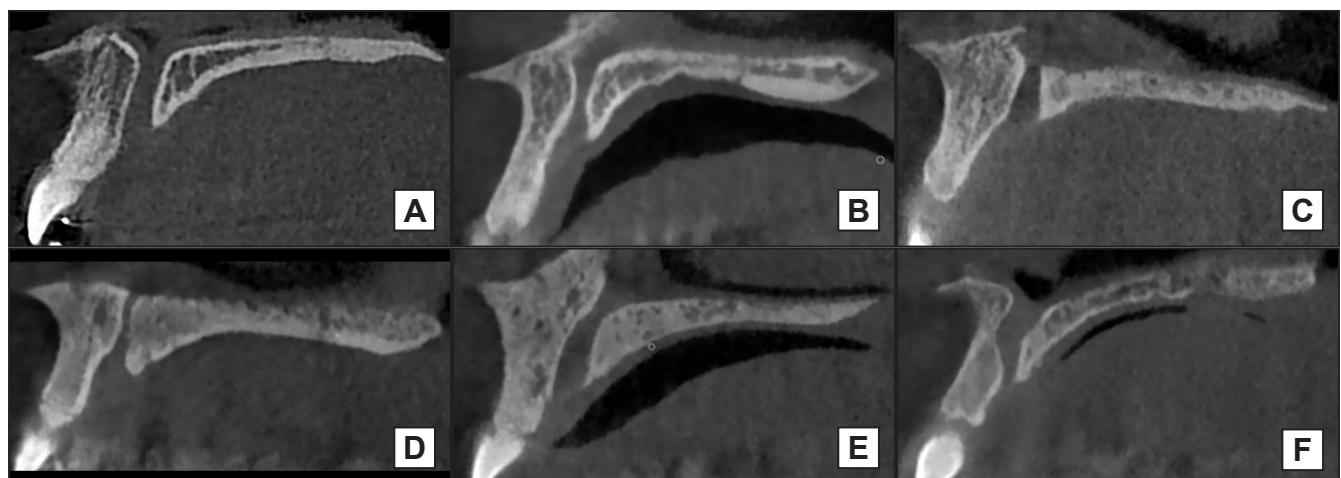


Figure 3. The classification of nasopalatine canal shapes in sagittal section: A = cylindrical; B = hourglass; C = cone; D = funnel; E = banana; F = reverse funnel.

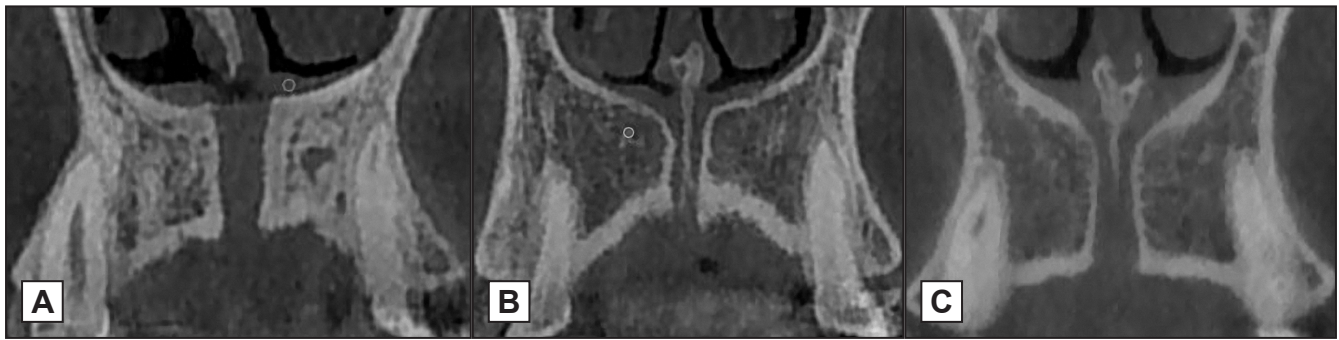


Figure 4. The classification of nasopalatine canal (NPC) shapes in coronal section: A = single NPC; B = two parallel NPC; C = Y type NPC.

In the coronal section, the shapes of the NPC were classified as: single canal, two parallel canals, Y type canal [12] (Figure 4A-C). SF, MP, and IF widths were measured (Figure 5). If the canal was of type B = or (C), the total value was recorded. The number of SF was defined in the axial section (Figure 6A-D). The shapes of the SF were classified as oval, round, and heart (Figure 7A-C).

All measurements were made by one observer - oral and maxillofacial radiologist (C.Ö.K.). To determine intra-observer consistency, linear measurements were repeated 4 weeks later images of 200 individuals (20% of images) randomly selected by the same observer. The intra-observer reliability was evaluated using the intra-class correlation coefficient for all variables, and the intra-class correlation coefficients were between 0.8 and 0.91.

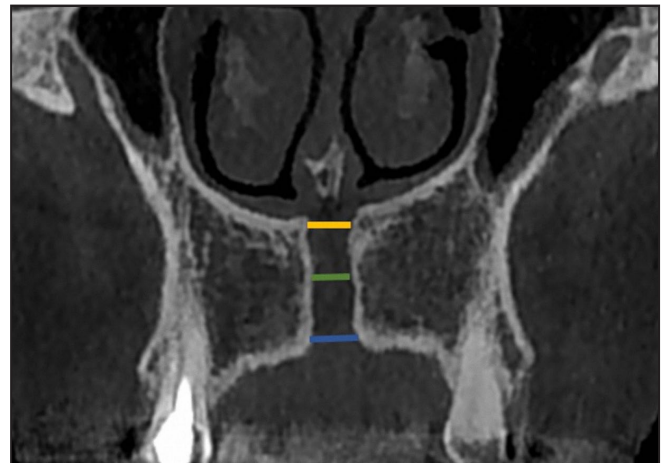


Figure 5. The measurements of the nasopalatine canal in coronal section. Yellow line = Stenson foramen width; green line = mid-level point width; blue line = incisive foramen width.

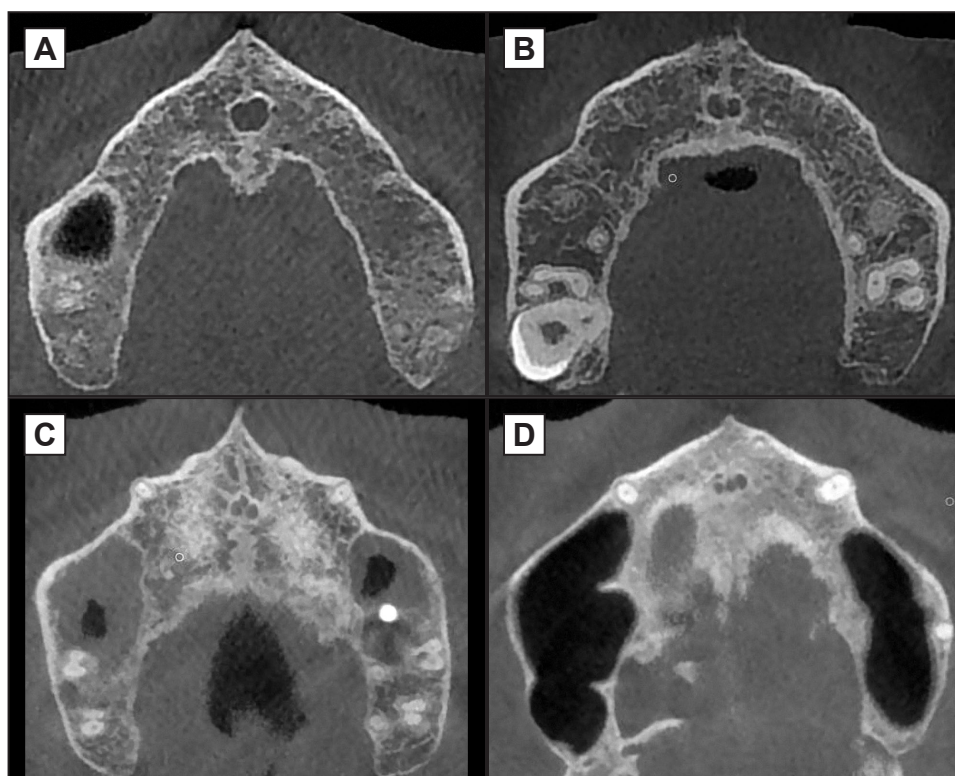


Figure 6. The numbers of Stenson foramen in axial section: A = one; B = two; C = three; D = four.



Figure 7. The shapes of Stenson foramen in axial section: A = round; B = oval; C = heart.

Statistical analysis

Descriptive statistics and frequency tables were used to indicate the general trend of each variable. To determine which statistical method to be used in determining the difference between the averages of the independent groups, the suitability of the data to the normal distribution was first tested with the Kolmogorov-Smirnov and Shapiro Wilk tests, and it was observed that the variables were not normally distributed. For this reason, while testing the differences between the group means, the Mann-Whitney U test was used in case of two independent groups, and the Kruskal-Wallis test was used in case of more than two independent groups. If there were significant differences after the Kruskal-Wallis test, the Mann-Whitney U test was used to compare the groups in pairs and the source of the difference was determined in this way. In the comparison of

qualitative variables, the number of observations (n) and their ratios (with % values) were shown, and their relationship was compared using the Chi-square test. Statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp.; Armonk, New York, USA). The significance level was accepted as 0.05 in all statistical analyses. Parametric and non-parametric data were expressed as mean and standard deviation (M [SD]).

RESULTS

In this study, the morphological evaluations of NPC were made on images of 1000 individuals aged 9 to 90 years. The study group consisted of 497 women (mean 40 [SD 17] years) and 503 men (43 [SD 17] years). Table 1 presents the IF, MP, and SF widths, NPC length, NPC angle measured in sagittal sections.

Table 1. The nasopalatine canal dimensions in sagittal section according to the general, gender, age groups and dental status

		N	IF	MP	SF	NPC length	NPC angle
			Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
General	-	1000	3.54 (1.11)	2.25 (0.9)	2.53 (1.01)	9.49 (2.61)	76.41 (9.08)
Gender	Female	497	3.31 (1.03)	2.14 (0.83)	2.4 (0.99)	8.78 (2.32)	75.21 (9.21)
	Male	503	3.77 (1.14)	2.37 (0.96)	2.66 (1.01)	10.19 (2.7)	77.6 (8.81)
	P value	-	0.000 ^a	0.000 ^a	0.000 ^a	0.000 ^a	0.000 ^a
Age groups	Group 1	119	3.16 (1.02) ^A	2.25 (0.9) ^{AB}	2.43 (1.01)	9.01 (2.18) ^A	79.64 (9.22) ^{AB}
	Group 2	208	3.31 (0.88) ^{AB}	2.13 (0.91) ^A	2.5 (1)	9.92 (2.58) ^B	76.38 (9.16) ^A
	Group 3	226	3.58 (1.21) ^B	2.05 (0.82) ^{AB}	2.59 (0.99)	9.63 (2.81) ^{AB}	77.1 (8.94) ^{AB}
	Group 4	291	3.63 (1.07) ^{BC}	2.3 (0.92) ^B	2.55 (1.05)	9.27 (2.6) ^{AB}	76.19 (8.36) ^B
	Group 5	156	3.94 (1.23) ^{BC}	2.36 (0.94) ^B	2.53 (0.93)	9.49 (2.62) ^C	73.42 (9.52) ^{AB}
	P value	-	0.000 ^b	0.001 ^b	0.504	0.017 ^c	0.000 ^b
Dental status	Group 1	818	3.53 (1.12)	2.23 (0.9)	2.54 (1.02)	9.71 (2.57) ^A	77.08 (8.79) ^A
	Group 2	47	3.49 (1.02)	2.31 (0.98)	2.43 (0.92)	9.12 (2.5) ^B	76.3 (9.02) ^B
	Group 3	48	3.40 (1.05)	2.2 (0.95)	2.4 (0.91)	8.65 (2.82) ^B	74.7 (7.93) ^{AB}
	Group 4	87	3.84 (1.12)	2.46 (0.83)	2.63 (0.95)	8.1 (2.47) ^B	71.21 (10.67) ^B
	P value	-	0.082	0.07	0.655	0.000 ^b	0.000 ^b

^aStatistically significant at level P ≤ 0.01 (independent samples Mann-Whitney U test).

^bStatistically significant at level P ≤ 0.01 (independent samples Kruskal-Wallis test).

^cStatistically significant at level P ≤ 0.05 (independent samples Kruskal-Wallis test).

The uppercase superscript indicates statistical differences within column (Dunn-Bonferroni post hoc analysis).

IF = incisive foramen; MP = mid-level point; SF = stenson foramen; NPC = nasopalatine canal; SD = standard deviation.

IF, MP and SF widths, NPC length, NPC angle showed a statistically significant difference according to gender. While there was a statistically significant difference between IF and MP widths and age, there was no statistically significant difference between SF width and age. Maximum IF and MP widths were determined at the age of 61 and over. Patients aged 9 to 18 had the shortest NPC length and the widest NPC angle. NPC length and NPC angle decreased with tooth loss, and both values were detected the least in edentulous patients.

In sagittal sections, 47.1% cylindrical-shaped NPC, 23.2% funnel-shaped, 14.8% cone-shaped, 8.8% hourglass-shaped, 3.5% reverse funnel-shaped,

and 2.6% banana-shaped were detected, respectively. There was no statistically significant difference in NPC shapes according to gender (P = 0.377), age groups (P = 0.188), and dental status (P = 0.122).

The effect of canal shapes on the sizes of NPC was evaluated. It was determined that all measurements except the canal angle showed statistically significant differences according to NPC shapes (P = 0.000). While SF width was wider in reverse funnel-shaped NPC, IF width was wider in funnel-shaped NPC. The shortest NPC length was in funnel-shaped NPC, while the longest was in reverse banana-shaped NPC (Table 2).

Table 3 presents the IF, MP, and SF widths measured in the coronal sections. IF, MP, and SF widths

Table 2. The nasopalatine canal dimensions in sagittal section according to the NPC shapes

	IF	MP	SF	NPC length	NPC angle
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Cylindrical	3.34 (0.99) ^A	2.55 (0.87) ^A	2.86 (0.89) ^A	9.03 (2.53) ^A	75.85 (9.27)
Hourglass	3.93 (1.06) ^B	1.59 (0.65) ^B	3.21 (0.96) ^A	10.36 (3.04) ^B	78.04 (10.09)
Cone	3.53 (1.08) ^A	1.98 (0.73) ^C	1.59 (0.6) ^B	9.4 (2.37) ^A	76.18 (8.37)
Funnel	3.99 (1.2) ^B	2 (0.9) ^C	2.02 (0.75) ^C	9.96 (2.55) ^{AB}	77.07 (8.93)
Banana	3.59 (0.92) ^{AB}	3.04 (0.63) ^{AD}	2.87 (0.85) ^{AD}	11.79 (2.05) ^{BC}	74.36 (7.01)
Reverse funnel	2.33 (0.85) ^C	2.27 (0.87) ^{AC}	3.5 (1.01) ^{AD}	8.91 (2.48) ^{AB}	78.13 (8.62)
Total	3.54 (1.11)	2.25 (0.9)	2.53 (1.01)	9.49 (2.61)	76.41 (9.08)
P value	0.000 ^a	0.000 ^a	0.000 ^a	0.000 ^a	0.148

^aStatistically significant at level P ≤ 0.01 (independent samples Kruskal-Wallis test).

The uppercase superscript indicates statistical differences within column (Dunn-Bonferroni post hoc analysis).

IF = incisive foramen; MP = mid-level point; SF = stenson foramen; NPC = nasopalatine canal; SD = standard deviation.

Table 3. The nasopalatine canal dimensions in coronal section according to the general, gender, age groups and dental status

		N	IF	MP	SF
			Mean (SD)	Mean (SD)	Mean (SD)
General	-	1000	3.36 (1.05)	3.18 (1.1)	3.98 (1.24)
Gender	Female	497	3.23 (0.98)	3.1 (1.05)	3.9 (1.24)
	Male	503	3.5 (1.1)	3.26 (1.14)	4.06 (1.25)
	P value	-	0.000 ^a	0.04 ^b	0.011 ^b
Age groups	Group 1	119	2.94 (0.98) ^A	2.78 (1.06) ^A	3.86 (1.24) ^A
	Group 2	208	3.15 (1) ^A	2.87 (0.94) ^A	3.76 (1.2) ^A
	Group 3	226	3.41 (1.05) ^B	3.26 (1.1) ^B	4 (1.22) ^{AB}
	Group 4	291	3.46 (0.99) ^B	3.36 (1.1) ^B	4.1 (1.31) ^B
	Group 5	156	3.73 (1.13) ^B	3.46 (1.12) ^B	4.11 (1.17) ^B
	P value	-	0.000 ^c	0.000 ^c	0.014 ^d
Dental status	Group 1	818	3.29 (1.02) ^A	3.11 (1.07) ^A	3.94 (1.23)
	Group 2	47	3.53 (1.1) ^{AB}	3.4 (1.16) ^{AB}	4.16 (1.46)
	Group 3	48	3.48 (1.02) ^{AB}	3.28 (1.1) ^{AB}	3.94 (1.31)
	Group 4	87	3.92 (1.2) ^B	3.65 (1.21) ^B	4.27 (1.16)
	P value	-	0.000 ^c	0.000 ^c	0.075

^aStatistically significant at level P ≤ 0.01 (independent samples Mann-Whitney U test).

^bStatistically significant at level P ≤ 0.05 (independent samples Kruskal-Wallis test).

^cStatistically significant at level P ≤ 0.01 (independent samples Kruskal-Wallis test).

^dStatistically significant at level P ≤ 0.05 (independent samples Kruskal-Wallis test).

The uppercase superscript indicates statistical differences within column (Dunn-Bonferroni post hoc analysis).

IF = incisive foramen; MP = mid-level point; SF = stenson foramen; SD = standard deviation.

were statistically significant differences according to gender and age groups. All values measured in the coronal section were found highest in patients aged 61 and over. In edentulous patients, IF and MP widths were higher than other individuals.

The most C-shaped (51.1%) and the least B-shaped (10.1%) NPC were detected. The shapes of NPC were not statistically significant according to gender (P = 0.931), age groups (P = 0.08), and dental status (P = 0.871). When the effects of canal shape on the morphometric measurements of NPC were evaluated, there was a statistically significant difference in MP and SF values compared to NPC shapes. SF and MP widths were observed in B-shaped NPCs in the coronal section while these values were lower in A-shaped NPCs (Table 4).

In axial sections, two SFs were detected in 452 patients, one SF in 395 patients, three SFs in 140 patients, and four SFs in 13 patients. The number of SF was not statistically significant according to gender (P = 0.766), age groups (P = 0.118), and dental status (P = 0.156). The most oval (60.7%) and the least heart-shaped (8.4%) SF were detected. The shape of SF was not statistically significant according to gender (P = 0.164), age groups (P = 0.33), and dental status (P = 0.522).

DISCUSSION

Anatomical structures, which can show various variations, can affect the placement of implants. Evaluating these structures before the procedure facilitates surgical procedures and prevents possible complications [13]. Sensory impairment and bleeding are common complications encountered during implant surgery. Damage to the neurovascular bundles can affect the patients of life owing to sensory disturbances or pain [14]. In addition, the connection of the implants with the neurovascular bundle may cause osseointegration unsuccess [12]. However,

there are also studies in the NPC region about the development of NPC cysts after implant surgery [15,16]. For these reasons, it is significant to determine the morphological features of the premaxillary region with a radiological study. Although two-dimensional radiographs are frequently used methods due to low radiation doses, they have limited features in demonstrating intra-bone neurovascular structures [3]. In addition, since two-dimensional images are obtained with intraoral and panoramic techniques, they are not considered dependable in radiological evaluations. CBCT is considered the ideal imaging modality for diagnosis in dentistry owing to its low cost and relatively low radiation dose [17]. Complications can be avoided by pre-surgical planning with three-dimensional imaging [18].

In the literature, the number of samples varies between 50 and 619 in studies evaluating the NPC using CBCT [1,7]. Hakbilen and Magat’s [1] study of 619 individuals using CBCT images is the most comprehensive study examining the NPC with CBCT. This study has the highest sample size with 1000 CBCT images obtained from a single center using the same device in all imaging. To acquire more valuable knowledge about the morphology of the NPC, the number of samples has been increased.

Bahşi et al. [17], Hakbilen and Magat [1] and Özçakır-Tomruk et al. [14] reported that there was no statistically significant difference between the width of IF measured in the sagittal section and age. Khojastepour et al. [19] and Friedrich et al. [20] found that as the age increases, the width of IF increases. In our study, a statistically significant difference was detected between age and IF width. It has been determined that IF width increases with age and the highest IF width is 61 years and over. It was determined that the IF width varies according to age, but there was no significant change in the SF width. We think that the dimensions of the IF may change because of the alveolar bone size changes, but the SF in the nasal base will not be affected.

Table 4. The nasopalatine canal dimensions in coronal section according to the NPC shapes

	IF	MP	SF
	Mean (SD)	Mean (SD)	Mean (SD)
A	3.27 (1.05)	2.98 (1.14) ^A	3.74 (1.34) ^A
B	3.46 (0.91)	3.51 (0.92) ^B	4.4 (1.11) ^B
C	3.42 (1.08)	3.27 (1.06) ^B	4.08 (1.15) ^B
P value	0.079	0.000 ^a	0.000 ^a

^aStatistically significant at level P ≤ 0.01 (independent samples Kruskal-Wallis test).

The uppercase superscript indicates statistical differences within column (Dunn-Bonferroni post hoc analysis).

IF = incisive foramen; MP = mid-level point; SF = stenson foramen; NPC = nasopalatine canal; SD = standard deviation.

In similar studies in the literature, the MP width was found between 2.07 mm and 3.85 mm [21,22]. In our study, the MP width was found to be 2.25 mm in accordance with the literature. Ito et al. [23], Al-Amery et al. [21], Friedrich et al. [20], and Tözüm et al. [22] reported that this value was higher in men. Kajan et al. [24] and Thakur et al. [25] reported that the width of the canal was not statistically significant according to gender. In our study, there was a statistically significant difference between the MP width and gender. In addition, contrary to similar studies, a significant difference was found between the MP width and age in this study [20,25].

In different studies, the length of the NPC ranged from 8.1 mm to 16.33 mm [18,21]. In our study, the NPC length was 10.19 mm. Also, contrary to previous studies, there was a statistically significant difference between age and the NPC length [1,4,14,17,25,26]. The length of the NPC was found to be the shortest between the ages of 9 to 18. This study is the only study in the literature with statistically significant results between age and the NPC length. Hakbilen and Magat [1] and Tözüm et al. [22] reported that the NPC length was decreased in edentulous patients. In our study, in accordance with these studies, it was determined that the length of the canal was shorter in edentulous individuals compared to other individuals. The angle of the NPC is important for the angle of the implant material during implant surgery. A limited number of researchers evaluated the NPC angle. In the literature, the angle of the canal has been reported between 69.32° and 74.28° [17,27]. In our study, the NPC angle was higher with an average of 76.41° compared to previous studies. Bahşi et al. [17] reported that there was no significant difference between the canal angle and age. Safi et al. [4] reported that as the age increases and/or loss of teeth, the angle of NPC decreases. In our study, it is compatible with this study. Also, contrary to previous studies, a statistically significant difference was found between the NPC angle and gender [2,4,10,17,27,28]. In the literature, this study is the only study reporting a significant relationship between the NPC angle and gender.

Jain et al. [27] reported that the NPC length, NPC angle, IF and SF widths in sagittal sections were not statistically significant differences according to the shapes of the NPC. Hakbilen and Magat [1] reported a statistically significant difference between the shape of the NPC and the morphometric measurements (SF, IF, and the length of NPC) of the NPC in the sagittal section. They reported that the SF diameter was wider in an hourglass-shaped NPC, the IF diameter was larger in a funnel-shaped NPC. And they detected that

the average longest canal length was in tree branch-shaped NPC, the shortest canal length was in cylinder-shaped NPC. In our study, except for the NPC angle, a statistically significant difference was found between all morphometric measurements (SF, IF, MP, and NPC length) of the NPC and NPC shapes. The SF width was determined in the widest reverse funnel-shaped NPC, the MP width was in the widest banana-shaped NPC, the IF width was in the widest funnel-shaped NPC, the canal length was in the longest banana-shaped NPC. In the literature, our study is the only study comparing MP width according to the NPC shapes in the sagittal section.

It was observed that the measurements of the NPC in the sagittal section were frequently performed in the studies, but there were a limited number of studies in which the measurements were performed in the coronal section. Panjnoush et al. [10] and Ito et al. [23] reported that there was no statistically significant difference between IF and SF widths and gender, age, or dental status. In our study, there was a statistically significant difference between IF, SF widths, and age and gender. Ito et al. [23] reported no statistically significant difference between the MP width and gender. In our study, there was a statistically significant difference between the MP width and gender, age, and dental status. IF and MP widths were higher in edentulous individuals. The widths of IF, MP, and SF were more in individuals aged 61 and over.

In previous studies, the variations of the NPC observed in coronal sections Bornstein et al. [12] classification was used. The NPC was the most common type A in the studies of Gönül et al. [2], Bornstein et al. [12], Özçakır-Tomruk et al. [14], Ito et al. [23], Etöz et al. [26], Sekerci et al. [29]. In our study, among the NPC variations in the coronal section, the NPC (51.1%) was the most common type C. Our results are consistent with similar studies [4,17,19,20,27,28,30].

In the coronal section, the relationship between NPC shapes and morphometric measurements was investigated. A statistically significant difference was found between MP and SF values and canal variations. In type B NPC, MP and SF widths were found higher than other variations. In the literature, this is the only study investigating the relationship between NPC variations and morphometric measurements in the coronal section.

CONCLUSIONS

According to the results of the study, while nasopalatine canal shows many variations, its dimensions may differ according to gender, age, and

dental status. All the morphometric dimensions of the nasopalatine canal were higher in males. It was found that the nasopalatine canal angle and the nasopalatine canal length decreased with tooth loss. This result is important for implant materials applied in prosthetic rehabilitation after tooth loss. When angling the dental implant material, nasopalatine canal should be evaluated to prevent damage. In addition, three-dimensional evaluation of the nasopalatine canal will be beneficial to avoid complications before the planned surgical procedures in the anterior maxillary region.

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