



ANATOMICAL CHARACTERISTICS OF NASOPALATINE CANAL USING CONE BEAM COMPUTED TOMOGRAPHY IMAGES

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ABSTRACT

It is widely accepted that any interventional treatment, such as surgery, requires a precise and predetermined treatment plan. Moreover, conventional images do not allow for the presentation of all canal dimensions, and patients concepts of beauty and their expectations are greater for the premaxilla region. Therefore, the use of three-dimensional images is essential in surgical procedures, such as pathological lesions or implant placement surgeries.

In cone-beam computed-tomography images, the nasopalatine canal was examined in sagittal, coronal, and axial planes. The diameters of nasopalatine and incisive foramina were separately measured, and the length of the nasopalatine canal was found by measuring the distance between the mid-levels of the nasopalatine foramen and incisive foramen. The shape of the canal was assessed in the sagittal and coronal planes in the mid-level of the canal. In addition, the shape of the canal and posterior borders were examined in the mid-level of the canal in the axial plane. The nasopalatine angle was measured as an anterior angle between the long axis of the canal and the hard palate. The number of canals in the midline and openings in each plane was also counted.

The nasopalatine canal in the sagittal plane was classified into six groups: conical (33.2%), cylindrical (25.6%), hourglass (24.7%), funnel-shaped (9.8%), reverse-cone (4.3%), and spindle (2.4%). In the coronal plane, the shape of the canal was assigned to three categories: single channel (59.2%), Y-shaped (31.2%), and dual-channel (9.6%), and the posterior border of the nasopalatine canal was classified into four groups: U-shaped (42.5%), V-shaped (37.2%), reverse-V-shaped (15.4%), and Y-shaped (4.9%). Finally, in the axial plane, the canal shape was classified into four groups: round (40.5%), oval (31.1%), heart-shaped (21.3%), and triangle-shaped (7%).

The use of three-dimensional images should be strongly considered in all surgical interventions involving the nasopalatine canal, such as dental implant placement since any error in surgical interventions will bring about serious consequences due to higher aesthetic expectations for the anterior maxillary region. Due to the lack of correct diagnosis of canal morphology in conventional images, such as periapical and panoramic radiography, it seems necessary to use three-dimensional radiography when performing surgical interventions in this region.

KEYWORDS: anatomical evaluation, nasopalatine canal, cone-beam computed-tomography.

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INTRODUCTION

The properties of the nasopalatine canal were studied and described by Stenson for the first time in 1683 [Görürğöz C, Öztaş B, 2021]. The nasopalatine canal (NPC), also known as the incisive canal, connects the oral and nasal cavities. The inferior opening of NPC is named incisive foramen or foramina of Stenson, and the superior opening of NPC is recognized as nasopalatine foramen in the literature. This canal contains the nasopalatine nerve, the terminal branches of the greater palatine artery, fat, and minor salivary glands which are surrounded by fibrous connective tissues [Bahşi I et al., 2019]. Due to the variable anatomy of the nasopalatine canal, some difficulties have been reported in surgical procedures in the premaxilla region, such as local anesthesia injections, and implant placement [Nemtoi A et al., 2019]. This canal is situated between both maxillae, posterior to the central incisor teeth, and in the midline of the palate at the maxillary area.

Adequate knowledge of this anatomical landmark is of utmost importance in oral cavity surgical procedures, such as dental implants, surgical extraction of an impacted tooth, endodontic retrograde surgeries of maxillary central incisors, the treatment of nasopalatine duct cysts, rapid palatal expansion surgery, dentoalveolar fractures, Ledford1 osteotomy surgeries, and many other important cases [Gönül Y et al., 2016; Görürğöz C et al., 2021]. There is considerable variability in the properties of the nasopalatine canal, such as the dispersion of canal shapes, canal length, and the

number of canals in different planes. Therefore, to avoid damage to the contents of the nasopalatine canal, it is recommended to use cone-beam computed-tomography (CBCT) technology due to its high accuracy and resolution, as well as the elimination of superimpositions commonly observed in conventional radiography.

To overcome it is possible, due to the uniting the knowledge and will of all doctors in the world

The three-dimensional CBCT images allow a more accurate examination of bone quantity and the exact position of the nasopalatine canal in the premaxilla region [Sudheer A et al., 2020]. Placement of implants into the NPC may lead to many complications, such as the failure of implant osseointegration, sensory disorders, paraesthesia, as well as bleeding in the event of nasopalatine artery damage [Gopal K, Kapoor P, 2019]. Due to the unknown anatomical and morphological characteristics of the nasopalatine canal, as well as the demographic characteristics of the study population, the present study aimed to investigate the different dimensions of this landmark and the relationship of the studied variables with age and gender using CBCT.

MATERIALS AND METHODS

A total of 328 CBCT images were randomly selected from among patients referring to an oral and maxillofacial radiology clinic in Yasuj based on the date of referral within 2018-2019. CBCT images were obtained using the 3Dpaxi model (Vatech Company, Korea). The cases with edentulousness, loss of maxillary incisors, and any suspected NPC pathology or metabolic diseases due to morphologic changes of the nasopalatine canal were excluded from the study. Moreover, rare forms that were observed in only one case and did not fall into any of the common classifications were removed from the whole images so as not to negatively affect statistical analyses.

After assigning a specific number to each radiographic image and recording the patient's age and gender, the morphology of the canal was assessed. That is to say, the shape of the nasopalatine canal was examined in three sagittal, coronal, and axial planes; moreover, the posterior border of NPC was examined in the coronal plane and registered based on the categories. In the axial plane, the shape of the canal was examined in the mid-level of the canal, and its different shapes were assigned to three categories: oval, round, triangle-shaped, and heart-shaped. In the coronal plane, the shape of the canal and its borders were examined in the mid-level of the anterior-posterior length. In this plane, the canal shape was classified as single, double, and Y-shaped.

The shape of the borders was also assigned to



four categories, V-shaped, U-shaped, Y-shaped and, and reverse-V-shaped. In the sagittal plane and in the midline sagittal view of the canal, the canal shape was classified as cone, hourglass, funnel, reverse-cone, cylindrical, and spindle. The canal length was measured in the sagittal plane and in the midline sagittal view parallel to the long axis of the canal, which extends from the center of the nasopalatine foramen to the middle of the incisive foramen. The diameter of the nasopalatine foramen was measured linearly from the hard palate perpendicular to the sagittal long axis in the sagittal plane. The diameter of the incisive canal was also measured linearly from the soft palate perpendicular to the sagittal long axis in the sagittal dimension.

If there were two or more openings at incisive or nasopalatine foramen, the canal diameter was measured as the total diameter of all available canals. The angle of the nasopalatine canal in the sagittal plane was measured by recording the an-

terior angle between the palate and the long axis of the nasopalatine canal. The number of canals, as well as incisive and nasopalatine openings, were examined in different sagittal, axial, and coronal planes. The mentioned information was recorded in pre-prepared tables. Quantitative and numerical variables were recorded, and a number was assigned to the qualitative variables for later use in statistical studies. This study was approved by the research ethics committee of Yasuj University of Medical Sciences, Iran (code: IR.YUMS.REC.1399.087). Before the study, the informed consent form for each patient to investigate on her/his CBCT image was provided. All methods were carried out in accordance with relevant guidelines and regulations of the journal and medical researches.

Statistical analysis: Data were statistically analyzed in SPSS software (version 22) using chi-square, Shapiro-Wilk, and Student's t-test. A p-

TABLE 1.

Shape of the nasopalatine canal (NPC)

Plane	shape of NPC	N (%)
Sagittal	Cylindrical	84 (25.6)
	Hourglass	81 (24.7)
	Banana	8 (2.4)
	Cone	109 (33.2)
	Funnel	32 (9.8)
	Reverse cone	14 (4.3)
	Total	328 (100)
Coronal	Shape of NPC Y	101 (31.2)
	Single canal	202 (59.2)
	Double canal	31 (9.6)
	Total	324 (100)
	Posterior border of NPC V	121 (37.2)
	Y	16 (4.9)
	U	138 (42.5)
Axial	Reverse V	50 (15.4)
	Total	325 (100)
	Round	133 (40.5)
	Oval	102 (31.1)
	Heart	70 (21.3)
	Triangle	23 (7.0)
	Total	328 (100)

TABLE 2.

The numbers of the nasopalatine foramen, incisive foramen, and nasopalatine canal at the mid-level

	Female	Male	Total
Round	68 (39.8)	65 (41.4)	133 (40.5)
Oval	52 (30.4)	50 (31.8)	102 (31.1)
Heart	38 (22.2)	32 (20.4)	70 (21.3)
Triangle	13 (7.6)	10 (6.4)	23 (7.1)
p	0.94		

TABLE 3.

Number of nasopalatine foramina, incisive foramina, and the nasopalatine canal (NPC) at the mid-level

Plane	Plane level	ONE opening	Two openings	Three openings
Coronal	Nasopalatine foramen	65 (19.8)	262 (79.9)	1 (3)
	Incisive foramen	290 (88.4)	38 (11.6)	–
Axial	Nasopalatine foramen	70 (21.3)	236 (72.6)	22 (6.1)
	Mid-level of NPC	216 (65.9)	72 (22)	40 (11.2)
	Incisive foramen	286 (87.2)	32 (9.8)	10 (3)

TABLE 4.

The measured numeric values were compared by genders

Plane	Parameter	Gender	Mean \pm SD	P
Coronal	The number of opening at the nasopalatine foramen	Female	1.74+0.44	0.001
		male	1.88+0.44	
	The number of opening at incisive foramen	Female	1.12+0.32	0.95
		male	1.1+0.32	
Axial	The number of opening at the nasopalatine foramen	Female	1.78+0.53	0.005
		male	1.94+0.48	
	The number of opening at the incisive foramen	Female	1.1+0.36	0.02
		male	1.22+0.51	
	The number of opening at mid-level of NPC	Female	1.44+0.69	0.46
		male	1.5+0.74	
sagittal	The diameter of nasopalatine foramen (mm)	Female	2.59+1.5	0.035
		male	2.47+1.7	
	The diameter of incisive foramen (mm)	Female	3.35+1.01	0.006
		male	4.18+1.28	
	The length of NPC (mm)	Female	9.7+2.2	0.024
		male	11.72+2.6	
	NPC angle	Female	69.67+8.59	0.92
		male	73.5+8.5	

value of less than 0.05 was considered statistically significant.

RESULTS

In the sagittal plane, the shape of the nasopalatine canal was classified into six groups: cylindrical, hourglass, cone, reverse cone, funnel, and spindle. Further, in the coronal plane, they were categorized as Y-shaped, single-canal, and double-canal. The borders of the canals were assigned to Y-shaped, U-shaped, and inverse-V-shaped. In the axial plane, the shape of the nasopalatine canal in the mid-level was divided into round, oval, heart-shaped, and triangle-shaped (Table 1). Distorted or rare shapes that were observed in only one image were excluded from the whole sample so as not to affect the statistical analysis. Based on age and

gender, the shapes of the nasopalatine canal were compared in three planes (Table 2). There was no statistically significant relationship between canal shape and gender in the axial plane ($p=0.94$).

The number of incisive and nasopalatine foramina in the axial and coronal planes, as well as the number of canals in the mid-level of the nasopalatine canal, were measured (Table 3). In addition, according to gender, there was a statistically significant difference only in the number of nasopalatine foramina in the axial and coronal planes ($p=0.001$, $p=0.005$, $p=0.02$) and also the number of incisive canals in the axial plane. No significant difference was observed in other parameters (Table 4). In the sagittal plane, the length of the canal and the diameter of the incisive and nasopalatine foramina were measured. Based on the gender, there was a statistically significant difference between nasopalatine foramen diameter ($p=0.035$), incisive foramen diameter ($p=0.006$), and canal length ($p=0.024$) (Table 5).

DISCUSSION

Although traditional intra-oral radiography imaging techniques are suitable due to a lower radiation dose, cost-effectiveness, and easy access, owing to the two-dimensional nature of conventional images, non-presentation of sagittal and

TABLE 5.

The evaluation of the nasopalatine canal in the sagittal plane

Gender	Mean ± SD	Minimum–maximum	P
The diameter of nasopalatine foramen (mm)			
female	2.59+1.5	0.09 -7.84	0.03
Male	2.97+1.64	0.52-8.07	
Total	2.78+1.6	0.09-8.07	
The diameter of incisive foramen (mm)			
Female	3.35+1.01	1.19-5.7	0.0001
Male	4.18+1.28	0.89-7.47	
Total	3.75+1.22	0.89-7.47	
The length of NPC (mm)			
Female	9.7+2.2	3.27-16.38	0.0001
Male	11.72+2.63	4.77-19.02	
Total	10.66+2.61	3.27-19.02	

axial dimensions of the canal, as well as the superimposition of the anterior nasal spine, the roots of the central incisors, and the angle of the nasopalatine canal, it is important in various dental procedures. This is assumed as important dental implant placement, which is more popular in the anterior palate due to higher aesthetic expectations for this region since any error arising from radiographic images with insufficient diagnostic quality can present patients with numerous problems in terms of functioning and beauty.

Although the use of CBCT images is more expensive and imposes a higher dose of radiation on patients, their use seems necessary in anterior palate surgeries since the obtained substantial benefits outweigh the shortcomings. The first step in surgical procedures is the assessment of the radiograph and selection of the appropriate treatment plan. In comparison to conventional radiographic images, CBCT images provide higher resolution and accuracy; moreover, they expose patients to a lower radiation dose and are most cost-effective, compared to other computed tomography (CT) methods, such as Multidetector-row computed tomography (MDCT) and spiral CT.

It is necessary to obtain high-resolution three-dimensional images in implant surgical procedures due to the following reasons: 1) high cost of surgery and the used materials and equipment, 2) the high sensitivity of the surgery, 3) the possibility of such errors as the penetration of implant into a nasopalatine canal that can cause bleeding during surgery, 4) non-osseointegration of the implant, 5) paraneesthesia in the hard palate, 6) high aesthetic expectations in maxillary anterior, and 7) serious problems in case of any implant positioning errors. This is true for the treatment of nasopalatine canal pathologies, and surgical extraction of an impacted tooth, and other anterior palate surgeries.

Shape of the nasopalatine canal

Nasopalatine canal in sagittal plane: Gopal KS and Kapoor P (2019) examined 50 CBCT radiographs and divided the different shapes of the canal into cylindrical, funnel, hourglass, and spindle. In the mentioned study, the majority of the canal shapes were cylindrical, funnel, hourglass, and spindle, respectively. In 2020 Shuder A. and co-

authors, (2020) assessed 50 CBCT radiographs and divided the NPC shapes into cylindrical, funnel, hourglass, and spindle. The highest frequency of canal shape was cylindrical (n=27; 54%), followed by funnel (n=16; and 32%), spindle (n=4; 8%), and hourglass (n=3; 6%). The authors investigated 320 CBCT radiographs and classified the shapes of the canal into 1) hourglass, (2) spindle, (3) cone, (4) funnel, (5) banana, (6) cylindrical, (7) tree branch-like, (8) kink, (9) other [Görürğöz C et al., 2021].

In the stated study, the highest frequency of canal shape was related to funnel (n=93; 29.1%), followed by the hourglass (n=52; 16.3%), cylindrical (n=49; 15.3%), cone (n=36; 11.6%), banana-shaped (n=27; 8.4%), kink (n=24; 6%), tree branch like (n=17; 5.3%), spindle (n=12; 3.8%), and others (n=10; 3.1%). In 2016, Gönül Y. and co-authors divided the various forms of the nasopalatine canal into cylindrical, hourglass, banana, and funnel by examining 100 MDCT images. The most reported shapes were cylindrical (48%), followed by hourglass (20%), banana (20%), and funnel (12%), respectively. In 2019, Bahşi I. and co-authors (2019) examined 150 CBCT radiographs and divided the various canal shapes into cylindrical, hourglass, banana-shaped, cone, funnel-shaped, and reverse cone-shaped. According to the referred research, the most detected canal shape was related to cylindrical (n=43; 28.7%), followed by hourglass (n=40; 26.7%), banana-shaped (n=24; 16%), cone (n=22; 14.7), funnel (n=20; 13.3%), and reverse cone-shaped (n=1; 0.7%).

In 2017 Safi Y. and co-authors assessed 326 CBCT radiographs and divided the shape of canals into cylindrical, funnel, hourglass, and spindle. In the stated study, the most reported canal shapes were cylindrical (n=213; 65.33%), funnel (n=19.01%), hourglass (14.41%) and spindle (1.22%). Nemtoi A. and co-authors (2019) examined 37 CBCT images and classified the shape of the nasopalatine canal into cylindrical, cone, and hourglass. In the mentioned study, the most reported canal shapes were cylindrical (n=20), followed by hourglass (n=9) and funnel (n=5). In the same context, Hakbilen S. and Magat G. (2018) assessed 619 CBCT images and classified NPC shapes into

cone, hourglass, cylindrical, funnel, and banana. The most common types of the nasopalatine canal were conical (26.17%), followed by hourglass (24.71%), cylindrical (16.80%), funnel-shaped (15.83%), and banana-shaped (11.44%).

In their study, Etoz M. and Sisman Y. (2014) assessed 500 CT images and reported the rate of different canal shapes as follows: hourglass (38.8%), funnel-shaped (27.3%), banana-shaped (14.7%), cone-shapes (19.2%), cylindrical (18.6%), and tree branch-like (1.4%). In the current study, 328 CBCT images were examined, and the shape of the nasopalatine canal was assigned to six categories: cylindrical, hourglass, spindle, conical, funnel, and reverse cone-shaped. The highest frequency was related to cone (n=109; 33.2%), followed by cylindrical (n=84; 25.6%), hourglass (n=81; 24.7%), funnel (n=32; 9.8%), reverse-cone-shaped (n=14; 4.3%), and spindle (n=8; 2.4%). Unlike the majority of conducted studies, conical NPC was the most reported canal shape in the present study. This discrepancy can be attributed to genetic differences of the studied populations, the number of statistical populations, and the great resemblance of some canals to two different shapes.

NPC in the coronal plane: In some studies, the nasopalatine canal was also classified into different shapes in the coronal plane. In their study, Görürgöz C. and colleagues (2021) assessed the division of the canal in the coronal plane. The middle-third level was the most frequent with 138 cases (43.1%), followed by the upper-third level in 90 cases (28.1%), and the lower-third level in 54 cases (16.9%). In 38 cases, no divisions were observed during the course of the NPC.

The shape of NPC was classified in three groups: Y-shaped (n=95; 63.3%), single-canal (n=54; 36%), and double canal (n=1; 0.7%) [Bahşi I et al., 2019]. In addition, the posterior borders of NPC were divided into four groups: V-shaped (n=66; 44%), Y-shaped (n=43; 28.7%), U-shaped (n=40; 26.7%) and reverse-V-shaped (n=1; 0.7%). Along the same lines, the authors examined 100 CBCT images and classified the shape of the nasopalatine canal into three groups: single canal, double canal and, Y-shaped canal [Bornstein M et al., 2011]. The highest frequency was related to single canals (45%), fol-

lowed by Y-shaped (40%) and double canals (15%). In a study conducted by Lopez-Jornet P. and colleagues (2015), 122 CBCT radiographs were examined, and different canal shapes were classified as Y-shaped, single canal, and double canal.

The highest frequency was related to Y-shaped canals (52.45%), followed by single (39.34%) and double (8.19%) canals. Gönül Y. and co-authors (2016) investigated 100 CBCT images and assigned the nasopalatine canal into three groups: single canal (58%), Y-shaped (19%), and double-canal (13%). Fernández-Alonso A. and co-authors (2014) examined 230 CBCT images and divided the nasopharyngeal canal into three groups: Y-shaped (45.9%), single-canal (41.1%), and parallel (10.3%). In the present study, the shape of the nasopalatine canal was classified into three groups: single canal (n=202; 59.2%), Y-shaped (n=101; 31.2%), and dual canal (n=31; 9.6%). Moreover, four radiographic images were distorted and removed from the statistical population. The shape of the posterior border of the canal was also studied in the present study. The posterior border was divided into Y, U, V, and reverse-V-shaped. The most reported cases were U-shaped (n=138; 42.5%), followed by V (n=121; 37.2%), reverse-V-shaped (n=50; 15.4%), and Y (n=16; 4.9%). Contrary to the study by Bahşi I. and co-authors (2019), in the present study, the highest frequency of the posterior border was related to the posterior-shaped border. This discrepancy can be ascribed to the great resemblance of some canals to two different shapes and genetic differences in the statistical population of the two studies.

Nasopalatine canals in the axial plane: The number and shape of canals in the axial plane were examined in some studies. It was reported that 98.4% of patients had single incisive foramen, while 1.3% had double incisive foramen [Görürgöz C et al., 2021]. Furthermore, the most common opening was double incisive foramen (n=252; 78.8%), followed by single incisive foramen (n=41; 12.8%), triple incisive foramen (n=23; 7.2%), and quadruple incisive foramen (n=4; 1.3%). In their study, Gönül Y. and co-authors (2016) reported the number of opening at nasopalatine foramen as follows: two openings (57%), three openings (21%), one opening (13%), and four openings (8%). Moreover, in the

current study, the shape of the canal in the midline axial view was determined as follows: round (52%), heart-shaped (25%), oval (15%), and triangle-shaped (6%). Bahşi I. and co-authors (2019) examined 150 CBCT images and assessed different canal shapes in the incisive foramen, the mid-level of the canal, and nasopalatine foramen. In the mid-level of the canal, the highest frequency was related to the round canal (n=78; 52%), followed by heart-shaped (n=55; 36.7%), oval (n=16; 10.7%) and triangle-shaped (n=1; 0.7%). Nasopalatine canals were classified into four groups: one opening (44.3%), two openings (38.4%), three openings (14.7%), four openings (2.7%) [Etoz M et al., 2014].

The authors stated that there are always two nasopalatine foramina and one incisive foramen [Song W et al., 2009]. In the mentioned study, based on the shape of the canal in the mid-level of the axial plane, the nasopalatine canal was classified into four groups: single canal (42.9%), double canal 23.2%, three canals (25%), and single canal (8.9%). The shape of the canal from an axial view in the study by Acar B. and co-authors (2015) was as follows: round (44%), heart-shaped (30%), and oval-shaped (26%). Liang X. and others (2009) classified nasopalatine foramina into three categories: one opening (44%), two openings (39%), three or four openings (17%). In the present study, the shape of the canal was examined at the mid-level and classified into four categories: round, triangle-shaped, oval, and heart-shaped. The highest frequency was related to round canals (n=133; 40.5%), followed by oval (n=102; 31.5%), heart-shaped (n=70; 21.3%) and triangle-shaped (n=23; 7%).

Similar to most studies, the highest frequency

in the current research was round canal; nonetheless, the order of other shapes was different which can be attributed to the resemblance of the canal shape to two different classifications at the same time or differences in statistical populations. The following table presents the results of comparing the numerical variables of different studies. In the studies a statistically significant relationship was detected between canal length and gender [Bornstein M et al., 2011; Lopez Jornet P et al., 2015; Gönül Y et al., 2016; Hakkılen S et al., 2018]; however, this association was rejected in a study performed by Safi Y. and co-authors (2017). In the present study, in the coronal plane, there was a statistically significant relationship between the number of openings at nasopalatine foramen and gender (p=0.001); nonetheless, this relationship was not observed between the number of openings at incisive foramen and gender (0.95).

In the axial plane, gender was significantly correlated with the number of openings at nasopalatine and incisive foramina (p=0.05; p=0.02). In the same plane, no significant relationship was observed between canals in the mid-level of the nasopalatine canal (p=0.46). In the sagittal plane, gender was significantly correlated with nasopalatine foramen diameter, incisive foramen diameter, and canal length (p=0.035; p=0.006; p=0.024); nevertheless, there was no statistically significant relationship between canal angle and gender (p=0.92). It was sometimes difficult to assign one type of canal to a category owing to numerous similarities in some qualitative variables, such as the shape of the canal in different dimensions. Therefore, it is suggested that interested researchers specify their classification criteria more clearly.

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