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Morphological CBCT parameters for an accurate differentiation between nasopalatine duct cyst and the normal nasopalatine canal

Aleksa Janovic[1*], Djurdja Bracanovic[1], Svetlana Antic[1] and Biljana Markovic-Vasiljkovic[1]

Abstract

Background The incisive foramen width was a traditional imaging criterion for diagnosing nasopalatine duct (NPD) cysts. Recent CBCT studies demonstrated significant dimensional variations of the nasopalatine canal, which raised questions about the accuracy of this criterion. This study investigated whether nasopalatine canal diameters assessed on CBCT images can accurately differentiate NPD cysts from normal nasopalatine canals.

Methods The study included 19 patients with NPD cysts (12 (63.2%) males, 7 (36.8%) females, mean age 44.7 ± 13.3), and a control group of 164 patients (72 (43.9%) males, 92 (56.1%) females, mean age 47.25 ± 17.74). CBCT images were retrospectively evaluated. The following nasopalatine canal diameters were measured on reference sagittal, coronal, and axial reformation images: nasal opening anteroposterior (AP) and mediolateral (ML) diameter, oral opening AP (APOO) and ML (MLOO) diameter, nasopalatine canal length, minimum ML (minML) diameter, anterior wall expansion (AWE), nasopalatine canal angle, and the mid-level AP diameter (midAP). All parameters were compared between groups. Discriminant functional analysis (DFA) was applied to detect CBCT parameters that best differentiate the NPD cyst from the normal canal.

Results Patients with NPD cyst had significantly greater values of APOO (7.06 ± 2.09 vs. 5.61 ± 1.70), MLOO (6.89 ± 2.95 vs. 3.48 ± 1.24), minML (2.88 ± 1.53 vs. 2.25 ± 1.09), AWE (2.15 ± 0.65 vs. 0.41 ± 0.67), and midAP (4.58 ± 1.61 vs. 2.48 ± 0.96). DFA showed MLOO, AWE, and midAP as the most accurate in distinguishing NPD cyst from the normal canal. When combined in the discriminant function equation X = 0.390·MLOO + 1.010·AWE + 0.288·midAP (cut score 1.669), the differentiation can be performed with a sensitivity and specificity of 98.8% and 76.9%, respectively.

Conclusion NPD cysts can be accurately distinguished from the normal nasopalatine canal by measuring MLOO, AWE, and midAP diameter on CBCT images.

Keywords Nasopalatine canal, Nasopalatine duct cyst, Morphology, CBCT, Discriminant functional analysis

*Correspondence:
Aleksa Janovic
aleksa.janovic@stomf.bg.ac.rs
[1]School of Dental Medicine, Center for Diagnostic Radiology, University of Belgrade, 6 Rankeova, Belgrade 11 000, Serbia

Background

The nasopalatine duct (NPD) cyst is the most common developmental non-odontogenic cyst in the maxillofacial region. It originates from the epithelial remnants of the embryological NPD [1]. The prevalence of the NPD cyst ranges from 1 to 11.6% [2]. The prevalence is even higher due to its clinically silent nature and increasing application of cross-sectional imaging for diagnosing various dento-maxillofacial diseases and dental implant planning. When symptomatic, it is usually diagnosed in adults between the fourth and sixth decade [3, 4]. However, asymptomatic and incidentally encountered NPD cysts during the routine radiological examination may be misinterpreted as an anatomical variation of the nasopalatine canal or mimic periapical inflammatory lesions [5–7].

On intraoral (periapical and occlusal) radiography, the NPD cyst typically presents as a round or heart-shaped circumscribed radiolucent lesion in the midline of the maxilla, sometimes superimposed with the anterior teeth and the anterior nasal spine [1]. On magnetic resonance imaging, NPD cyst shows homogeneous high signal intensity on T2-weighted images and intermediate to high signal intensity on T1-weighted images corresponding to keratin and viscous fluid content [8]. Traditionally, diagnosis of the NPD cyst should be suspected when the incisive foramen is wider than 6 mm on intraoral radiography [9, 10]. This value was thought to be the upper range of the normal incisive foramen width [11]. However, extensive application of 3D cross-sectional imaging in the recent decade, especially CBCT, and an increasing interest in the nasopalatine canal morphology brought the accuracy of the aforementioned diagnostic criterion into question. Many authors demonstrated high variability of the incisive foramen width in normal nasopalatine canals that is not in line with traditional knowledge [12–14]. Additionally, Ueda et al. [12] reported that the traditional cut-off value of 6 mm could be used to diagnose NPD cysts on standard CT images only in younger patients. Some authors also highlighted an age-related increase in the size of the nasopalatine canal in normal subjects [13], which might result in a false positive diagnosis of NPD cyst.

Concerning the abovementioned findings, there is a need to revise the existing criterion for the NPD cyst diagnosis on cross-sectional imaging. This is primarily because surgical management highly depends on the cyst size [4]. The risk of postoperative complications and the need for preoperative endodontic treatment to incisors and/or canines have been reported to increase significantly in large cysts [4, 15]. Additionally, the presence or absence of the symptoms does not correlate with the cyst size [4]. Since there are still no clearly suggested criteria for the NPD cysts diagnosis on CBCT images, we thoroughly analyzed the CBCT morphology of the nasopalatine canal in patients with NPD cysts and the control group. This study aimed to reveal which CBCT parameters, if any, are of a diagnostic value to differentiate normal nasopalatine canal from the NPD cyst accurately.

Methods

This retrospective study included CBCT images of 19 patients (12 (63.2%) males, 7 (36.8%) females, mean age 44.7±13.3) with NPD cysts diagnosed and treated between 2015 and 2022. The control group of 164 adult patients (72 (43.9%) males, 92 (56.1%) females, mean age 47.25±17.74) was selected from the CBCT database stored in the Center for Diagnostic Radiology of the same institution. All patients were referred to CBCT imaging due to various indications: 27 patients for anterior restorations, 29 patients due to impacted teeth, 34 patients due to prosthetic restorations, 48 patients for orthodontic treatment, and missing relevant teeth in 26 patients. Patient selection for the control group was carried out according to the following inclusion criteria: (1) no signs of NPD cyst on clinical examination (data obtained from the medical records), (2) the frontal region of the maxilla in the field of view on CBCT images, (3) the absence of dental implants in the anterior teeth region, (4) absence of extensive bone lesions affecting the nasopalatine canal integrity, (5) no history of trauma, (6) no history of developmental jaw anomalies, and (7) good quality of CBCT images (no severe artifacts, motion blur).

CBCT imaging was carried out on Scanora 3Dx device (Soredex Co., Tuusula, Finland). Different fields of view were used for scanning: 50×50 mm (S field), 50×100 mm (S+field), and 80×100 mm (M field). The following scanning parameters were applied: voltage of 90 kVp, tube current of 8–10 mA, and the voxel size ranged from 0.15 mm to 0.4 mm (resolution mode marked as "standard"). Section thickness was in the range of 0.15–0.4 mm, depending on the voxel size. Evaluation of CBCT images and measurements in sagittal, coronal, and axial planes were performed in the OnDemand3D Viewer (Cybermed Inc., Seoul, Korea).

The morphology of the nasopalatine canal was assessed by measuring linear and angular parameters in both the patient and control groups (Figs. 1 and 2). There were no NPD cysts with extensive bone destruction in our series that limited CBCT analysis. Many of the assessed CBCT parameters were measured according to the protocol described in the literature [13, 16]. The definition of each parameter and a brief description of the measurement technique are summarized in Table 1.

The anteroposterior diameter of the nasal opening (APNO, in mm), anteroposterior diameter of the oral opening (APOO, in mm), nasopalatine canal length (L, in mm), the mid-level anteroposterior diameter (midAP,

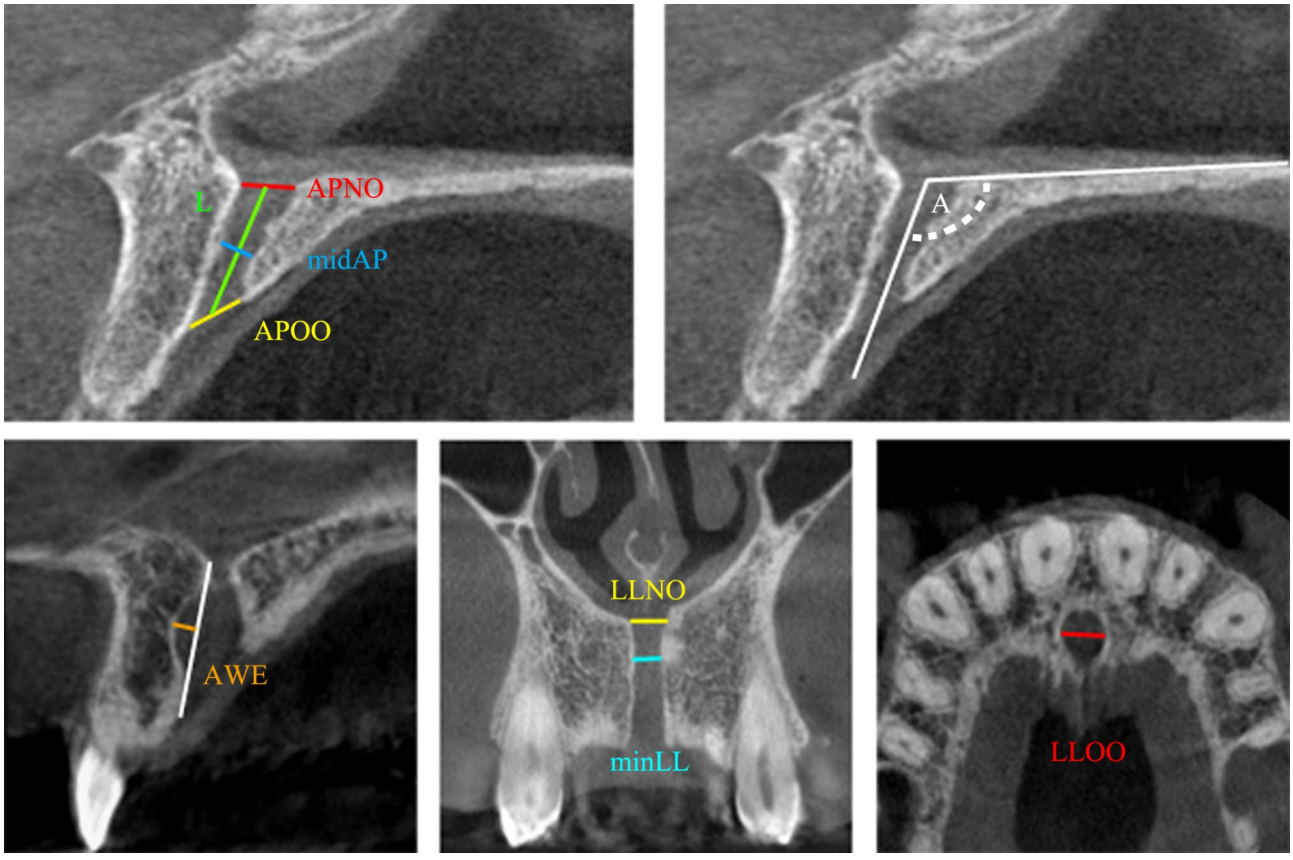

Fig. 1 Morphological parameters of the nasopalatine canal measured on reference CBCT section images. A, B. Measurements in a reference sagittal plane: **APNO** (in mm) - anteroposterior diameter of the nasal opening, **APOO** (in mm) - anteroposterior diameter of the oral opening, **midAP** (in mm) - mid-level anteroposterior diameter of the canal, **L** (in mm) – length of the canal, **A** (in degrees) **–** the angle between the canal axis and the nasal floor. C. **AWE** (in mm) – anterior wall expansion measured on the same sagittal image. D. Measurements in a reference coronal plane: **MLNO** (in mm) – mediolateral diameter of the nasal opening, **minML** (in mm) – minimum mediolateral diameter. E. Measurements in a reference axial plane: **MLOO** (in mm) – mediolateral diameter of the oral opening

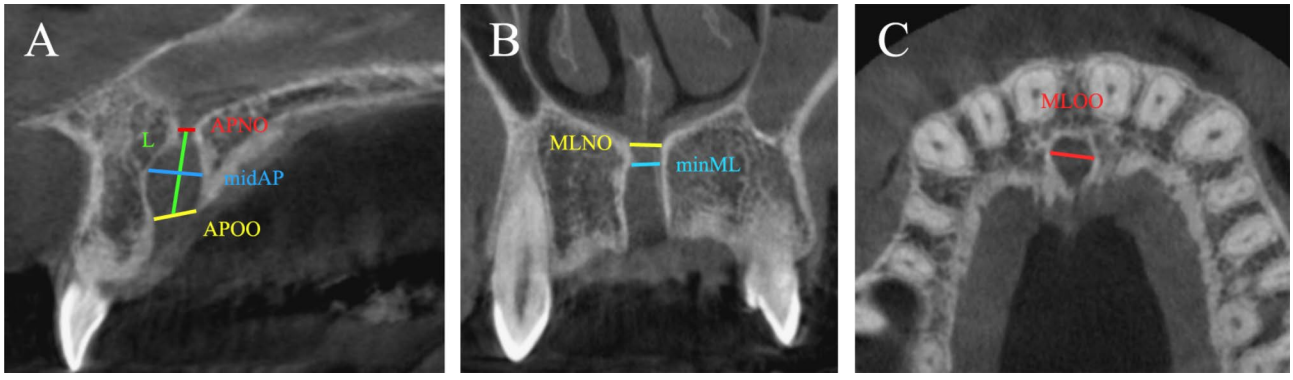

Fig. 2 CBCT parameters measured in a patient with NPD cyst. (**A**) Sagittal plane measurements. Note the increase in size of the APOO and midAP caused by a cyst. (**B**) Coronal plane measurements. MinML was also increased due to the cyst. (**C**) Axial plane measurement

in mm), and the nasopalatine canal angle (A, in degree) were measured in a sagittal plane [13, 16]. A reference sagittal image was set running through the longitudinal axis of the nasopalatine canal using a 3D navigation tool that simultaneously shows the canal position in the axial and coronal plane (Fig. 1A-C). The anterior and posterior nasal spines were used as reference points in the axial plane. For two nasal openings (Y-shaped canal in coronal view), sagittal images were scrolled laterally to show both nasal openings and to measure AP diameters. The mean value was calculated and used in the further analysis. In

Table 1 CBCT parameters used in the study with a brief measurement technique description

PARAMETER	ABB.	DEFINITION
Nasal opening		
Anteroposterior diameter	APNO	Anteroposterior diameter of the nasal opening measured on a reference sagittal plane
Mediolateral diameter	MLNO	Mediolateral diameter of the nasal opening measured on oblique coronal reformation passing through the longitudinal axis of the nasopalatine canal
Oral opening		
Anteroposterior diameter	APOO	Anteroposterior diameter of the oral opening measured on sagittal section
Mediolateral diameter	MLOO	Mediolateral diameter of the oral opening measured on oblique axial reformation at the APOO level
Length	L	The nasopalatine canal length measured between the midpoint of the nasal and oral opening along the longitudinal axis in the reference sagittal plane
Minimum width	minML	The minimum mediolateral diameter of the canal measured on oblique coronal reformation passing through the longitudinal axis of the canal
Anterior wall expansion	AWE	The maximum distance between the anterior wall of the canal and the line connecting the anterior edges of the nasal and oral opening on the sagittal section
Angle	A	The angle between the longitudinal axis of the canal and the nasal floor measured on the sagittal section
Mid-level anteroposterior diameter	MidAP	The distance between the anterior and posterior walls at the middle of the canal, perpendicular to the longitudinal axis, measured on the sagittal plane

the case of the double nasopalatine canal, both canals were measured, and mean values were used.

The expansion of the anterior wall of the nasopalatine canal (AWE, in mm) was introduced by the authors of the current study as a new parameter. The AWE was used to quantify a focal bulging of the anterior wall of the nasopalatine canal typically found in patients with an NPD cyst (Fig. 1C). The AWE measurement was performed on the same sagittal reference image (Fig. 1C). During the first step, the line connecting the anterior edges of the nasal and oral opening was drawn (white line in Fig. 1C). The second, the distance between this line and the most prominent point on the anterior wall of the canal was defined as AWE. The measurement was taken perpendicular to the white line, as shown in Fig. 1C. This parameter was also measured in normal canals since certain anatomical variations of the canal shape may have a positive AWE („banana"-shaped canal, spindle-shaped canal).

The mediolateral diameter of the nasal opening (MLNO, in mm) and the minimum mediolateral diameter (minML, in mm) were measured on the oblique coronal plane. A reference coronal plane was set by tilting the line showing the coronal section on a sagittal reformated image to fit the longitudinal axis of the canal. The reference coronal plane passed through the middle of the APNO and APOO (Fig. 1D). The mediolateral diameter of the oral opening (MLOO) was measured on the axial plane (Fig. 1E). When setting a reference axial plane, the same sagittal reformated image was used to tilt the line corresponding to the axial section. The line was running through the anterior and posterior edges of the oral opening.

Two radiologists, experts in dento-maxillofacial radiology with more than ten years of experience, made the measurement. They performed CBCT analysis independently and were blind to each other's measurement outcomes. Inter-observer reliability was estimated using interclass correlation coefficients.

Statistical analysis

Obtained linear and angular CBCT parameters were analyzed in SPSS software (version 17.0; SPSS Inc., Chicago, IL, USA). Mean and standard deviation were calculated for each CBCT parameter. The Kolmogorov-Smirnov test evaluated the distribution of the data normality. The Student's t-test assessed the differences in CBCT parameters between patients with NP cysts and the control group. Discriminant functional analysis was applied to find CBCT parameters that best differentiate the NP cyst from the normal NP canal. The level of significance was set at 0.05.

Results

The NPD cysts were presented on CBCT images by a spheric, sharply demarcated lesion located in the vicinity of the oral opening of the nasopalatine canal. The cyst content appeared homogenous. The maximum width of the NPD cyst ranged from 7.8 mm to 19.6 mm (mean width of 14.1 mm). The most dominant effect on surrounding structures was the expansion of the oral opening and the anterior and lateral walls of the canal. Table 2 displays CBCT parameters measured in patients with NPD cysts and in the control group. CBCT parameters showed greater values in patients with NPD cysts except for the nasal opening, length, and angle. The detected differences were confirmed as highly statistically significant for the oral opening dimensions (APOO, MLOO), AWE,

Table 2 Comparative analysis of CBCT parameters (mean ± standard deviation) in patients with NPD cyst and control group

CBCT parameter	Patient Group (*n* = 19)	Control Group (*n* = 164)	Statistical analysis	
			t test	*p* value
APNO	3.11 ± 0.74	3.49 ± 1.40	0.727	0.468
MLNO	3.50 ± 1.63	3.52 ± 1.59	0.679	0.498
APOO	7.06 ± 2.09	5.61 ± 1.70	-3.691	**0.002***
MLOO	6.89 ± 2.95	3.48 ± 1.24	-11.537	**< 0.001***
L	11.50 ± 2.94	11.47 ± 2.56	-0.142	0.887
minML	2.88 ± 1.53	2.25 ± 1.09	-1.972	**0.050***
AWE	2.15 ± 0.65	0.43 ± 0.67	-10.388	**< 0.001***
A	109.98 ± 9.21	105.91 ± 8.81	-1.648	0.101
MidAP	4.58 ± 1.61	2.48 ± 0.96	-4.294	**0.001***

Table 3 Model accuracy using discriminant functional analysis for the NPD cyst diagnosis based on CBCT parameters

CBCT parameter	Nasopalatine canal		Total (*n* = 183)
	Cyst (*n* = 19)	Normal (*n* = 164)	
APOO	12/19	127/164	139
	63.2%	77.4%	75.9%
MLOO	12/19	159/164	171
	63.2%	96.9%	93.4%
minML	9/19	111/164	120
	47.4%	67.7%	65.6%
AWE	14/19	150/164	164
	73.7%	91.5%	89.6%
MidAP	13/19	150/164	163
	68.4%	91.5%	89.1%

and midAP (Table 2). MinML showed the boundary level of significance between groups.

CBCT parameters that differed significantly between groups were included in discriminant functional analysis. The calculated model accuracy is shown in Table 3. When analyzing the total accuracy of each CBCT parameter, the model accurately classified from 65.6 to 93.4% cases. The highest classification accuracy was detected for MLOO, AWE, and midAP in descending order (from 93.4 to 89.1%). When analyzed the patient and control group, respectively, the model accuracy values were slightly higher for the normal nasopalatine canal.

When combined MLOO, AWE, and midAP together, these CBCT parameters could differentiate accurately 96.7% (177/183) cases using the following equation:

$X = 0.390 \cdot MLOO + 1.010 \cdot AWE + 0.288 \cdot midAP$.

The calculated cut score was 1.669 (normal canal < 1.669 < NPD cyst). The obtained sensitivity and specificity for the equation were 98.8% and 76.9%, respectively.

Statistical analysis showed excellent inter-observer reliability between two radiologists for all measurements. The interclass correlation coefficient (ICC) for each analyzed CBCT parameter was as follows: 0.913 for APNO, 0.928 for APOO, 0.924 for midAP, 0.940 for L, 0.873 for A, 0.893 for AWE, 0.958 for MLNO, 0.879 for minML, and 0.962 for MLOO.

Discussion

Although diagnosing the NPD cyst requires clinical, radiological, and histopathological evaluation, oral radiologists seem to rely on traditional criteria based on the incisive foramen width. If the foramen width is greater than 6 mm on intraoral radiography, the pathology of the nasopalatine canal should be suspected [9]. This was slightly modified by Mraiwa et al. [14], who suggested a cut-off value of 10 mm based on the 3D imaging findings. Further attempts to define a precise, incisive foramen width to distinguish a normal canal from a cyst had introduced additional confusion due to significant inter-study differences in values that were considered normal. Indeed, extensive CBCT investigations of the nasopalatine canal revealed its high dimensional variability in normal subjects [11, 13, 16–19]. The upper range of the normal incisive foramen width was 11,41 mm [13], which exceeds the traditional cut-off value. Many published cases or case series with NPD cysts presented CBCT findings in a descriptive form offering no skeletal normative value for an accurate diagnosis of the NPD cyst [2, 3, 5–7, 20–25]. Only Ueda et al. [12] tested the incisive foramen width of 6 mm as a cut-off value on CT images in the Japanese population. However, the results were not accurate enough, particularly in the elderly population. The authors suggested a cut-off value of 7 mm to distinguish the normal canal from the NPD cyst in patients over 60 years of age, whereas the cut-off value of 6 mm can be used in younger patients.

The current study demonstrated that the NPD cyst significantly changes the nasopalatine canal morphology. In our series, changes occurred mainly in the lower part of the canal in the vicinity of the oral opening, where cysts developed. The most significant dimensional changes were detected in the diameter of the oral opening, minimum ML diameter, and midAP diameter. Based on the discriminant functional analysis results, the ML diameter of the oral opening showed the highest total accuracy among analyzed CBCT parameters. This single parameter could accurately differentiate the NPD cyst from the normal canal in more than 90% of cases. The anterior wall expansion of the canal was an additional CBCT parameter that was confirmed as an excellent predictor for the NPD cyst diagnosis. The current study introduced the AWE to assess the degree of the nasopalatine canal pathologic dilatation outside its anatomic margins. On the sagittal CBCT image, AWE can be perceived as a focal outpouching of the anterior wall at the level of the cyst (Fig. 1C). This change in the canal configuration

occurs as a consequence of pressure-induced bone resorption and remodeling to a slow-growing cyst. A similar discrimination value between the normal canal and the cyst could be achieved with the midAP diameter. Ueda et al. [12] recently reported a cyst-related increase in canal length in the Japanese population. However, the NPD cyst did not significantly impact the canal length in our series. This CBCT parameter showed similar mean values in both groups and was not considered in further discriminant analysis.

When combined, MLOO, AWE, and midAP could predict the presence of the NPD cyst with a high sensitivity of more than 98%. The obtained equation could be used in clinically suspected cysts and incidentally found nasopalatine canal widening. The equation result below the cut score of 1.669 suggests no NPD cyst diagnosis, whereas a value higher than the cut score indicates NPD cyst presence. The specificity was lower (76,9%) but still good enough. A variable nasopalatine canal morphology could explain the discrepancy between sensitivity and specificity in our series. For example, relatively higher values of MLOO could appear in the hourglass and wedge-shaped canal. These shape variants increase the wall divergence toward the oral opening. The upper range of the MLOO in our control group was 11.5 mm, which is in line with the findings of Friedrich et al. [13]. Our sample also overlapped the MLOO in normal canal and cysts (minimum cyst width was 7.8 mm, while the MLOO was up to 11.5 mm). The value of the canal midAP diameter could also be influenced by the nasopalatine canal shape and the cyst location and size. Namely, the spindle-like shape of the canal may have an increased midAP diameter that matches the value of the cyst if this parameter is the only one considered.

On the contrary, the small cyst and/or dominant extraosseous position of the cyst (at the level of the oral opening) may not reach the middle of the canal, so the midAP diameter may not necessarily be enlarged. Finally, although AWE is predictive for the NPD cyst, the anterior curved or so-called banana-shaped nasopalatine canal in a sagittal plane may be misinterpreted as the anterior wall bulging. However, NPD cyst-induced bulging is usually focal, while the rest of the wall lies in its anatomical position. The entire anterior wall is curved in the banana-shaped canal and could be easily differentiated from the cyst. Possible false negative results in the case of AWE could arise if the cyst is too small to induce bone expansion.

The discriminant analysis clearly demonstrated particular morphological parameters of the nasopalatine canal that could allow a confident radiological diagnosis of the NPD cyst. Compared with traditional criteria, the obtained equation based on MLOO, AWE, and midAP could objectively differentiate the normal canal from the NPD cyst. As demonstrated in our sample, it could be easily applied in both small and large cysts. The shape of the nasopalatine canal may not significantly affect the accuracy of the equation because shape variations usually reflect an increase of only one CBCT parameter. No such canal shape could simultaneously increase all three CBCT parameters. If one of the CBCT parameters is enlarged in the normal canal, its effect on the equation result could be diminished or annulled by the other two parameters. This study has some limitations that need to be addressed. First, a relatively small number of patients with NPD cysts was included in the study. They showed certain CBCT imaging characteristics that might not cover all possible clinical scenarios. Therefore, the proposed discriminant equation may not reach the same sensitivity and specificity in all other cases of NPD cysts, e.g., in cases with extremely large cysts or in extensive bone destruction. Although we minimized the possibility that patients from the control group may have NPD cysts, this could not be strictly excluded. The fact that the study included white Caucasians could potentially limit the equation application to other populations and ethnic groups. This has to be considered since some authors advocate that there are ethnic differences in the anatomy of the nasopalatine canal [26, 27], although other authors deny such differences [28]. Future studies could estimate the accuracy of the equation in various ethnic groups.

Conclusion

In our series, CBCT morphology of the nasopalatine canal differed significantly between patients with NPD cysts and healthy subjects regarding the AP and LL diameter of the oral opening, minimum ML diameter, anterior wall expansion, and midAP diameter. Our results showed that MLOO, AWE, and midAP are the best discriminatory parameters in the NPD cyst diagnosis. The NPD cyst can be diagnosed with a high accuracy on CBCT images by measuring these three parameters and applying a discriminant function equation.

Author contributions

AJ made the research question, contributed to the study design and data interpretation, and wrote the most of the manuscript. DB and SA performed CBCT analysis, and contributed in writing Methods section of the manuscript. BMV supervised CBCT analysis, contributed to the statistical analysis, and manuscript writing and editing. All authors read and approved the final version of the manuscript.

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Data availability

Data and materials available at request.

Declarations

Ethics approval and consent to participate
This study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Institutional Research Ethics Committee (No. 29/V-1).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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