

Morphological analysis of anatomical structure of nasopharynx in cone-beam computed tomography in Korean population

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ABSTRACT

Purpose: This study evaluated the nasopharyngeal anatomy, particularly the fossa of Rosenmüller (FoR), on cone-beam computed tomography (CBCT) in a Korean population to establish normative reference data by sex and age.

Materials and Methods: In CBCT images, FoR was classified into three types (A-C) for image analysis. Measurements of nasopharyngeal dimensions were performed in Types B and C. Sex- and age-related differences were evaluated using chi-square and independent t-tests, and reliability was assessed using the intraclass correlation coefficient.

Results: In total, 492 CBCTs (244 males, 248 females; 20-69 years) were included. Type C was the most frequent morphology and increased with age. Types A and B were more prevalent among males than among females, whereas Type C was predominant among females (57.3%) compared with males (34.4%). Asymmetry was more frequent in males (13.9%) than in females (10.1%). Significant sex differences due to the larger males were found in the distance of the torus levatorius, the distance between the sphenopalatine notch and the right torus levatorius, and the horizontal and vertical dimensions of the FoR. No significant side-to-side differences were observed. Reliability was excellent (ICC=0.97).

Conclusion: Type C was the most frequent morphology in both sexes, whereas Types A and B were more frequently observed in males than in females. These differences may indirectly contribute to sex-related disparities in nasopharyngeal carcinoma (NPC) incidence. The normative reference values may aid early detection in dental imaging, and further prospective studies including NPC patients are needed to clarify the role of nasopharyngeal morphology. (*Imaging Sci Dent 20250264*)

KEY WORDS: Cone-Beam Computed Tomography; Nasopharynx; Fossa of Rosenmüller; Sex Characteristics

Introduction

Nasopharyngeal carcinoma (NPC), a distinct subtype of head and neck malignancy, most commonly arises from the mucosal epithelium of the nasopharynx. One of the most frequent sites of origin is the lateral wall of the nasopharynx, particularly a deep anatomical structure known as the pharyngeal recess, or fossa of Rosenmüller (FoR).¹ This recess is located posterior to the curtain-like torus tubarius, a muco-

sal elevation formed by the underlying cartilaginous opening of the Eustachian tube. The FoR forms a key anatomical landmark that is highly relevant in both oncological and imaging contexts.² As FoR is more commonly used in clinical and radiological literature, the term FoR is adopted throughout this paper.

The morphology of soft tissue structures in the oral and pharyngeal regions is influenced by patient positioning during imaging. Structures such as the torus tubarius may shift due to gravity when the patient is in a supine position, as with conventional medical (multi-detector) computed tomography (MDCT) or magnetic resonance imaging (MRI), resulting in partial collapse or obscuration of the pharyngeal recess. In contrast, cone-beam CT (CBCT), which is typically performed with the patient seated or standing upright

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for dental diagnostics, has been shown to provide superior visualization of the nasopharyngeal soft tissue structures, including the FoR.³⁻⁵ This is especially relevant since CBCT scans taken for dental purposes often include the nasopharyngeal region as part of the field of view. Importantly, previous studies have reported that the FoR is more clearly delineated in CBCT images compared to supine-based modalities such as MDCT.^{3,4} As a result, researchers have begun to focus on CBCT as a valuable tool for morphologic assessment of the nasopharynx. Also, it has been emphasized that dental professionals need heightened vigilance and enhanced interpretation skills for incidental findings in the nasopharyngeal region during routine dental imaging.^{2,6}

This imaging advantage is of particular significance in East and Southeast Asia, where the incidence of NPC is markedly higher than in Western populations. Epidemiological data indicate that the prevalence of NPC is particularly high in Southeast Asia, while remaining relatively low in Korea and Japan.⁷ As Korea represents a low-prevalence region, anatomical investigations in the Korean population may yield meaningful insights into protective factors or structural differences associated with reduced NPC risk. Such findings could also provide a valuable basis for comparative research with high-risk populations in Southeast Asia.

In this study, the morphological features and dimensions of the nasopharyngeal structures—particularly the FoR—on CBCT images were analyzed, and normative morphological data based on age and sex in a Korean population was established. The ultimate goal is to contribute reference data for early detection of NPC. Given the relatively low prevalence of NPC in Korea compared to other Asian countries, morphological characterization based on Korean data may provide a unique foundation for exploring protective factors or identifying structural variations associated with lower NPC incidence.

Materials and Methods

Patients who underwent CBCT at Yonsei University Dental Hospital between January 1, 2021, and December 31, 2023, for dental treatment purposes were retrospectively collected. Among adult patients aged 20 to 69 years, 50 males and 50 females were consecutively included for each age group. CBCT images with significant movement or metal artifacts were excluded from the analysis. This study was approved by the Institutional Review Board (IRB) of our institution (No. 2-2024-0065).

CBCT images were obtained using an Alphard 3030 unit (Asahi Roentgen Ind., Co., Ltd, Kyoto, Japan) with the following parameters: tube voltage, 90 kVp; tube current, 8 mA; exposure time, 17 s; field of view (FOV), 15 × 15 cm; and voxel size of 380 μm.

Morphological types of the FoR were classified according to Takasugi et al.⁸ as follows (Fig. 1); Type A: shallow FoR with a depth of less than 5 mm, Type B: deep FoR with a depth of 5 mm or greater and openings less than 1 mm wide, Type C: deep FoR with a depth of 5 mm or greater and openings 1 mm wide or greater, and Asymmetry: different classification respectively on left and right FoR.

Measurements were performed for Types B and C following the protocol described by Erdem et al.⁹ and Sutthiprapanorn et al.³ Prior to measurement, images were reoriented to align the basion and posterior nasal spine (PNS) on the same plane, followed by reslicing at 2.0-mm thickness. A vertical reference line was established passing through the PNS and the spinal landmark, and a horizontal reference line perpendicular to the vertical line and passing through the PNS was set. Two auxiliary reference lines, parallel to the vertical line, were drawn to contact the most medial points of the right and left torus levatorius. The axial and coronal views showing the greatest extent of the fossa of Rosen-



Fig. 1. Representative images of the fossa of Rosenmüller (FoR) classification types based on opening and depth dimensions. A. Type A with shallow FoR with a depth of less than 5 mm. B. Type B with deep FoR with a depth of 5 mm or greater and openings less than 1 mm wide. C. Type C with deep FoR with a depth of 5 mm or greater and openings 1 mm wide or greater.

müller on both sides were selected, and measurements were obtained at the level where the FoR appeared sharpest and widest. Measurements were then performed based on key anatomical points where the structures intersected these reference lines. Morphological distances of measurement were as followed (Fig. 2); PNS-1: distance from PNS to the posterior pharyngeal wall, 2-3: distance of right torus levatorius, 4-5: distance of left torus levatorius, 3-5: distance between right and left torus levatorius, PNS-3: distance between PNS and right torus levatorius, PNS-5: distance between PNS and left torus levatorius, hFoR: horizontal depth of Rosenmüller fossa in axial view, vFoR: vertical length of Rosenmüller fossa in coronal view.

Descriptive statistics for classification types (A, B, C, and asymmetry) were summarized as frequencies and percentages. Sex-related differences were assessed using the chi-square test of independence. Differences in distances between males and females were primarily evaluated using independent t-tests, while comparisons between the right and left sides were performed as a baseline analysis. The distribution of types between males and females according to age group was also compared using the chi-square test of independence. Statistical significance was set at $P < 0.05$ for all analyses. Intraobserver reliability was determined by calculating the intraclass correlation coefficient (ICC) in a random sample of 140 cases. Data were analyzed using GraphPad Prism, version 10.0.0 (GraphPad Software, Boston, MA, USA).

Results

A total of 492 CBCT image sets were analyzed (244 males and 248 females). The mean age of the included subjects

was 43.8 ± 14.6 years (male: 44.2 ± 14.5 , female: 43.3 ± 14.8). The number of subjects in each age group is presented in Table 1.

For type classification, Types A and B were more prevalent among males (22.1% and 29.55% respectively) than among females (7.3% and 24.6% respectively), whereas Type C was predominant among females (57.3%) compared with males (34.4%). Asymmetry was observed more frequently in males (13.9%) than in females (10.1%) (Fig. 3). The chi-square test revealed a statistically significant difference in distribution according to sex ($\chi^2 = 34.83$, $df = 3$, $P < 0.05$). Takasugi type analysis revealed sex-related differences mainly in Types A and C, while Type B and asymmetry showed no significant difference.

Measurements in males were significantly larger than those in females for the distance of the torus levatorius ($P < 0.05$), the distance between the PNS and the right torus levatorius ($P < 0.05$), the horizontal depth of the FoR ($P < 0.05$), and the vertical length of the FoR ($P < 0.05$) (Table 2). Comparisons between the right and left torus levatorius distances were performed as a baseline analysis, and no significant differences were observed in either sex ($P > 0.05$).

Table 1. Distribution of subjects by age group and sex

Age group (year)	Male	Female
20s (20-29)	47	50
30s (30-39)	48	50
40s (40-49)	50	48
50s (50-59)	50	50
60s (60-69)	49	50
Total	244	248

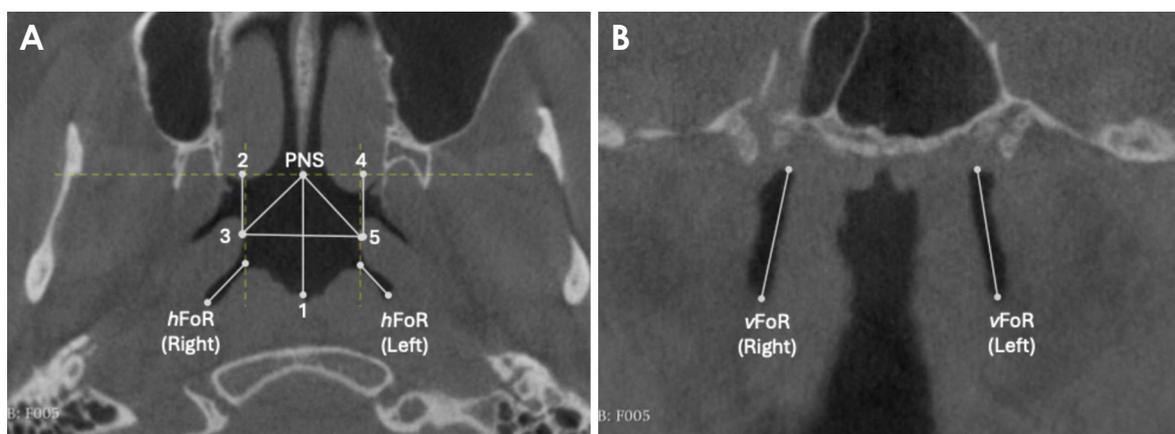


Fig. 2. Morphological distances of measurement in axial view (A) and coronal view (B). PNS: posterior nasal spine, hFoR: horizontal depth of Rosenmüller fossa in axial view, vFoR: vertical length of Rosenmüller fossa in coronal view.

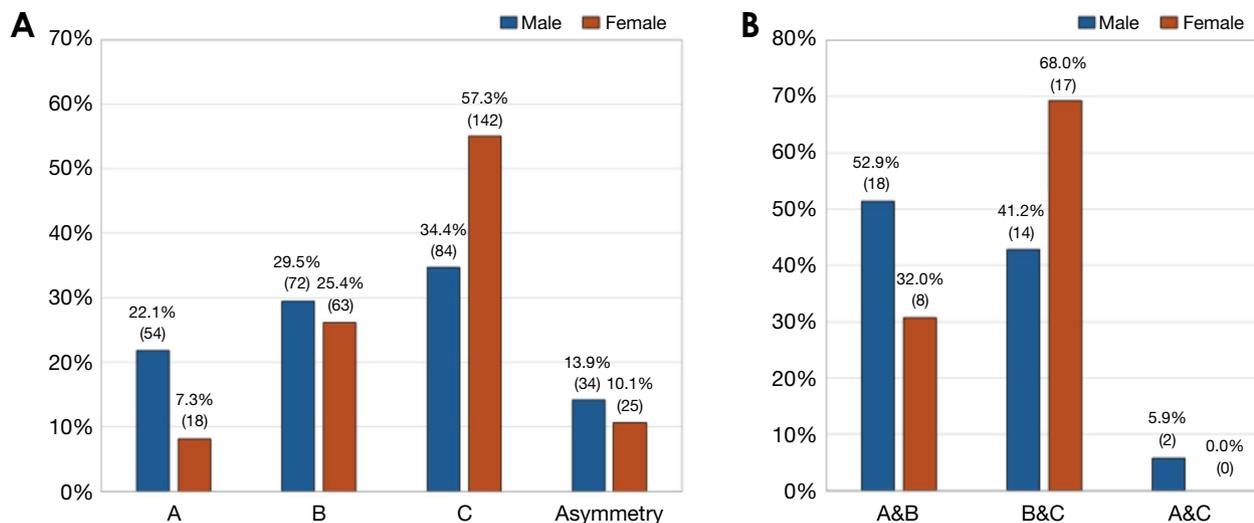


Fig. 3. Sex-specific distribution of fossa of Rosenmüller types (A) and asymmetry patterns (B).

Table 2. Comparison of distance measurements between males and females (mean ± standard deviation)

	Male (n = 156)	Female (n = 205)	P-value
PNS to the posterior pharyngeal wall (PNS-1)	20.05 ± 4.15	20.82 ± 3.90	0.0712
Distance of torus levatorius (2-3, 4-5)	12.63 ± 2.84	12.22 ± 2.83	<0.05
Distance between right and left torus levatorius (3-5)	20.70 ± 3.41	20.31 ± 2.81	0.2383
Distance between PNS and torus levatorius (PNS-3, PNS-5)	16.63 ± 2.51	16.22 ± 2.55	<0.05
Horizontal depth of FoR (hFOR)	12.45 ± 2.61	11.99 ± 2.32	<0.05
Vertical length of FoR (vFoR)	18.32 ± 6.44	16.90 ± 6.44	<0.05

PNS: posterior nasal spine, FoR, fossa of Rosenmüller

Table 3. Difference in measurements between right and left according to sex

		Male		Female	
		Mean ± SD	P-value	Mean ± SD	P-value
Distance of torus levatorius	Right	12.39 ± 2.95	0.0796	12.30 ± 3.04	0.1097
	Left	12.93 ± 2.97		12.75 ± 2.87	
Distance between PNS and torus levatorius	Right	16.75 ± 2.62	0.2570	16.46 ± 2.73	0.2741
	Left	16.37 ± 2.59		16.22 ± 2.63	
Horizontal depth of FoR	Right	12.06 ± 3.17	0.8529	11.78 ± 2.83	0.7215
	Left	11.98 ± 3.10		11.60 ± 2.93	
Vertical length of FoR	Right	17.94 ± 6.09	0.7645	16.75 ± 4.99	0.6195
	Left	18.05 ± 6.83		17.05 ± 5.05	

SD: standard deviation, PNS: posterior nasal spine, FoR: fossa of Rosenmüller

(Table 3).

According to age group, there was no significant difference in the distribution of types between males and females

in their 20s or 30s. However, significant sex-related differences were observed in the 40s ($P < 0.05$), 50s ($P < 0.05$), and 60s ($P < 0.05$) age groups. Takasugi type analysis indi-

Table 4. Distribution of types according to age group between male and female

	Male				Female				χ^2	P-value
	Type A	Type B	Type C	Asymmetry	Type A	Type B	Type C	Asymmetry		
20s	4	15	19	9	5	16	23	6	1.03	0.7934
30s	9	15	18	6	6	14	23	7	1.28	0.7337
40s	13	18	12	7	5	11	28	4	12.43	<0.05
50s	13	13	16	8	1	9	38	2	23.58	<0.05
60s	15	11	19	4	1	13	30	6	15.28	<0.05

cated that females showed a higher proportion of Type C, whereas males tended to show a higher proportion of Type A in these older age groups (Table 4).

The intraclass correlation coefficient (ICC) was 0.97, indicating excellent reliability.

Discussion

This study investigated the characteristics of the nasopharyngeal shape in a large sample of a Korean population, in which the incidence of NPC is relatively low compared with other Asian regions.⁷ When the FoR was classified by type, Type C—characterized by a distinct opening—was found to be relatively frequent. However, a sex-based comparison revealed that Type C was significantly less common in men than in women. Although this finding does not directly indicate an association the higher NPC incidence of men over women,^{7,10} it may reflect morphological differences that could be relevant to future studies on sex-related susceptibility to NPC. Moreover, structural measurements demonstrated that men had significantly larger nasopharyngeal dimensions, including the FoR, than women. These structural differences could be considered as one of the possible morphological factors of interest for the sex disparity in NPC occurrence, although careful consideration is needed as this is not a definitive explanation.

Previous studies have also attempted to identify various factors associated with NPC occurrence. The relatively higher burden of NPC in Eastern and South-Eastern Asia has largely been attributed to the high prevalence of Epstein-Barr virus (EBV) infection.¹¹ In addition, dietary habits such as the frequent intake of salted fish and preserved foods have been reported as contributing factors.¹² Nevertheless, NPC incidence in Southern China is approximately 20–50 times higher than that in Western countries.¹¹ Interestingly, second- and third-generation Chinese immigrants in Western countries remain at an elevated risk of NPC, suggesting that genetic or anatomical predispositions may play a role, beyond

environmental and cultural influences.¹² Therefore, comparative investigations of morphologic structures may provide valuable insights into the underlying risk factors, and the results of the present study should be considered within this broader context.

The FoR classification of the current study was comparable to the findings of Kaplan et al.,¹³ who also reported Type C as the most dominant type, followed by Types B and A. Although their study included a smaller sample size of 150 subjects compared with the present study, the distribution across the three types was similar, demonstrating a consistent trend. However, as the study did not clearly specify the ethnicity of the population included in the study, it is difficult to interpret their data in relation to the risk of NPC. In contrast, Takasugi et al.'s study⁸ on 97 Japanese subjects reported Type B as the most frequent, while Type A was the least common. In addition, their study was conducted using MDCT, which is performed in the supine position. Therefore, some cases classified as Type B in their study might actually have been Type C. Considering this, the finding of fewer Type A cases and higher frequencies of Types B and C is consistent with our results.

On the other hand, attention should be paid to the cases classified as asymmetric FoR, as such asymmetry has been recognized as a key radiological feature in the diagnosis of NPC. Unlike previous studies, the current study specifically analyzed cases where the left and right FoR exhibited different types. NPCs most frequently arise from the FoR, located along the lateral wall of the nasopharynx near the pharyngobasilar fascia. This fascia forms the structural boundary of the nasopharyngeal wall and separates the mucosal and muscular layers.¹ Because CBCT scans are typically obtained with the patient in a seated or standing position, they provide a clear visualization of the FoR, making this modality suitable for screening this region. Consequently, asymmetry in these areas may serve as a valuable imaging feature suggestive of potential NPC involvement. Though the overall prevalence of this asymmetry was low, clinicians should

carefully review the patient's clinical symptoms and overall health when detected on CBCT. As it was mentioned in the previous study,³ CBCT presented more accurate evaluation of the FoR shape than MDCT due to its patient positioning during examination.^{3,4} Further diagnostic evaluation should be actively considered when asymmetry detected in CBCT with patient showing following symptoms: red-flag signs such as swollen lymph nodes, nosebleeds, bloody saliva, double vision, ear infections, facial numbness, headaches, hearing loss, nasal obstruction, tinnitus, or sore throat.¹⁴

Also, previous study reported that there was significant difference in type distribution among sexes.¹³ Among structural types of FoR, Type A represents an almost completely closed FoR with little or no orifice. It might be suspected that if carcinogens accumulate equally across individuals, Type A may retain them for a longer period due to restricted drainage. Whereas Type C, with its more widely open recess, may allow more effective clearance of inflammatory products or carcinogens. In our study, significant sex-related differences were observed in the distribution of Types A in males and C in females. Considering the higher incidence of NPC in males, these structural differences may partially contribute to the disparity in NPC occurrence between sexes.

In addition, the fact that the FoR dimensions were significantly larger in males than in females warrants attention. Previous studies have also reported that the depth of the FoR is greater in males,^{8,13,15} and our results confirmed that several nasopharyngeal dimensions, including FoR depth and vertical length, were significantly larger in males. Lifestyle factors such as higher smoking rates, a well-known carcinogenic risk factor, as well as a potentially protective effect of endogenous estrogens in females, have also been suggested as contributors to sex-related differences in NPC incidence.^{10,16} Taken together, these findings support the hypothesis that larger anatomical structures in males may result in a greater mucosal surface area exposed to carcinogens, thereby contributing to the higher NPC burden in males.

Although numerous studies have examined biological and lifestyle factors associated with NPC, relatively few have focused on the potential role of nasopharyngeal morphology in its development.^{7,8,10} In this context, our findings from a Korean population—where the incidence of NPC is notably lower than in other Asian regions—may provide meaningful insights into morphological features that could contribute to reduced susceptibility. Nevertheless, this study has limitations. As a retrospective analysis, it was restricted to describing the morphological characteristics of individuals without NPC, rather than directly comparing patients with the disease.

In conclusion, this study characterized the morphological features of the nasopharynx, with a particular focus on the FoR, using CBCT images from the Korean population. Although Type C morphology was the most common in both sexes, it was particularly prevalence in females. When each type was compared by sex, Types A and B were more frequently observed in males than in females, and males demonstrated significantly larger nasopharyngeal dimensions. These morphological differences may contribute to the sex-related disparity in NPC incidence while cautious interpretation is needed as the current study did not directly assess their association with NPC incidence. The reference values established in this study provide normative baseline data that may aid in the early detection of NPC during routine dental imaging. Further prospective and comparative studies involving patients with NPC are warranted to clarify the role of nasopharyngeal morphology in disease occurrence.

Conflicts of Interest: None

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