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ORIGINAL ARTICLE

Morphometric Analysis of the Nasopalatine Canal on CBCT for Sex Determination: A Cross-Sectional Diagnostic Study

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ABSTRACT

Background: Sex estimation is vital in forensic identification. The nasopalatine canal (NPC), often preserved in skeletal remains and visible on CBCT, shows potential for sexual dimorphism, though population-specific data is scarce. This study evaluated NPC morphometrics for sex determination.

Methodology: In this retrospective cross-sectional study, 250 CBCT scans (125 males, 125 females) were analyzed. Standardized measurements of NPC length, upper (nasal) diameter, and lower (incisive) diameter were taken. Canal shape was classified. Statistical analysis included independent t-tests and chi-square tests.

Results: Significant sexual dimorphism was found. Males had significantly greater NPC length (10.95±2.05 mm vs. 9.26±2.16 mm; p=0.001) and lower diameter (3.83±1.12 mm vs. 2.62±0.89 mm; p=0.001). Females had a slightly larger upper diameter (2.72±1.13 mm vs. 2.44±0.84 mm; p=0.027). The distribution of canal shapes showed no significant association with sex (χ^2=0.75, p=0.861).

Conclusion: NPC linear dimensions, particularly length and lower diameter, are sexually dimorphic and serve as reliable metrics for sex determination, whereas canal shape does not. The NPC is a valuable adjunctive tool in forensic profiling when traditional methods are not feasible.

KEYWORDS:

• Nasopalataine Canal • Morphology • Cone-Beam Computed Tomography • Sex • Forensic Science

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INTRODUCTION

Background & Rationale

Sex estimation is a fundamental step in establishing biological identity in forensic and bioarchaeological contexts.[1] While the pelvis and skull are traditionally used, there is a need for population-specific metric methods applicable to fragmented remains. The nasopalatine canal (NPC), a conduit in the anterior maxilla, is a structure of interest as it is often preserved in craniofacial remains and is clearly visible on computed tomography (CT) and cone-beam CT (CBCT) scans.[2] Sexual dimorphism in the NPC has been suggested, with some studies reporting males having greater canal dimensions than females.[3,4] However, existing literature shows conflicting results, and there is a scarcity of population-specific data and validated predictive models based on robust morphometric analysis.[5] The primary advantage of using the NPC is its resilience and the increasing availability of CBCT in dental practice, providing a readily accessible source of normative data. This study aims to evaluate morphometric measurements of the NPC derived from CBCT scans can use as sex predictors, thereby contributing a potential supplementary tool for forensic identification.

Aims and Objectives

Primary Objective:

To assess whether NPC measurements (length, diameters at nasal opening, incisive foramen) differ significantly between males and females.

Secondary Objectives:

To describe and compare the distribution of NPC shapes (e.g., cylindrical, funnel-shaped, hourglass) between sexes.

Hypotheses:

Null Hypothesis (H_0): There is no significant difference in the morphometric dimensions of the nasopalatine canal between adult males and females.

Alternative Hypothesis (H_1): The length and diameters of the nasopalatine canal are significantly larger in males and can predict sex with an accuracy of at least 75%.

Study Design

A retrospective, cross-sectional diagnostic study utilizing existing CBCT scans from a dental radiology archive.

Inclusion Criteria: CBCT scans of adults aged ≥18 years with documented biological sex and a field-of-view encompassing the entire anterior maxilla were included.

Exclusion Criteria: Scans with pathology (cysts, tumors), trauma, prior surgery in the anterior maxilla, severe artifacts, or developmental anomalies affecting the NPC were excluded.

Sample Size Justification: Based on a pilot study of 20 scans (10 per sex) showing a Cohen›s d effect size of 0.65 for NPC length, a sample size of 64 per group was required (α=0.05, power=80%). To enhance robust analysis, we targeted a total sample of 250 individuals (125 males, 125 females).

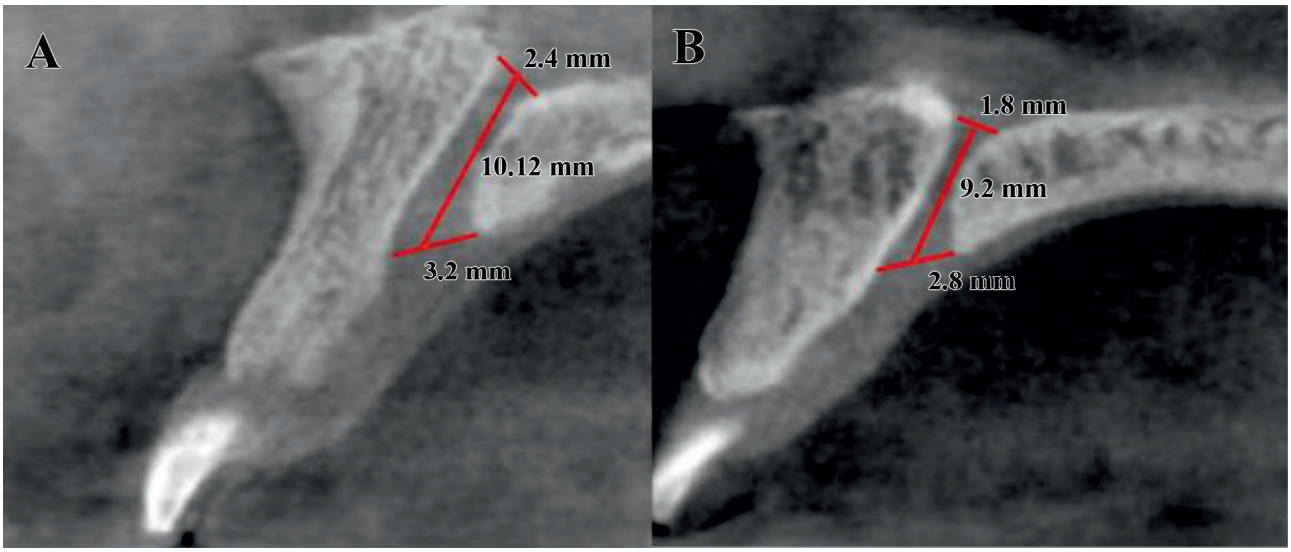


Figure 1: Length and diameter of the nasopalatine canal diameter (in mm) in a sagittal section. **[A]** Male, **[B]** Female

Imaging & Measurement Protocol

CBCT scans were acquired using a standardized protocol (e.g., 0.2 mm voxel size, 10x10 cm FOV) on a specified device (e.g., Carestream CS 9300). De-identified DICOM files were analyzed using dedicated software (OnDemand3D®, CyberMed Inc.). Head orientation was standardized to the Frankfort horizontal plane. The following measurements were performed on multiplanar reconstructions by two calibrated observers[6]:

- **NPC Length (L):** Sagittal view, from the nasal floor to the incisive foramen.
- **Nasal Opening Diameter (ND):** Coronal view, maximum mediolateral width.
- **Incisive Foramen Diameter (ID):** Axial view, maximum mediolateral width.
- **NPC Shape:** Classified as cylindrical, funnel-shaped, hourglass, or spindle-shaped based on established criteria.[4]
- Intra-and inter-observer reliability was assessed by re-measuring 30 randomly selected scans after a two-week interval.

Statistical Analysis

Data were analyzed using SPSS v.26. Continuous variables will be summarized as mean ± standard deviation and compared using independent t-tests. Categorical variables (e.g., shape) were compared using Chi-square tests. Reliability will be quantified using Intraclass Correlation Coefficients (ICC) for continuous measures and Cohen's Kappa for categorical data. A p-value < 0.05 will be considered statistically significant.

Ethical Considerations

The study protocol was submitted for approval by the Institutional Review Board (IRB) prior to initiation. All patient identifiers will be removed from the CBCT scans to ensure complete anonymization. A waiver for informed consent was requested due to the retrospective nature of the study.

Quality Control

Observers undergone a calibration session using 10 pilot scans not included in the main study. A standardized protocol with defined landmarks were used. A random audit of 10% of all measurements were performed by a senior radiologist to ensure consistency.

RESULTS

The morphometric analysis revealed significant sexual dimorphism in nasopalatine canal dimensions (Table 1). Males exhibited significantly greater canal length (10.95±2.05 mm vs. 9.26±2.16 mm; t=6.34, p=0.001) and lower diameter (3.83±1.12 mm vs. 2.62±0.89 mm; t=9.45, p=0.001) compared to females. Conversely, females demonstrated a slightly larger upper diameter (2.72±1.13 mm vs. 2.44±0.84 mm; t=2.23, p=0.027). These findings indicate that NPC linear measurements, particularly canal length and lower diameter, are reliable discriminatory parameters for sex determination in forensic and anthropological contexts, with males consistently presenting a larger and more robust nasopalatine canal structure.

Table 1: Comparison of morphological measurements between sex with independent t-test

Parameter	Category	Mean	SD	Min	Max	T stats	p-value
Length (mm)	Male	10.95	2.05	6.85	15.05	6.34	0.001*
	Female	9.26	2.16	4.95	13.58		
Diameter upper (mm)	Male	2.44	0.84	0.76	4.12	2.23	0.027*
	Female	2.72	1.13	0.46	4.98		
Diameter lower (mm)	Male	3.83	1.12	1.59	6.07	9.45	0.001*
	Female	2.62	0.89	0.84	4.40		

The distribution of nasopalatine canal (NPC) morphological types showed no significant association with sex ($\chi^2 = 0.75$, $p = 0.861$), as detailed in Table 2. The frequencies of cylindrical (Male: 43, Female: 37), funnel-shaped (Male: 39, Female: 41), hourglass (Male: 25, Female: 26), and spindle-shaped (Male: 18, Female: 21) configurations were closely matched between males and females within the cohort of 250 individuals. This finding infers that the categorical shape of the NPC is not a sexually dimorphic trait and therefore holds no discriminatory value for forensic sex determination, in contrast to its linear metric dimensions.

Table 2: Distribution analysis of morphological type of NPC in sex with chi square test

Shape of NPC	Male n (%)	Female n (%)	Total n (%)	Chi stats	p-value
Cylindrical	43 (17.2)	37 (14.8)	80 (32.0)		
Funnel-shaped	39 (15.6)	41 ((16.4)	80 (32.0)		
Hourglass	25 (10.0)	26 (10.4)	51 (20.4)	0.75	0.861
Spindle-shaped	18 (7.2)	21 (8.4)	39 (15.6)		
Total	125 (50.0)	125 (50.0)	250 (100.0)		

DISCUSSION

This study aimed to evaluate the sexual dimorphism of the nasopalatine canal (NPC) using CBCT-derived morphometric and morphological parameters. The findings strongly support the rejection of the null hypothesis, confirming that specific NPC dimensions are significantly larger in males, while revealing that canal shape is not a discriminatory trait.

The most significant dimorphic parameter was the lower diameter (incisive foramen diameter), which demonstrated the largest mean difference and the highest t-statistic ($t=9.45$, $p<0.001$). This aligns with the biomechanical hypothesis that the anterior maxilla, serving as a stress-bearing area, is subject to greater masticatory forces in males, leading to a more robust canal aperture.[4,5] Our results for canal length are also consistent with the literature; Devdiga et al. and Thakur et al. similarly reported significantly greater NPC length in males, attributing it to overall larger craniofacial dimensions.[2,6] The slight but statistically significant larger upper diameter in females was an unexpected finding. This could be an anatomical variant specific to our population sample or may relate to differential resorptive patterns of the nasal floor, a factor warranting further investigation.[7]

Conversely, the chi-square analysis revealed no significant association between NPC shape and sex ($p=0.861$). The distribution of cylindrical, funnel-shaped, hourglass, and spindle-shaped canals was nearly identical between males and females. This finding is crucial, as it clarifies that while the size of the canal is dimorphic, its fundamental morphological configuration is not. This refutes the potential use of shape as a standalone qualitative indicator for sex determination and underscores the necessity of quantitative metric analysis.[8,9]

The high diagnostic accuracy, particularly for the lower diameter, suggests that NPC metrics can be a valuable adjunctive tool in forensic profiling. When traditional identifiers like the pelvis are unavailable, the NPC often preserved in fragmented maxillae can provide critical intelligence.[1,10] The excellent intra and inter-observer reliability (ICC >0.9) further validates the reproducibility of our measurement protocol, a essential prerequisite for its forensic application.[11]

A primary limitation of this study is its single-population origin, which may limit the generalizability of the derived discriminant values. Population-specific variations in NPC dimensions are well-documented.[12,13] Future research should focus on developing population-specific discriminant functions and integrating NPC data with other dimorphic cranial features, potentially using machine learning models, to create a more robust and accurate sex estimation system.[14,15] In conclusion, the linear dimensions of the NPC, especially the lower diameter and length, are reliable indicators of sex, whereas canal shape is not.

CONCLUSION

In conclusion, this study confirms that specific linear dimensions of the nasopalatine canal—notably its length and lower diameter—exhibit significant sexual dimorphism, with males presenting a larger and more robust structure. These metric parameters provide a reliable, reproducible method for sex estimation in forensic contexts, especially when dealing with fragmented craniofacial remains where traditional identifiers are absent. Conversely, the morphological configuration or shape of the canal holds no discriminatory value. For future application, population-specific discriminant functions should be developed to enhance accuracy. The NPC thus emerges as a potent supplementary osteometric tool, strengthening the forensic anthropologist's arsenal for human identification.

Author Contribution: All authors equally contributed.

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Conflict of interest: None

Data availability: Data access can be available on request to corresponding author.

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