



# Morphometric Analysis of Fossa Navicularis Magna in Patients with Cleft Palate: A Cone Beam Computed Tomographic Study

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## Abstract

**Background:** The present study investigated the prevalence and morphometric characteristics of fossa navicularis magna (FNM) in cleft palate/lip patients using cone beam computed tomography (CBCT) scans.

**Methods:** This retrospective study evaluated 400 CBCT scans of cleft palate/lip subjects aged between 10 and 39. The image sections were scrutinized for the presence and the shape of FNM. Axial and sagittal sections were examined to determine the length, depth, width, and volume of FNM. Two independent examiners evaluated FNM, considering age groups and gender.

**Results:** This study included 400 CBCT scans from 208 males (52%) and 192 females (48%). The mean age was  $17.78 \pm 4.1$  years. FNM was more common among the female cleft palate/lip population (53.1%) and among subjects aged 10–19 years (group A), with no significant association ( $P > 0.05$ ). We observed a statistical difference between the length ( $P = 0.033$ ), width ( $P = 0.025$ ) and volume ( $P = 0.037$ ) of FNM among subjects aged 10–19 years. Considering the difference between genders, the length of FNM ( $P = 0.011$ ) was significant among the female cleft palate/lip population. Considering the shape of FNM, the oval form (69.8%) was more frequent than the round form (30.2%).

**Conclusion:** In the present study, FNM was observed in 24% of the cleft palate/lip population, which is comparatively higher than the previously reported incidence of FNM among the general (non-cleft) population. To the best of our knowledge, this was the first study to evaluate and systematically assess the morphometric characteristics and volume of FNM among cleft palate/lip patients.

**Keywords:** Incidental findings, Clivus, Posterior cranial fossa, Prevalence, Headache

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## Introduction

The basioccipital bone extending from the anterior aspect of the foramen magnum combines with the body of the sphenoidal bone using speno-occipital synchondrosis, which results in the formation of a homogenous bone structure known as the clivus. The ossification of synchondrosis is completed by 13 to 18 years of age (1). An incidental observation of the clivus at the skull base is the presence of a notched bony dehiscence called fossa navicularis magna (FNM) (2). It originates from the embryonic development of the pharyngeal bursa, an epithelium-lined recess located between the roof of the nasopharyngeal region and the notochord (1). Some of the terminologies for FNM include large pharyngeal fossa, key-hole defect, fossa pharyngea and transverse or longitudinal segmentations (2,3).

Oral clefts, such as congenital cleft palate (CP) and/or cleft lip (CL), are the most frequently observed birth

defects globally. Factors such as genetic or external causes influence the formation of oral clefts through the failure or inappropriate fusion of tissue structures (4). According to a meta-analysis by Salari et al, cleft lip and palate were prevalent in 0.3 and 0.33 in every 1000 live births, respectively (5).

While previous studies attempted direct measurement of dry bones to obtain the morphometric traits and variations, three-dimensional imaging techniques are now widely employed to examine craniomaxillofacial bone architecture. The fact that the morphometric data were procured on dried bones with an undetermined demographic origin in many cases presented another significant challenge (6). The advent of cone beam computed tomography (CBCT) in maxillofacial imaging has ushered in a transformative shift from conventional 2D imaging to advanced 3D imaging, providing remarkable benefits over traditional radiography and medical



computed tomography (CT) (7,8). The wide availability and escalating utilization of CBCT in all fields of dentistry have resulted in a soaring number of imaging investigations of the maxillofacial region (9). The heightened awareness among dental practitioners regarding the critical anatomic landmarks of the maxillofacial area has led to a significant rise in such coincidental findings, often uncovered serendipitously during routine radiographic examinations (7,10). Considering patients with congenital cleft deformities, CBCT constitutes an important aspect of maxillofacial imaging required during treatment planning (11). However, data on the prevalence of FNM and its radiographic features observed among the population with congenital oral clefts is sparse. Hence, the present study aimed to analyze the morphometric features of the fossa navicularis and assess their prevalence in the cleft palate/lip population using CBCT.

### Methods

This retrospective study was conducted in alignment with the principles enlisted in the Declaration of Helsinki. The graphics of full-volume CBCT scans were obtained from the subjects who visited the Department of Maxillofacial Radiology from January 2021 to December 2022. The radiographs were screened based on the selection criteria. Our study included CBCT images of cleft palate/lip patients aged 10-39, captured with high diagnostic clarity for a range of maxillofacial indications. Overall, 434 large-volume CBCT scans fulfilling the inclusion criteria were selected, including 208 males and 192 females. Of these, 34 radiographs were excluded due to insufficient image clarity, obscured visibility of the clivus caused by artifact superimposition, and signs of surgical interventions in the region of interest. Radiographs from individuals with a history of trauma or neurological disorders were also excluded from the study.

### Image acquisition

The CBCT scans were procured with a Planmeca 3D Mid model CBCT scanner (Helsinki, Finland). Using exposure parameters of 8–10 mA (tube current), 80–90 kVp (tube voltage), and an average exposure time of 27 seconds with a 360° rotation, a qualified radiographer employed standard imaging protocols to obtain radiographs. The voxel sizes of the resulting radiographic images varied from 200  $\mu\text{m}$  to 400  $\mu\text{m}$ . A standardized head position (Frankfort horizontal plane parallel to the floor), relaxed lip posture, and teeth in occlusion were maintained while obtaining the radiographs. Planmeca Romexis software (version 4.6.2) was used to evaluate the CBCT scans. Two independent oral and maxillofacial radiologists, each with at least 10 years of clinical and radiological expertise, assessed the scans. To minimize bias from visual fatigue, both radiologists reviewed no more than 10 longitudinal sets of CBCT scans at a time. The brightness

and contrast of the radiographic images were adjusted using the software's processing tool to ensure optimal viewing. Radiographic assessment was conducted based on gender, age, the presence of FNM, and morphometric measurements. There were no differences in the radiographic interpretations between the radiologists conducting the evaluation.

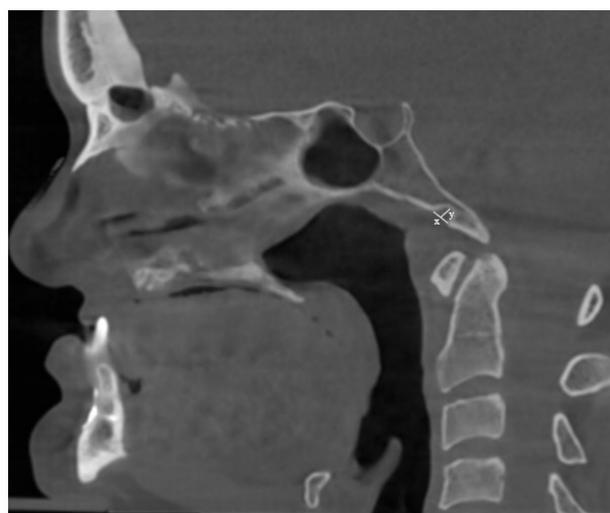
### Image analysis

The acquired CBCT scans were thoroughly examined at various sections under proper lighting to detect the presence of FNM by scrolling through the radiographic images. Sagittal and axial sections revealed the presence of fossa navicularis as a distinct depression on the inferior aspect of the clivus around the mid-sagittal region. After determining the incidence of FNM, the following five parameters were measured in the CBCT sections.

1. Length of FNM ( $x$ ): The sagittal diameter is given by measuring the longest anteroposterior dimension of FNM with the aid of sagittal sections (Figure 1).
2. Depth of FNM ( $y$ ): The distance measured from the base point of FN is seen on the antero-inferior aspect of the clivus in the sagittal section perpendicular to 'x' (Figure 1).
3. Width of FNM ( $z$ ): The distance along the transverse axis extending between two lateral-most points of FN seen on the anterior aspect of the clivus in the axial sections (Figure 2).
4. Volume of FNM ( $\text{m}^3$ ): Determined from the values of  $x$ ,  $y$ , and  $z$ .
5. Shape of FNM: The shape of FNM was described either as round or oval (Figure 3A and 3B).

### Statistical analysis

The collected data were entered in Microsoft Excel 2010 and statistically analyzed using the Statistical Package for



**Figure 1.** Sagittal (CBCT) section of cleft palate patient demonstrating the length ( $x$ ) and depth ( $y$ ) of fossa navicularis magna on the antero-inferior aspect of clivus

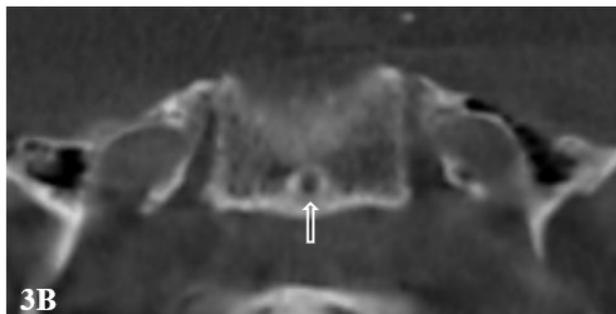
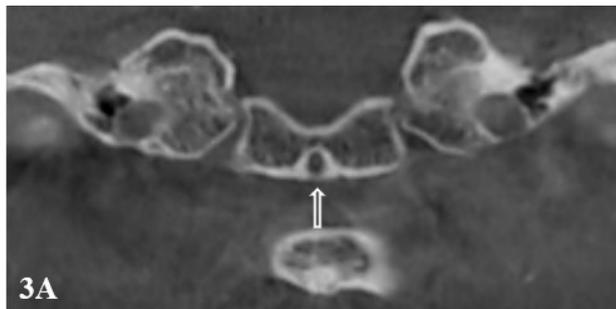
Social Sciences software (IBM, Armonk, NY, USA) version 26. The categorical data were represented as percentages and analyzed using the Mann-Whitney U test to compare gender measurements. The age-based differences were analyzed using the one-way ANOVA test. A *P* value of 0.05 was considered to be statistically significant.

**Results**

The analysis encompassed 434 CBCT scans, of which



**Figure 2.** Axial (CBCT) section of cleft palate patient demonstrating the width (z) of fossa navicularis magna on the anterior aspect of clivus



**Figure 3.** (A) Coronal (CBCT) section showing an oval outline of the fossa navicularis magna with a major axis in the sagittal plane. (B) Coronal (CBCT) section showing a round outline of the fossa navicularis magna

400 were chosen considering the inclusion and exclusion criteria. The mean age of the subjects was  $17.78 \pm 4.1$  years, with an age range of 10 to 39 years, and there were 208 males and 192 females. **Table 1** depicts the frequency of FNM based on gender and age groups.

Out of 400 CBCT scans, 96 (24%) showed FNM, of which 45 (46.9%) belonged to males and 51 (53.1%) belonged to females. The CBCT scans were placed in three groups, with group A comprising of subjects aged 10–19 years (59.7%), group B comprising 20–29-year-olds (36.2%), and group C consisting of 30–39-year-olds (4%). Though there was no statistically significant association between the occurrence of FNM with age and gender ( $P > 0.05$ ), we observed the prevalence of FNM to be predominant among the subjects aged between 10 and 19 years and the female population. Considering the measurements of FNM among the different age groups, a statistically significant difference was observed between the length ( $P = 0.033$ ), breadth ( $P = 0.025$ ) and volume ( $P = 0.037$ ) of FNM among subjects aged between 10 and 19 years. Considering gender variability, the length of FNM ( $P = 0.011$ ) was statistically significant among the female population. **Tables 2** and **3** compare the measurements (length, breadth, width and volume) of FNM among different age groups and genders, respectively. Analysis of the shape of FNM revealed an oval outline in 67 (69.8 %) and a round outline in 29 (30.2%) of the population.

**Discussion**

In recent decades, the connection between clival anomalies and their clinical implications has garnered increasing attention to various pathologies of the head and neck region. The various anatomical anomalies of the clivus region include FNM, craniofacial canal and

**Table 1.** Frequency of fossa navicularis magna based on gender and age groups

	Fossa navicularis magna		Total	P value
	Present	Absent		
<b>Gender</b>				
Male	45 (21.6%)	163 (78.3%)	208	0.249
Female	51 (26.6%)	141 (73.4%)	192	
<b>Age</b>				
10–19 years	60 (25.1%)	179 (74.8%)	239	0.232
20–29 years	35 (24.1%)	110 (75.9%)	145	
30–39 years	1 (6.3%)	15 (93.7%)	16	
<b>Age distribution in males</b>				
10–19 years	26 (20.6%)	100 (79.4%)	126	0.590
20–29 years	18 (24.6%)	55 (75.4%)	73	
30–39 years	1 (11.1%)	8 (88.9%)	9	
<b>Age distribution in females</b>				
10–19 years	34 (43.03%)	79 (56.9%)	113	0.167
20–29 years	17 (23.6%)	55 (76.4%)	72	
30–39 years	0 (0%)	7 (100%)	7	

**Table 2.** Comparison of the measurements (length, depth, width, and volume) of fossa navicularis magna among the different age groups

Measurements of fossa navicularis magna		Age group			P value <sup>a</sup>
		Group A 10–19 years	Group B 20–29 years	Group C 30–39 years	
Length (mm)	Mean ±SD	6.29 ±2.27	5.29 ±2.33	2.0	0.033
Depth (mm)	Mean ±SD	2.23 ±0.9	2.19 ±0.8	1.70	0.823
Width (mm)	Mean ±SD	4.28 ±1.27	3.62 ±1.45	2.0	0.025
Volume (m <sup>3</sup> )	Mean ±SD	68.32 ±39.82	48.83 ±42.16	6.8	0.037

SD, standard deviation.

<sup>a</sup>One-way ANOVA test.**Table 3.** Comparison of the measurements (length, depth, width, and volume) of fossa navicularis between genders

Measurements of fossa navicularis		Gender		P value <sup>a</sup>
		Males	Females	
Length (mm)	Mean ±SD	5.08 ±2.23	5.22 ±2.02	0.011
Depth (mm)	Mean ±SD	2.24 ±0.91	2.18 ±0.83	0.935
Width (mm)	Mean ±SD	3.80 ±1.51	4.15 ±1.46	0.103
Volume (mm <sup>3</sup> )	Mean ±SD	47.80 ±42.22	57 ±47.20	0.096

SD, standard deviation.

<sup>a</sup>Mann-Whitney U test.

canalis basilaris medianus (12). Considering that most individuals with FNM do not present any symptoms, the medical significance of this anomaly remains controversial. However, given its potential role as a conduit for spreading metastatic or local pathologies from the pharyngeal to the intracranial region, clinicians should be strongly encouraged to identify it through routine imaging modalities (13).

### Origin of FNM

The FNM, an incidental discovery of skull radiographs, was defined by Testut in 1921 as a notch-shaped bony pit seen on the base of the clivus (14). To this day, the origin of FNM has been attributed to two main theories: 1. The theory of vascular origin indicates the persistent expansion of the cranial vessels leading to the formation of FNM, and 2. The theory of notochordal origin wherein the extension of an epithelium-lined pharyngeal bursa (diverticulum) or Tornwaldt's bursa towards the expanding skull base in the midline during the embryonic development of an individual results in the development of FNM (15-18).

### Prevalence of FNM

Our study reported a prevalence of 24%, similar to previous study findings, which reported a prevalence rate varying between 16.4% and 28.8% (6,11,19,20). This variation in the prevalence rates could be attributed to the characteristics of the study population, such as the presence/absence of oral clefts and racial and geographic variations. In addition, radiographic factors like the imaging modality and exposure parameters could also lead

to variation in the identification of FNM. To date, various approaches have been utilized to assess the frequency of FNM in various populations, the most common of which are 3D imaging modalities like CT in addition to cadaveric specimens and dried atlas specimens (1,2,13,21). Ray et al and Cankal et al reported a varying prevalence of FNM of 1.49% among 202 dry skulls and 5.3% among 492 dried skulls, respectively (1,21). In another study by Cankal et al, with the aid of CT images, the prevalence of FNM was comparatively lower, about 3%, in a total of 525 CT images (1). The significantly lower prevalence rates of FNM in CT studies can be explained based on its limited detection of the fossa navicularis, which are less than 2 mm in depth (22). Contrarily, CBCT imaging modalities with an increased spatial resolution and subsidiary radiation dose precisely detect FNM of <2 mm depth as they have a minimum slice thickness of 0.1 mm (22,23). Previous studies also reported the prevalence of FNM in various cultural groups and its association with intracranial infections like Tornwaldt's cysts, retropharyngeal abscess, *Fusobacterium*-induced secondary osteomyelitis, recurrent meningitis and sinusitis and isolated cranial nerve palsies (2,13,24).

Considering gender variability, the prevalence of FNM was more frequent among the female (53.1%) than the male cleft lip/palate population (46.9%). Though there was no statistically significant association between gender and incidence of FNM, we generally observed a female predominance among the study population, similar to Adanir et al and Kaplan et al (6,19). Considering the age group variability, FNM was found to be more frequent among subjects aged 10 to 19 years. Our findings aligned with the findings of Ersan, who also observed an increased prevalence among cleft lip/palate patients ranging between 10 and 19 years with no statistical difference (11).

### Morphometric features of FNM

Literature evidence has indicated an FNM length ranging from 7 to 13 mm, a depth of 2 to 5.5 mm and a width of 6 to 8 mm (2,6,19). In a CBCT study by Ersan, FNM length of 5.8 mm, depth of 2.2 mm and width of 4.7 mm was reported (22). A CT study conducted by Cankal et al reported the length of FNM as 5.12 mm, the depth of FNM as 2.24 mm, and the width as 2.85 mm. (1) However, our study was the

first to assess the morphometric characteristics of FNM along with its volumetric measurements among the cleft lip/palate population. Our results reported a length of  $6.29 \pm 2.27$  mm and a width of  $4.28 \pm 1.27$  mm, significantly larger among the subjects aged between 10 and 19 years. We also found a substantial association between the age and volume of FNM ( $68.32 \pm 39.82$  m<sup>3</sup>). Though previous studies assessed the morphometric measurements of FNM, no significant association was reported between FNM and age groups. The increased incidence and more extensive morphometric measurements of FNM among younger patients can be attributed to the morphologically variable hematopoietic contents of the clivus differing at various stages of development (13). In addition, maturation of the clivus region occurs during the second decade of life, which further explains the morphological variability (25). Considering the gender variability, we found a statistically significant association between the length of FNM ( $5.22 \pm 2.02$ ) among the female cleft lip/palate population. The current study's findings were comparable to the observations of Adanir et al, Ersan and Magat, who also reported the same (2,20,22). According to Collins, the shape of FNM may be defined as round or oval in outline (26). We observed an oval shape in 69.8% and a round shape in 30.2% of the individuals, similar to the findings of Ersan et al and Adanir et al (6,22).

#### **Association with cleft lip/palate**

One of the commonly seen birth defects of the orofacial region is the occurrence of cleft palate/lip, with a frequency observed in the range of 3% to 63% (27). Studies indicate the existence of additional bony abnormalities of the craniofacial region with the development of oral clefts (11). The frequency of FNM of clivus in the present study was 24%, which was comparatively higher than the percentages reported in previous studies conducted among the general (non-cleft) population. This could be explained based on changes in the physical features of clivus that occur in some acquired or congenital abnormalities (25). In human genetic development, the average angle of the base of the skull varies among different races (28). A decreased angle of the clivus region due to an early fusion or a reduced rate of sphenoid-occipital synchondrosis is associated with several craniofacial abnormalities (12,23). Establishing the link between cleft palate/lip and other deformities of the craniofacial region is crucial, thus highlighting the embryonic phenomena that lead to these malformations.

#### **Clinical significance of FNM**

The medical relevance of FNM may be attributed to its diagnostic concern, as these deviations are often misinterpreted as cranial pathologies or vice-versa. This skull base anomaly occurs in the clinically significant sphenoid sinus, nasopharyngeal, and clivus regions.

(1,2,13,21). FNM has been shown to be associated with the spread of intracranial infections caused by *Fusobacterium* and *Streptococcus intermedius* (24). Prabhu et al reported the occurrence of a retropharyngeal abscess in FNM in a 5-year-old female diagnosed with clival osteomyelitis secondary to intermittent fever and neck stiffness. According to the authors, the presence of FNM might have facilitated the transmission of infections from the nasopharyngeal region into the intracranial cavity (29). A similar case was reported by Segal et al, who identified the occurrence of FNM in a 12-year-old female with intra-cranial infection in addition to palsy of the left abducent nerve, positive meningeal signs, thrombosis of the left jugular vein associated with a worsening headache (2). Previous studies have reported the occurrence of recurrent sinusitis and meningitis, photo-sensitivity, bitemporal headaches of throbbing type and retro-orbital pain, ultimately leading to reduced mobility of the head and neck region secondary to prolonged muscle stiffness (13,24). The first report of an infectious Tornwaldt cyst of FNM affecting a younger individual was published by Benadjaoud (24). Though Tornwaldt's cysts are typically asymptomatic, enlargement of these cysts can result in conditions like post-nasal drip, obstruction of the nasal and pharyngeal bursa, occipital headache and dysfunction of the eustachian tube (30). Often, this structural deviation of the clivus poses an obstacle in the differential diagnosis of various lesions of the head and neck region such as a nasopharyngeal tumor, adenoid retention or Rathke's pouch cyst, hypertrophied adenoids, mucocoele affecting the sphenoidal sinuses, dermoid teratomas of the posterior aspect of the nasopharynx (2,28,29,31). Due to the rising number of reports enlisting the presence of FNM as a probable cause for the spread of intra-cranial infections via caudocranial structures, as well as its crucial location in the posterior aspect of cranial fossa, the understanding of this intracranial anatomical variant using radiological imaging as a baseline screening tool is essential to assist in the diagnosis and prediction of any likely consequences, which might be beneficial for the cleft patients. (2,25,29,31). The present study has the inherent limitations of cross-sectional studies, such as the inability to acquire the patient's medical history. Though various pieces of evidence in the literature emphasize the abnormalities of the maxillofacial skeleton and cleft anomalies, their association is still ambiguous. Therefore, to ascertain the true prevalence of this structural variant and to expedite the identification of the etiological component in pertinent infectious scenarios, a thorough evaluation of the basal region of the skull, exploration of the development of FNM and their relationship with the embryonic phenomena underlying the oral cleft malformation process should be focused on by future researchers.

## Conclusion

To conclude, the present study assessed the frequency and morphometric features of FNM, which were more common among the cleft lip/palate population than the previously reported general (non-cleft) population. The presence of FNM showed a predilection for subjects in the age range of 10 to 19 years, along with a female predominance. In addition, FNM's morphometric and volumetric characteristics were much more prominent among the subjects aged 10 to 19. We also suggest a possible relationship between the embryonic formation of oral clefts and anatomical variations of the clivus region. This needs to be studied in large-scale prospective studies as their association is still unclear.

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## Authors' Contribution

**Conceptualization:** Renita Lorina Castelino.

**Data curation:** Deepthi Darwin.

**Formal analysis:** Renita Lorina Castelino.

**Funding acquisition:** Renita Lorina Castelino.

**Investigation:** Deepthi Darwin.

**Methodology:** Deepthi Darwin.

**Project administration:** Renita Lorina Castelino.

**Resources:** Mohamed Faizal Asan.

**Software:** Deepthi Darwin.

**Supervision:** Renita Lorina Castelino.

**Validation:** Renita Lorina Castelino.

**Visualization:** Gogineni Subhas Babu.

**Writing—original draft:** Deepthi Darwin.

## Competing Interests

On behalf of all authors, the corresponding author states that there is no conflict of interest.

## Ethical Approval

This research was approved by the ethics committee of the Nitte (Deemed to be University) ( ID: ETHICS/ABSMIDS/640/2025).

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