ORIGINAL ARTICLE

sciendo

10.2478/AMB-2024-0006

CANALIS BASILARIS MEDIANUS AS AN ANATOMICAL VARIATION IN THE BASILAR PART OF THE OCCIPITAL BONE: A DESCRIPTIVE CONE BEAM COMPUTED TOMOGRAPHIC STUDY

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Abstract. Objectives: *Canalis basilaris medianus (CBM) is a unique anatomical variation located in the basal occipital region of the skull, rarely encountered in head and neck radiographic imaging. The aim of the present study was to evaluate the prevalence and types of CBM using Cone Beam Computed Tomography (CBCT) scans.* ***Materials and Methods:*** *CBCT (Full FOV) images of 200 patients aged between 10 to 70 years were selected for the current retrospective study following the inclusion and exclusion criteria. The image sections from the scan data were scrutinized for the presence of CBM, in addition to its classification based on the type of morphology. The presence and types of CBM were recorded based on the age and gender. The chi-square test was used to analyze the presence and types of CBM with regard to gender and age group.* ***Results:*** *The overall prevalence of CBM was estimated as 9.5%. CBM was present in 13% of males and 3% of females ($p = 0.021$). Considering the types of CBM, the superior recess type was predominantly observed followed by the inferior recess, superior and inferior type. However, there was no significant gender-based differences noted among the types of CBM ($p > 0.05$). Also, there was no statistically significant difference noted in the prevalence of CBM in different age groups ($p > 0.05$).* ***Conclusion:*** *It is necessary for maxillofacial radiologists to have a solid understanding of both normal and variant skull-base anatomy to facilitate recognition of variants such as CBM in order to recognize the associated anomalies. To our knowledge, this was the first study done which assesses the gender-based differences among the various types of CBM.*

Key words: *Canalis basilaris medianus, Skull base, Anatomic variation, Cone Beam Computed Tomography*

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Received: *18 January 2023;* ***Revised/Accepted:*** *20 April 2023*

INTRODUCTION

The anatomy of the skull has been studied extensively in the past centuries and many anatomical variations of the skull have been identified and well documented in the scientific literature [1, 2]. Minor variations within the parts of the cranial cavity, particularly in the basal occipital region, have been of great interest to anatomists and clinicians due to their neurological importance. Apart from the common foramina of the skull base, there are several other, rarely found foramina that have been identified as anatomical variations. This includes canalis basalis medianus (CBM), foramen meningo-orbitale, craniopharyngeal canals, palatovaginal canals, foramen of Vesalius and canaliculus innominatus [3, 4]. The majority of these variations result from the typical developmental process and their presence is primarily determined genetically [5].

CBM is unique anatomical variant that can be described as a well-defined, corticated canal structure in the basilar part of the occipital bone (basiocciput). CBM is an extremely rare variant that is encountered during head and neck imaging [6]. Computed Tomography (CT) is regarded as the best modality for imaging of osseous structures of the head and neck region [7]. However, the introduction of Cone Beam Computed Tomography (CBCT) in the field of maxillofacial imaging has led to a revolutionary change from two-dimensional (2D) to three-dimensional (3D) imaging due to its advantages over conventional radiography and medical CT. CBCT with typically large Field of View (FOV) can aid in the imaging of significant structures of the skull with diagnostic efficacy comparable to CT, along with the advantage of low radiation dosage, wide availability and cost effectiveness superior to CT [8].

Improved knowledge of dental practitioners in the identification of significant anatomic landmarks of the maxillofacial region has contributed to a rise in the incidental findings which are detected accidentally during routine radiographic examinations. Though CBM is a well-recognized anatomical variant, studies evaluating its morphology and prevalence are sparse. Hence, the present study is aimed to evaluate the radiographic characteristics of CBM and its prevalence using CBCT among general population.

MATERIALS AND METHODS

The present retrospective study was carried out in accordance with the principles of the Declaration of Helsinki. The images of large-volume CBCT scans were collected from the patients who reportedly underwent radiographic investigation in the Department of Oral and Maxillofacial Radiology, AB Shetty Memorial Institute of Dental Sciences, Nitte (Deemed to be University), Mangalore, in the period of January 2021 to December 2022. Full FOV CBCT volumes and clinical data of patients were utilized for the study based on the selection criteria. Our study included a total of 226 CBCT volumes that belonged to patients aged 10 to 70 years, taken with good diagnostic quality for a variety of maxillofacial indications. However, a total of 26 radiographs were excluded due to a lack of image clarity, poor visibility of the clivus as a consequence of the superimposition of artefacts and evidence of surgical interventions over the region of interest. Radiographs of subjects with a documented history of any syndrome, neurovascular diseases and trauma were also excluded from the study.

Image acquisition

All the CBCT volumes included in the study were procured using Promax 3D Mid model CBCT unit (Planmeca, Helsinki, Finland). The radiographs were taken under standard imaging protocols by a trained radiographer with a varying exposure parameter of 8 to 10 mA (tube current); 80 to 90 kVp (tube voltage) and an average exposure time of 27 seconds over a rotation of 360 degrees, depending on the built of the patient. The resultant voxel sizes of the radiographic images ranged from 200 µm to 400 µm. All the radiographs were obtained with a standardized head position (the Frankfort horizontal plane placed parallel to the floor), relaxed lips position and teeth in occlusion. The Scan data were studied in a full screen monitor using Planmeca Romexis software (Version 4.6.2) by two independent Oral and Maxillofacial Radiologists with a minimum of 10 years of clinical and radiological experience. Both radiologists examined no more than 10 longitudinal sets of the CBCT scans at a time to reduce bias caused by visual fatigue. In order to guarantee optimal viewing, the brightness, as well as the contrast of the radiographic images was modified with the aid of the software processing tool. Radiographic evaluation was done based on criteria such as gender, age, presence of CBM and its morphological types. There were no significant inter-examiner discrepancies in the radiographic interpretation among the evaluating radiologists.

Image analysis and interpretation

The obtained scan data were carefully inspected at different levels under appropriate lighting for the presence of CBM by scrolling across the radiographic images. Sagittal sections revealed the

presence of CBM in the form of a well-corticated osseous defect in the basi-occipital region of the clivus. Following the determination of the incidence of CBM, the CBCT sections were evaluated for the following six morphological types as described by Currarino [6]:

1. The complete variants of CBM, such as (a) inferior (Figure 1A), (b) superior (Figure 1B) and (c) bifurcating types have open ends on both sides.
2. The incomplete variants of CBM, such as (d) inferior basi-occiput recess (Figure 2A), (e) superior basi-occiput recess (Figure 2B) and (f) long channel in the basi-occipital region have an open end and a blind end on each side [6, 9].

Statistical Analysis

The presence and types of CBM were recorded based on the age and gender. The collected data were entered in Microsoft Excel-2010 and statistical analysis was carried out using the Statistical Package for Social Sciences software (IBM, Armonk, NY, USA), Version 26. The categorical data were represented as percentages. The chi-square test was used to analyze the presence and types of CBM with regard to gender and age group. A p-value of 0.05 was considered as statistically significant.

RESULTS

The analyses included a total of 226 CBCT scans and 200 were selected based on the inclusion and exclusion criteria. The mean age of the subjects was 34 ± 16.2 years with an age range of 10 to < 70 years. The scan volumes that were included in our study belonged to 131 males and 69 females. Table-1 displays the frequency of CBM based on gender and age groups. Out of 200 CBCT scans, 19 (9.5%) showed CBM, of which 17 (89.5%) belonged to males and 2 (10.5%) belonged to females. The CBCT scans were divided into five age groups, with group A including 10 to 20 years (18.5%), group B including 21 to 30 years (27%), group C including 31 to 40 years (20.5%), group D including 41 to 50 years (15%) and group E including 51 to 70 years (19%) of age. There was a statistically significant relationship between the occurrence of CBM with gender as we observed a male predominance (p =

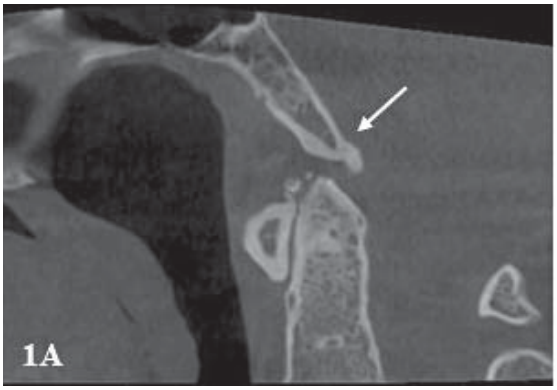

Fig. 1A. Sagittal (CBCT) section demonstrating the inferior type (complete variant) of CBM in the basi-occipital region

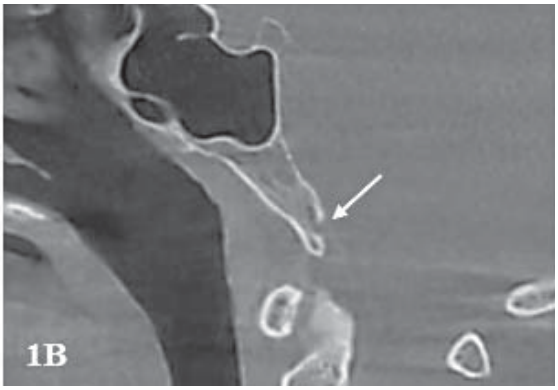

Fig. 1B. Sagittal (CBCT) section demonstrating the superior type (complete variant) of CBM in the basi-occipital region

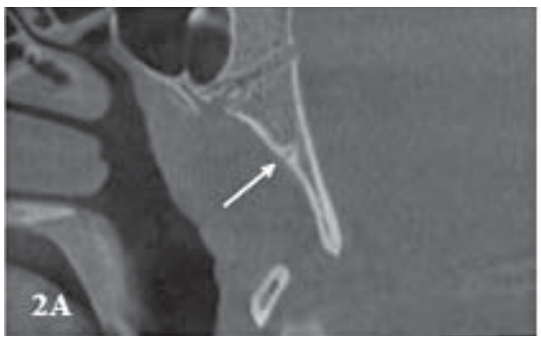

Fig. 2A. Sagittal (CBCT) section demonstrating the inferior recess type (incomplete variant) of CBM in the basi-occipital region

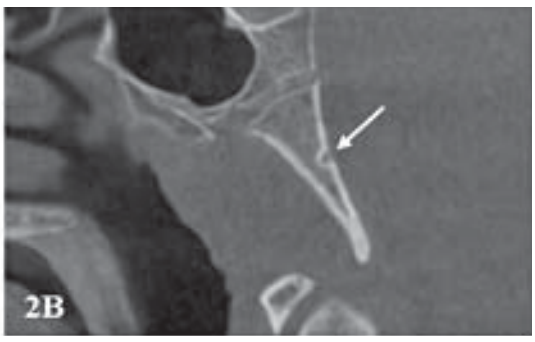

Fig. 2B. Sagittal (CBCT) section demonstrating the superior recess type (incomplete variant) of CBM in the basi-occipital region

0.021). On comparison of the presence of CBM in the different age groups, the present study showed the highest prevalence in the age group of 21 to 30 years (Group B) followed by 41 to 50 years (Group D), 10 to 20 years (Group A), 31 to 40 years (Group C) and 51 to 70 years (Group E), respectively (Figure-3). However, there was no significant relationship ($p > 0.05$) between the occurrence of CBM among the different age groups. On observing the various morphological types of CBM, the superior recess type (incomplete variant) was the most predominant among males followed by Inferior recess (incomplete variant). The complete variants of CBM such as superior and inferior type, were noted one in each among the males. Out of two females, both had superior recess type (incomplete variant) of CBM. Other types of CBM such as the bifurcating (complete variant) and channel type (incomplete variant) were not found among the scan volumes that were studied. However, there was no statistical significance noted among the different types of CBM ($p > 0.05$) (Table 2, Figure 4).

Table 1. Frequency of CBM based on Gender and Age groups

	Canalis basilaris medianus		Total	p-value
	Present	Absent		
Gender				
Male	17 (12.9%)	114 (87%)	131	0.021
Female	2 (2.9%)	67 (97.1%)	69	
AGE				
Group A 10-20 years	4 (10.8%)	33 (89.2%)	37	0.455
Group B 21-30 years	7 (12.9%)	47 (87%)	54	
Group C 31-40 years	3 (7.3%)	38 (92.7%)	41	
Group D 41-50 years	4 (13.3%)	26 (86.7%)	30	
Group E 51-70 years	1 (2.6%)	37 (97.4%)	38	

Table 2. Comparison of various types of CBM based on Gender

	Type of CBM				p-value
	Inferior	Superior	Inferior Recess	Superior Recess	
Male	1	1	7	8	0.570
Female	0	0	0	2	
Total	1 (5.3%)	1 (5.3%)	7 (36.8%)	10 (52.6%)	19

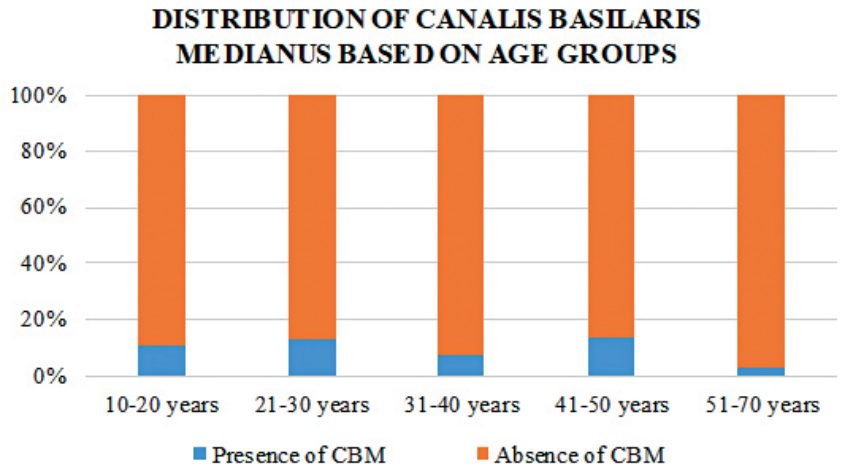

Fig. 3. Bar graph illustrating the distribution of various types of CBM based on age groups

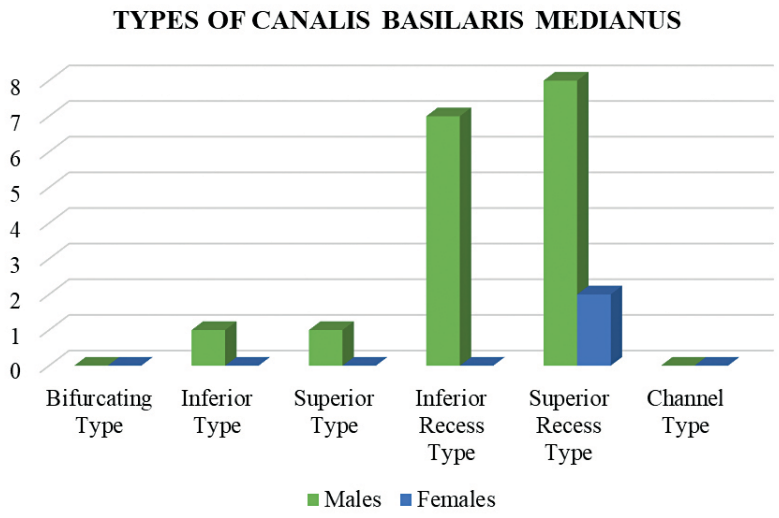

Fig. 4. Bar graph illustrating the distribution of various types of CBM among males and females

DISCUSSION

Over the last few decades, the relationship between anomalies of the clivus and their clinical impact has been gaining interest among various pathologies that are associated with the head and neck region. The clivus is a component of the cranial base that is formed by the body of the sphenoid bone and the basilar part of the occipital bone, connected by the spheno-occipital synchondrosis. It is situated along the anterior part of the occipital bone, sloping downwards from the dorsum sellae. Though clivus is a small part of the cranium, numerous anatomical variations are known to exist in the structure of the clivus, out of which fossa navicularis magna, craniopharyngeal canal and CBM are identified as the most prominent variants [10, 11].

In spite of the fact that a majority of individuals with CBM are asymptomatic, the clinical implication of this skeletal anomaly is controversial. However, considering its serious implications as a disseminating pathway for the spread of various pathologies from the pharyngeal to the intra-cranial region, clinicians should be aware regarding its identification using the routine maxillofacial imaging modalities such as CBCT which facilitates the multiplanar assessment of the craniofacial structures including the base of the skull region [12]. Sagittal CBCT sections are considered as the best plane for the demonstration of CBM along the base of skull [13]. Our study was undertaken primarily to assess the prevalence of CBM and their types using CBCT scans among the general population who reported to a tertiary dental hospital.

Origin of CBM

CBM which is considered as one of the incidental findings of the skull radiographs, was described as early as 1880 by Grubber in dry skulls. To date, the origin of CBM has been explained on the basis of two theories: 1. Theory of vascular origin which states that the formation of CBM is due to the persistent cranial vessels including the emissary veins. 2. Theory of notochordal origin which discloses the formation of CBM as a result of post-natal continuance of the canalis chordae (remnant of the notochord) [6].

Prevalence of CBM

The overall prevalence of CBM in our study population, aged between 10-70 years, was found to be 9.5%. Our finding is higher than the rates documented in previous literature reports, where Serindere et al. [14] reported a prevalence of 4% and Akkoca et al. [15] reported a prevalence of 4.3% both among the Turkish population. Abdolmaleki et al. reported a prevalence of 5.4% among the Iranian population [16]. Another study conducted in a South-Asian population had reported a prevalence of 5.33% [13]. The least prevalence of CBM reported by Bayrak et al. was 2.5% among the Turkish population [17]. Variations in the prevalence rates could be due to the difference in the age group and ethnicity of the population studied. In addition, radiographic factors like imaging modality and exposure parameters could also lead to variations in the identification of CBM.

In the present study, CBM was found to be more predominant in males (13%) than females (3%), with a statistically significant difference. Though there is no clear consensus reason regarding the gender-based prevalence of CBM, our findings were similar to that of Serindere et al. [14] who reported an increased prevalence among males. In addition, literature evidence report the prevalence to be higher in children than adults [6, 9]. However, we did not find any significant difference in the prevalence of CBM among different age groups. Moreover, CBM is believed to be a developmental anomaly rather than a pathologi-

cal variety, as we assume that a varied age could not be a delineating factor.

Morphological types of CBM

In the present CBCT study, we found the superior recess type of CBM to be more predominant followed by inferior recess type and both the females who exhibited CBM were of the superior recess type. Bayrak et al. [17] reported superior recess type to be more prevalent among females and Serindere et al. [14] reported inferior recess type to be more prevalent among males, which was in conformity with our study even though there was no statistical significance observed among the different types of CBM. Pasalkar et al. [13] in their study reported superior recess type to be predominant among the Indian population, which is similar to our finding. We also observed the complete variants such as superior and inferior types of CBM, but other types of CBM were not found in our study population. Despite the scarcity of literature on prevalence studies evaluating the CBM, our study was one among the few to assess the gender-based differences among the morphological forms of CBM.

Clinical significance of CBM

The clinical importance of CBM may be due to its diagnostic concern as these variations act as a potential pathway for the progression of intra-cranial infections. This anomaly of the skull base is present in the region of the sphenoid sinus, nasopharyngeal and clivus region, which are all considered as anatomical structures of clinical significance [18]. Therefore, this anatomical variant of the clivus should be considered as one of the differential diagnoses of conditions, such as iatrogenic fractures of the clivus postneurosurgical procedures and enterogenous cyst, such as meningocele. Various pathological conditions have been reported to be associated with CBM. Recurrent meningitis secondary to atypical bacterial infection has been documented to be associated with a canal type of CBM and surgical repair of the canal by grafting was considered to remove the potential passage of the infection for the prevention of recurrence of meningitis [6, 19]. CBM is known to be associated with cysts such as Tornwaldt's cyst [20] and meningocele [21]. Khairy et al. described the presence of CBM to be related with a case of cerebrospinal fluid (CSF) leak in a twenty-two old male patient who complained occurrence of chronic manifestations such as running nose and headache associated with the frontal region [22]. Previous reports suggesting the presence of an incomplete inferior recess in the basi-occipital region have also been described as an incidental finding on skull base radiographs in cases of Apert's syndrome and neurofibromatosis in children [6]. However, there is a lack of clear consensus regarding the coexistence and detrimental effects of the anatomical variant over the pathology.

Limitations and future prospects

Our study was an attempt to evaluate the prevalence of CBM among Indian population and we have found significant difference in the prevalence among males and females. However, the study has certain inherent limitations owing to its retrospective nature, as there is a lack of clinical correlation with the presence of CBM. Further prospective, large-scale clinico-radiographic studies should be advocated to facilitate a better understanding of the pathological relationship of CBM in disorders of the cranial cavity in addition to ascertaining the true prevalence of this anatomical variant of the clivus region.

CONCLUSION

In conclusion, the present study evaluated the frequency of CBM along with its morphological types which showed an increased male predilection. It is essential for maxillofacial radiologists to have a solid understanding of both normal and variant skull-base anatomy within the imaged field, such as CBM, in order to recognize the associated anomalies and to facilitate proper decisions by the clinicians especially in surgical procedures. The morphological study of the skull and its foramina can also serve as a way to compare and understand the changes in human evolution.

Acknowledgements: *No acknowledgements.*

Conflicts of interest: *The authors report no conflicts of interest.*

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