Imaging Science in Dentistry 2021; 51: 351-61
https://doi.org/10.5624/isd.20210039

Anomalies of the clivus of interest in dental practice: A systematic review

Troy E. McCartney[1], Mel Mupparapu[1,*]

[1]*Department of Oral Medicine, University of Pennsylvania School of Dental Medicine, Philadelphia, PA, USA*

ABSTRACT

Purpose: The clivus is a region in the anterior section of the occipital bone that is commonly imaged on large-volume cone-beam computed tomography (CBCT). There have been several reports of incidental clivus variations and certain pathological entities that have been attributed to the variations. This study aimed to evaluate the effects of these variations within the scope of dentistry.

Materials and Methods: Medical databases (PubMed, Scopus, and Web of Science) were searched using a controlled vocabulary (clival anomalies, cone-beam CT, canalis basilaris medianus, fossa navicularis magna, clival variation). The search was limited to English language, humans, and studies published in the last 25 years. The articles were exported into RefWorks® and duplicates were removed. The remaining articles were screened and reviewed for supporting information on variations of the clivus on CBCT imaging.

Results: Canalis basilaris medianus and fossa navicularis magna were the most common anomalies noted. Many of these variations were asymptomatic, with most patients unaware of the anomaly. In certain cases, associated pathologies ranged from developmental (Tornwaldt cyst), to acquired (recurrent meningitis). While no distinct pathognomonic aspects were noted, there were unique patterns of radiographic diagnosis and treatment modalities. Most patients had a normal course of follow-up.

Conclusion: Interpretation of CBCT volumes is a skill every dentist must possess. When reviewing large-volume CBCT scans, the clinician should be able to distinguish pathology from normal anatomic variations within the skull base. The majority of clivus variations are asymptomatic and will remain undetected unless incidentally noted on radiographic examinations. ***(Imaging Sci Dent 2021; 51: 351-61)***

KEY WORDS: Radiology; Cone-Beam Computed Tomography; Posterior Cranial Fossa

Introduction

The human skull consists of 22 bones, with the main networks pieced together through fibrous connections called sutures. These sutures allow flexibility and growth between the large flat bones throughout maturation. Over time, these sutures eventually fuse, resulting in an individual's permanent anatomy. However, not all aspects of the skull follow this same pattern. A second way in which bones of the skull form a unity is referred to as synchondrosis, where joints with bony surfaces join through cartilage. Of these unions, there is none more impactful than the joint between the sphenoid and the occipital bone. The occipital bone is located on the most posterior-inferior aspect of the skull and houses the back part of the brain. Just like many of the other bones of the skull, the occipital bone is subdivided into separate parts based on certain characteristics, including distinct anatomy, grooves, or canals. The part affiliated with the spheno-occipital synchondrosis is the clivus.[1]

The clivus is located on the most anterior section of the occipital bone. This bony part of the cranial base slopes down from the dorsum sellae. While the clivus was previously considered unexceptional, some studies have shown that this aspect does in fact show repeating patterns in certain anomalies from person to person, the 2 most notable of which are canalis basilaris medianus (CBM) and fossa navicularis magna (FNM).[1] CBM has been described radio-

Received February 17, 2021; Revised May 27, 2021; Accepted June 11, 2021
Published online Aug 11, 2021
*Correspondence to : Prof. Mel Mupparapu
Department of Oral Medicine, University of Pennsylvania School of Dental Medicine, 240 S 40th Street, Philadelphia, PA 19104, USA
Tel) 1-215-746-8869, E-mail) mmd@upenn.edu

Imaging Science in Dentistry · pISSN 2233-7822 eISSN 2233-7830

graphically as a channel-like osseous defect, usually less than 2 mm in diameter, with smooth borders found in the basiocciput clivus region.[1,2] This variation has also been subcategorized into 6 different subtypes based on whether the channel through the clivus is complete or incomplete.[3] In contrast, FNM has been reported as a notch-like, rounded osseous defect with corticated margins in the lower part of the clivus or basiocciput bone.[4,5] These variations have been traced to 2 possible theorized origins, vascular or notochordal. The vascular origin theory states that these variations are caused by persistent enlargement of emissary veins, which are veins that connect vessels outside the cranium to vessels inside the cranium.[4] In contrast, the notochordal origin theory, which is slightly more accepted, states that a remnant of the cephalic end of the notochordal canal prevents complete ossification of the clivus during formation.

With the substantial increase in imaging and technology used in the field of dentistry, this anatomic location has gained a crucial place in the diagnostic process. A particularly important advance in imaging is cone-beam computed tomography (CBCT), an important evaluation tool in the field of dentistry that allows the provider to view a 3-dimensional (3D) representation of the region of interest. This systematic review based on published descriptions of clivus anomalies aimed to arrive at an understanding of their features; any notable consequences of the finding, including age, development, and potential pathology; and how patients with clivus anomalies can be managed.[1,4]

Materials and Methods

Information sources

The search was conducted at the University of Pennsylvania School of Dental Medicine in Philadelphia, PA, USA using commonly available electronic databases (PubMed, Scopus, and Web of Science). The search was limited to English-language articles published in the past 25 years, with a focus on human studies only.

Search

The search strategy was a combination of MeSH (Medical Subject Headings) terms and free text words. In PubMed, the following search was performed: (clival anomalies) OR (((((canalis basilaris medianus) OR fossa navicularis magna) OR clivus CBCT) OR clivus variation) OR ((((“Cranial Fossa, Posterior” [Mesh]) AND “Cranial Fossa, Posterior/pathology” [Mesh])) AND Variation)). In Scopus and Web of Science, the search was: ((clivus AND CBCT) OR (Clivus AND Variation)).

Data collection process

The results of all 3 searches were exported into RefWorks® (ProQuest, Ann Arbor, MI, USA), where duplicates were deleted. The remaining articles’ abstracts were screened by the authors for relevance to the topic of clivus variation and the use of CBCT imaging in diagnosis. The full-text articles were obtained and read for confirmation of direct relevance, as listed in the tables. Articles were further excluded due to a lack of significance or patient-based cases.

Data analysis

The case-based articles that were selected for this research were entered into a table and described under the following subheadings: demographics, variation, developmental or acquired aspects, radiographic findings, symptoms, treatment/follow-up, and clinical significance.

Study selection

From the original yield of 456 titles after duplicates were removed, 40 articles were selected for full-text analysis. Eleven studies were eventually chosen as case-based publications that contained information clival anomalies and CBCT imaging. These 11 studies were analyzed in terms of the above-stated criteria. In addition to those 11 studies, 5 articles were selected as essential background information (Fig. 1). These 5 articles were analyzed in terms of the prevalence, dimensions, and significant patterns noted. Three separate tables were created and analyzed. The reasons for exclusion included a lack of imaging, content unrelated to the clivus, a lack of supporting information, and irrelevance.

Characteristics of the case-based studies

The 11 studies chosen reported a total of 17 cases of rare clival variations. Of the 17 cases reported, 6 were related to CBM. Nine of the 17 cases described FNM, and the remaining 2 presented cases involved a craniopharyngeal canal and a normal clivus. Although the normal clivus case was included in a study that was chosen for this review, this specific case was not analyzed. The age of the patients ranged from 1 month to 68 years, with a mean of 26.8 years. The patients included 6 males and 11 females (Tables 1 and 2)

Characteristics of the statistical studies

The 5 studies chosen used either dry skull or 3D CBCT imaging to determine the prevalence of clival variations. Three of the studies focused solely on FNM, 1 study focu-

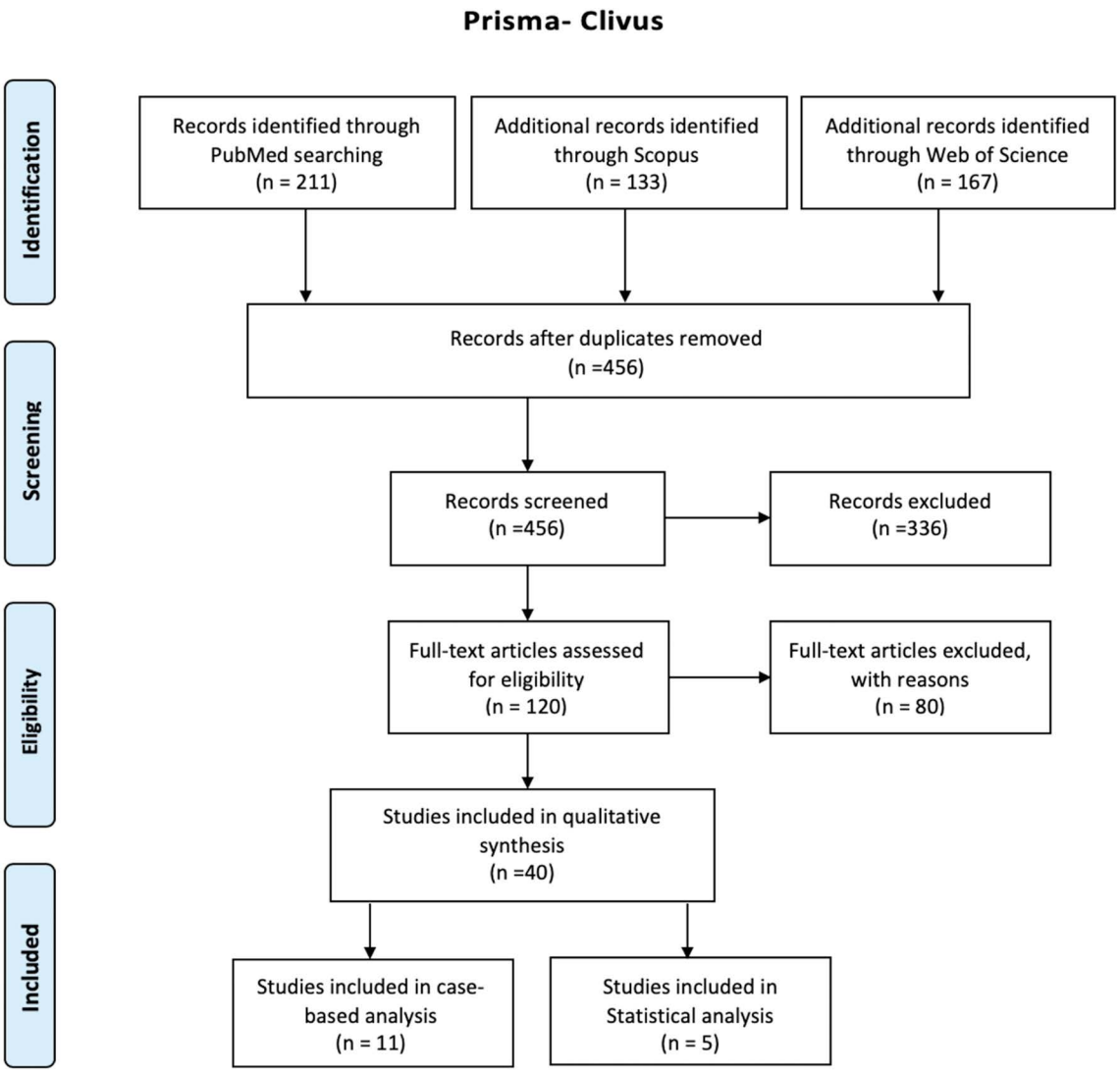

Fig. 1. PRISMA flow chart shows the search process and selection of final articles used for this research.

sed solely on CBM, and 1 study focused on FNM, CBM, and craniopharyngeal canal. The population groups ranged in size from 168 subjects to 1059 subjects, although 1 study did not specifically include the number of patients analyzed. All 5 studies presented findings on the prevalence of the analyzed variations, and 3 of the studies also presented dimensional variations of the clivus (Table 3).

Methodological evaluation

Case selection was evaluated with a methodological assay quality chart. Cases were evaluated based on 8 items in 4 domains:[6] selection, ascertainment, causality, and reporting. Only items applicable to the study were evaluated. Numerical scoring was not performed in this systematic review following the recommendation, and an overall judgment regarding the methodological quality and synthesis of the studies included was made in light of the questions deemed most crucial for each clinical scenario. For the methodological evaluation, overall judgments of acceptable or unacceptable were made (Table 4).

Results

The case studies largely fell into the 2 major categories of clival variations: CBM and FNM (Table 1). Furthermore, 3 of the cases fell into the additional subcategories of inferior incomplete CBM, inferior complete CBM, and superior complete CBM. It is important to note that the case-study articles were published due to the uniqueness of the pathology, and these findings therefore do not show a perfect correlation with the real prevalence of variations and pathologies.

Table 1. Summary of case-based publications and their characteristics

Authors	Demographics	Variation	Developmental (D) or acquired (A) aspects	Symptoms	Treatment	Follow-up
Lohman et al.[12] (2011)	45 years/male	CBM - incomplete inferior	D: Tornwaldt nasopharyngeal cyst	Presented for a work-up for Parkinson disease	Skull base resection and biopsy was clinically unnecessary and complicated at this time	None given
Morabito et al.[14] (2012)	1 month/female	CBM - inferior complete	D: Pharyngeal enterogenous cyst A: Partial herniation of the bulb	Presented with growth retardation, vomiting at the end of every feed, nystagmus, crisis of desaturation, and bradycardia	Surgical excision of the enterogenous cyst; a fistula was noted in the posterior pharyngeal wall and closed by suturing	Good; no sequelae and developing normally
Jacquemin et al.[2] (2000)	12 years/female	CBM - incomplete inferior	A: Recurrent meningitis	Presented with headaches, neck stiffness, and profound reduction in acuity of the left eye	IV steroids	No relapse of meningitis to date; vision in her left eye remained poor
Syed et al.[1] (2016)	1) 11 years/female 2) 63 years/female	1) CBM - incomplete inferior 2) CBM - complete superior	None	Both cases presented with no clinical symptoms	Both cases did not require treatment	None given
Sajisevi et al.[13] (2015)	1) 16 years/male 2) 43 years/male 3) 4 years/male	1) CPC 2) Normal clivus; extraosseous mass 3) CBM	1) Infrasellar craniopharyngioma 2) Chondroid chordoma 3) Recurrent nasopharyngeal polyp	1) Presented with a history of craniopharyngioma resection and nasal obstruction 2) Presented with a 1-year history of nasal obstruction and headache 3) Presented with recurrent nasopharyngeal polyp, increased snoring and nasal congestion	1) Total resection of the mass and craniopharyngeal canal 2) Total resection of the mass; drilling of the clival attachment site 3) Adenoidectomy and pressure equalization with recurrent polyps and adenoid pad surgically resected	1) Histology exam revealed adamantinomatous craniopharyngioma 2) Histology exam revealed chondroid chordoma 3) No further clinical symptoms and no return of nasopharyngeal polyposis
Beltramello et al.[7] (1998)	33 years/female	FNM	D: Prominent bursa or related notochord remnant; bone defect filled with lymphoid tissue of pharyngeal tonsil	Presented with symptoms of sinusitis including fever, facial tenderness, and pressure in the sinus	None reported	None reported
Prabhu et al.[9] (2009)	5 years/female	FNM	D: Lymphoid tissue of pharyngeal tonsil served as route of infection A: Acute clival osteomyelitis-group A *Streptococcus*	Presented with fever, neck stiffness and pain, and cervical lymphadenopathy	Surgical drainage of the retropharyngeal abscess IV ceftriaxone for 4 weeks; 4 weeks of oral amoxicillin	Follow-up CBCT showed significant improvement in the osteolytic process

Table 1. Continued

Authors	Demographics	Variation	Developmental (D) or acquired (A) aspects	Symptoms	Treatment	Follow-up
Segal et al.[10] (2013)	12 years/female	FNM	A: Intracranial infection, retropharyngeal abscess	Presented with fever, worsening headache, neck stiffness, change in consciousness, positive meningeal signs, left abducens nerve palsy, and thrombus in the left jugular with involvement of the sigmoid sinus	IV antibiotic treatment and anticoagulants	Resolution of strabismus with only mild abducens paresis; partial resolution of venous sinus thrombosis
Syed et al.[4] (2016)	1) 65 years/female 2) 50 years/male 3) 12 years/female 4) 68 years/female	FNM	None	All 4 cases presented with no clinical symptoms	None needed	None given
Benadjaoud et al.[8] (2017)	7 years/male	FNM	D: Tornwaldt cyst A: Secondary osteomyelitis: *Streptococcus intermedius* and *Fusobacterium*	Presented with headache, inability to extend the neck, fever, pain on lateral extension of the neck, and acute febrile left torticollis	Surgical transnasal aspiration; antibiotic therapy with a combination of cefotaxime, metronidazole, and gentamicin for 7 days; IV amoxicillin with clavulanic acid for 14-days; oral antibiotic therapy with pristinamycin for 3-months after discharge	Good; 3-month follow-up CBCT was considered normal and antibiotics were stopped
Alalade et al.[11] (2018)	9 years/female	FNM	A: Recurrent meningitis, recurrent sinusitis, and developed isolated abducens nerve palsy	Presented with bitemporal throbbing headaches, left retro-orbital pain, photosensitivity, neck stiffness, and fever	Initially IV ceftriaxone for 6 weeks, followed by 6 weeks of oral amoxicillin; surgical endonasal endoscopic removal/repair of clival tissue and FNM	Good; no sequelae

CBM: canalis basilaris medianus, FNM: fossa navicularis magna, IV: intravenous, CPC: craniopharyngeal canal, CBCT: cone-beam computed tomography

Table 2. Summary of clinical and radiographic significance of the findings noted

Author	Radiographic findings	Clinical significance
Lohman et al.[12] (2011)	CBCT: Thin bony defect with s cleft extending from the pharyngeal surface of the basiocciput into the posterior third of the clivus	This is the first case to present a possible association of CBM with Tornwaldt cyst. Multiple differential diagnoses (DD) were offered, but neuroradiologists elected not to surgically treat this case, and therefore no final diagnosis could be made. The DD included Tornwaldt cyst, cephalocele, and ecchordosis physaliphora.
Morabito et al.[14] (2012)	CBCT: Wide osseous defect involving the basiocciput	This is the first case to report a histological association between complete CBM and pharyngeal enterogenous cyst. Unlike the Lohman paper, this patient underwent surgery and resection. Moreover, this patient was affected extremely early into life and demonstrated the failure of a single embryogenic step.
Jacquemin et al.[2] (2000)	CBCT: Axial CT showing anterior indentation of the clivus	This is one of the early case reports connecting CBM with meningitis. This presentation was described as atypical including visual loss. The resolution of the case was completed with IV steroids and without the use of antibiotics, which were used in all other previous published cases with these features.
Syed et al.[1] (2016)	1) CBCT: Incidental findings in the clivus described as a well-defined, corticated, and channel-like hypodense radiolucency from the pharyngeal aspect of the basiocciput to the intracranial aspect of the clivus. 2) CBCT: Sagittal view of the intracranial part of the clivus showed a discontinuity, described as corticated, hypodense channel in the superior-inferior direction	1) This case presents asymptomatic canalis basilaris medianus that required no further treatment. The presentation is the pathognomonic representation of CBM. 2) This case presented a channel along the intracranial aspect, which initially appeared as a fracture of the clivus. However, there was no true osteolytic destruction; thus, no additional treatment was necessary.
Sajisevi et al.[13] (2015)	1) CBCT: Large peripherally enhancing cystic mass occupying the nasopharynx and the right pterygopalatine fossa; no bony destruction of clivus; mass connected to a craniopharyngeal canal 2) CBCT: Heterogeneous polypoid mass next to the clivus without bony destruction 3) CBCT: Mass originating from a bony defect of the middle clivus	These cases presented embryologic remnant defects of the clivus. Each presented a different variation, necessitating different management. Craniopharyngioma should be identified with CBCT and resected in inclusion with the craniopharyngeal canal. Case 2 demonstrates that variation in the clivus region is not limited and can include malignant pathology. Chordomas will present as soft-tissue masses with irregular calcifications (a "honeycomb" appearance). Surgical resection was indicated in this case as well. In case 3, meningocele was suspected due to CBCT showing a nasopharyngeal mass in relation with canalis basilaris medianus.
Beltramello et al.[7] (1998)	CBCT: Notch-like defect in the basiocciput	One of the first cases to report a mass affiliated with a clival variation. The case report explains that FNM must be differentiated from canalis basilaris medianus. Furthermore, it states that FNM can be easily differentiated from pathological bone destructive lesions.
Prabhu et al.[9] (2009)	CBCT: Presence of a large retropharyngeal abscess crossing the midline; osteolytic process with cortical destruction; notch-like defect	This case shows that the FNM can lead to infection transmission in the skull base. Unlike others, this case showed an actual osteolytic process in conjunction with the variation.
Segal et al.[10] (2013)	CBCT: Small fluid collection in the nasopharynx just in front of the clivus; air bubbles in the clivus; bony dehiscence; and a bony defect in the area classified as fossa navicularis	This case demonstrates that the presenting symptoms of infection through FNM are fever, neck pains, and neck stiffness.

Table 2. Continued

Author	Radiographic findings	Clinical significance
Syed et al. (2)[4] (2016)	1) CBCT: Inferior aspect of the basiocciput showed a notch-like defect with a regular cortical margin 2) CBCT: Well-defined and solitary osseous defect on the inferior surface of the basiocciput; well-defined and corticated periphery 3) CBCT: Well-defined and solitary notch in the inferior part of the basiocciput; 10 mm posterior to the SOS; the notch could be seen in both coronal and axial views 4) CBCT: Well-defined, corticated, solitary, circular, lytic area on the inferior basiocciput	Four cases presented where specialists referred a case with abnormal findings, with each being a non-pathologic variation and asymptomatic. FNM should be considered in the diagnosis when there is clear radiographic defect in the clivus region, and a lack of symptoms related to the finding.
Benadjaoud et al.[8] (2017)	CBCT: Showed fossa navicularis magna associated with clival osteomyelitis related to a retropharyngeal abscess	This is the first case published of an infection arising from Tornwaldt cyst situated in the FNM. There should be a suspicion of FNM in children with fever, headache, neck pain, and torticollis when no obvious focus can be established.
Alalade et al.[11] (2018)	CBCT: Notch-like defect classified as fossa navicularis magna through the clivus	This case presents the great significance of the radiographic diagnosis of FNM and how it can play a role in intracranial infections

CBCT: cone-beam computed tomography, CT: computed tomography, FNM: fossa navicularis magna, CBM: canalis basilaris medianus, DD: differential diagnosis, IV: intravenous, SOS: spheno-occipital synchondrosis.

In the FNM cases presented, 5 of the cases contained pathology associated with the variation, while 4 cases involved no pathology. Of the cases that involved pathology, 1 was found to have only a developmental pathology (a notochord remnant bone defect filled with lymphoid tissue of the pharyngeal tonsil).[7] Two were found to have a developmental pathology with an additional acquired pathology.[8,9] Prabhu et al.[9] presented a case with a pharyngeal tonsil remnant that served as the route of acute clival osteomyelitis. Benadjaoud et al.[8] presented a case with a Tornwaldt cyst that also served as the route of secondary osteomyelitis. Two cases were found to have an acquired pathology in the absence of a developmental pathology. One of these cases involved an intracranial infection and recurrent meningitis, while the other showed sinusitis and abducens nerve palsy.[10,11] In addition, Segal et al.[10] presented a case with a unique thrombus in the left internal jugular vein.[11] Finally, 4 cases were presented as strictly incidental findings with no pathology whatsoever.

In all of the cases involving an infection, including osteomyelitis, intracranial infection, and recurrent meningitis, the patient presented with fever, neck pain, and stiffness of the neck. The stiffness of the neck was largely concluded to be connected to swelling of the cervical lymph nodes. Additional symptoms such as change in consciousness,[10] abducens nerve palsy,[10] and throbbing headaches[11] were noted. The patient with only a developmental pathology also presented with symptoms of sinusitis, which included fever and facial tenderness.[7] The patients with no related pathology presented with no symptoms.

No treatment was deemed necessary for the patients who presented with no symptoms at the time, and no follow-up was noted.[4] All of the patients who presented with infection were treated with intravenous (IV) antibiotic treatments, differing in type and duration. The IV antibiotic therapies included ceftriaxone and amoxicillin. The osteomyelitis and meningitis cases were treated with a mix of both IV and oral antibiotics,[8,9,11] while the intracranial infection was treated with IV antibiotics and anticoagulants due to jugular involvement. Moreover, all 3 infection cases were also treated surgically with drainage, and Alalade et al.[11] mentioned repair of the clival defect. All cases showed a favorable course of follow-up, with the slight exception of only partial resolution of the venous sinus thrombosis.[10] In the case of a remnant notochord reported by Beltramello and colleagues,[7] further treatment was decided against. Their study concluded that the ability to differentiate this anatomic variant from a more severe pathology was crucial.

In the publications dealing with CBM, 2 cases were found

Table 3. Summary of the prevalence and presentation of variations of clival anomalies

Author	Variation	Study	Results: prevalence	Results: dimensions	Results: notes
Currarino[3] (1988)	CBM	Combination of multiple large series skull data studies	CBM: 2-3% in adults; 4-5% in children	None presented	N/a
Cankal et al.[15] (2004)	FNM	492 dry human skulls 525 CT images	FNM: 5.3% of dry skulls; 3% of CT scans	Depth: 1.10-4.11 mm (mean: 2.24 mm); Diameter (l) 1.79-9.22 mm (mean: 5.12 mm); Transverse diameter (w) 1.5-3.9 mm (mean: 2.85 mm)	Age range of study: 3-75 years, with a mean of 33 years
Ersan[16] (2017)	FNM	CBCT of 723 patients (female: 420, male: 303)	FNM: 6.6%	Depth: 1.2-6.8 mm (mean: 2.2 mm); Length 2-10.4 mm (mean: 5.8 mm); Width: 2-8.9 mm (mean: 4.7 mm)	Observed in males more frequently; more oval cases than round; age: 10-68 years; mean age: 34 ± 18.7 years
Magat[5] (2019)	FNM	168 CBCT scans (female: 96, male: 71)	FNM: 27.5%	Dept: 2.22 mm; Length: 8.55 mm; Width: 5.37 mm	Sex was not a significant factor; the study showed higher numbers than others, as explained by differences in methodologies, ethnicities, and sample sizes
Bayra et al.[17] (2019)	FNM, CBM, and CPC	1059 3D images (CBCT and CT)	FNM: 7.6% CBM: 2.5% CPC: 0.3%	None presented	Reported no significant difference between sexes for depth and width measurements; the FNM was longer in males than in females

CBM: canalis basilaris medianus, FNM: fossa navicularis magna, CPC: craniopharyngeal canal, CT: computed tomography, CBCT: cone-beam computed tomography

to have only a developmental pathology (Tornwaldt nasopharyngeal cyst[12] and recurrent nasopharyngeal polyps[13]). One case was found to have a developmental pathology (pharyngeal enterogenous cyst) with an acquired pathology (partial herniation of the bulb).[14] One case was found to have only an acquired pathology (recurrent meningitis).[2] Lastly, 2 cases involved strictly incidental findings.[1]

As with FNM, the 2 cases that presented with no pathology showed no additional signs or symptoms.[1,4] In the cases reported by Syed et al.[1] and Lohman et al.,[12] the anomalies were found incidentally on CT scans and during the work-up of a case of Parkinson disease, respectively. The remaining 3 patients all presented with symptoms ranging from extremely severe, such as vomiting, nystagmus, and bradycardia,[14] to moderate, such as headaches, neck stiffness, and vision difficulty,[2] or mild, such as snoring and nasal congestion.[13]

All 3 patients who presented with no symptoms were not deemed to require treatment, and no follow-up information was noted. The 2 patients who presented with developmental pathology were treated surgically, and no further complication or pathology was reported.[13,14] The case with only an acquired pathology was uniquely treated with IV steroids.[2] The follow-up reported no relapse of meningitis to date, but the patient's left eye vision remained poor.[2]

Statistical outcomes

The statistical publications were included to provide information on the true prevalence of each of these variants (Table 3). Each of the studies was performed in a different

Table 4. Methodological evaluation and acceptability of the publications analyzed in this research

Author	Selection (uniform across the subjects)	Ascertainment (exposure and outcomes)	Causality (follow-up)	Reporting (is replication possible)	Overall value
Lohman et al.[12] (2011)	×	×	○	○	Acceptable
Morabito et al.[14] (2012)	×	×	×	×	Acceptable
Jacquemin et al.[2] (2000)	×	×	×	×	Acceptable
Syed et al.[1] (2016)	○	×	○	×	Acceptable
Saijsevi et al.[13] (2015)	○	×	×	×	Acceptable
Beltramello et al.[7] (1998)	×	○	○	○	Acceptable
Prabhu et al.[9] (2009)	×	×	×	×	Acceptable
Segal et al.[10] (2013)	×	×	×	×	Acceptable
Syed et al. (2)[4] (2016)	×	×	○	×	Acceptable
Benadiaoud et al.[8] (2017)	×	×	×	×	Acceptable
Alalade et al.[11] (2018)	×	×	×	×	Acceptable

population pool, yielding inconsistent results. Two of the 5 studies analyzed CBM, 4 of the 5 studies investigated FNM, and 1 study explored both.

In the FNM studies, the reported values varied to a much greater extent than in the CBM results. The reported prevalence was as low as 3% and as high as 27.5% of the population. Cankal and colleagues[15] presented separate analyses of dry skulls and imaging studies, and found FNM in 5.3% of dry skulls, but only in 3% of CT scans. However, Magat[5] presented an outlier study with an incredible reported 27.5% prevalence of FNM variations on CT scans. Their article mentioned the substantial difference from previous studies and related the change to differences in methodologies, ethnicities, and sample size. The ranges of dimensions of FNM varied as well, with the mean diameter ranging from 2.85 to 5.37 mm, the mean length ranging from 5.12 to 8.55 mm, and the mean depth being approximately 2.2 mm in all 3 studies.[5,15,16]

In the statistical studies of CBM, the results were relatively close in prevalence. Bayrak and colleagues[17] found that approximately 2.5% of people had this variation, while Currarino[3] discovered the variation in 2-3% of adults and 4-5% of children. Currarino[3] categorized CBM into 6 different subtypes: 3 complete subtypes (superior, inferior, and bifurcate) and 3 incomplete subtypes (superior recess, inferior recess, and long channel).

Discussion

With the increase in large-volume CBCT scans being taken in the dentistry field, the interpretation of these images has become significant, as missed findings can potentially increase liability in practice. While the area of the clivus may not be the immediate concern, this anatomic landmark is captured in a vast majority of films. During interpretation, the dental practitioner must be able to distinguish normal from abnormal findings, and consequently, decide whether an abnormality (if present) would affect the continuation of treatment. In this study, recurring patterns have been identified that will help clinicians in identifying and diagnosing anomalies within the clivus region and provide assistance in deciding on future treatment.

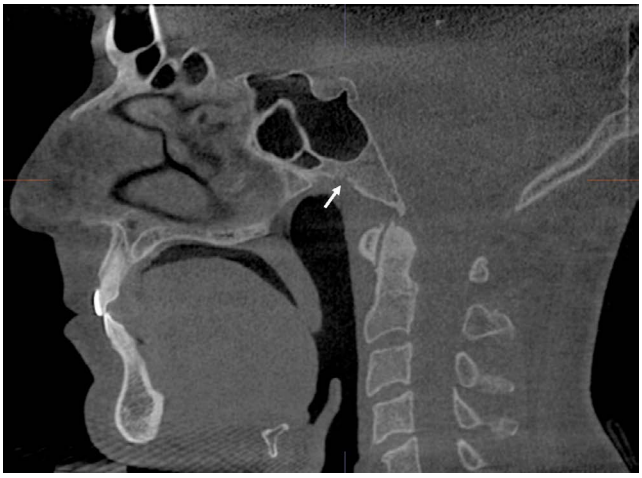

Fig. 2. Mid-sagittal cone-beam computed tomographic image shows notch-like defect within the pharyngeal portion of the clivus. This is one of the classic appearances of fossa navicularis magna.

Each of the cases discussed provides a significant piece of information regarding when to include these variations in the differential diagnosis, what to look for on imaging, what symptoms to identify, when/how to treat, and what

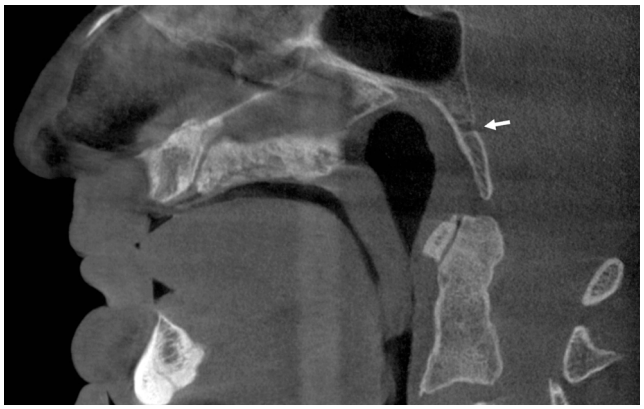

Fig. 3. Mid-sagittal cone-beam computed tomographic image shows notching of the superior surface of the clivus demonstrating canalis basalis medianus. The superior recess is 1 of the 6 forms of canalis basilaris medianus described in the literature.

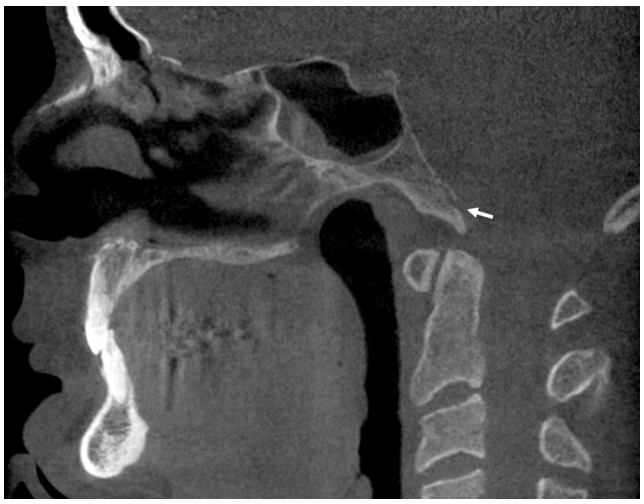

Fig. 4. Mid-sagittal cone-beam computed tomographic image shows complete superior canalis basalis medianus.

the prognosis is following certain treatments. For many of the cases, it was the first time that a certain pathology was published in association with clivus variation, and these cases therefore set precedents for handling these conditions in future patients (Table 2).

The radiographic findings were relatively consistent for each of the findings. The FNM cases showed a circular, notch-like corticated defect on the inferior portion of the basiocciput (Fig. 2). In patients with no clinical symptoms, the notch appeared with a well-defined and corticated periphery.[1] However, in the cases associated with pathology, the CBCT readings showed an osteolytic process with cortical destruction,[9] a bony dehiscence with "air bubbles" present,[10] and evidence of clival osteomyelitis.[8] In the cases of infection, a mass or abscess associated with the clivus was also commonly seen on the CBCT image.[8,9] In the CBM cases (Figs. 3 and 4), there was slightly more variation in the appearance due to the existence of different subtypes. In a general sense, the findings of each case were described as a channel-like corticated radiolucency originating from the pharyngeal or superior aspect of the basiocciput to the intracranial aspect of the clivus. At first glance, this tract-like radiolucency could appear similar to a fracture of the clivus, but with the absence of any further osteolytic process. Asymptomatic cases were described as having these well-defined channels,[1] whereas the cases associated with pathology did not show as well-defined of a pattern and often had a mass affiliated with the clivus.[12-14]

A recurring pattern of symptoms affiliated with infection through the clival variation was consistently noted. A patient presenting with fever, neck pain, and stiffness of the neck, without a respiratory or other obvious infection, should be considered for CT imaging. If these symptoms present with clivus involvement, FNM or CBM should be considered in the examination and included in the differential diagnosis. Other common symptoms associated with these clival variations were nasal congestion, headache, and vision defects.

With respect to treatment, asymptomatic cases that did not cause any potential harm to the patients were left untreated.[1,4,12] A surgical approach was a common choice for symptomatic pathologies such as cysts,[14] nasopharyngeal polyps,[13] osteomyelitis,[8,9] and recurrent meningitis.[11] All infections were treated with IV antibiotics (such as ceftriaxone and amoxicillin) with the exception of 1 recurrent meningitis case that was treated with IV steroids.[2]

The course of follow-up was promising for all cases and treatments. The prognosis of these clival variant pathologies can be classified as good, with only vision defects having lasting effects.

This review highlights a couple of key takeaways. First, these variations could affect patients of all ages, including within the first months of life. Second, as a whole, the majority of clivus variations might remain asymptomatic and undiscovered unless radiographically examined. Most of the cases of clival variations were found incidentally on CBCT scans or during research on the prevalence of this condition, and thus required no specific treatment. However, this was not always the case, and symptomatic cases have been published with increasing frequency to promote a better understanding of diagnoses in this area. The findings showed that recurrent cases of infection, especially meningitis, appearance of osteolytic destruction without accompanying symptoms, or the common presenting symptoms

of fever, neck pain, and neck stiffness without an accompanying focus, are all reasons to suspect the possibility of a clival variation. Finally, this review showed that while most treatments were consistent, there are different potential approaches. For example, Lohman et al. presented a case where the physician decided against surgical treatment for cyst removal,[12] whereas Morabito and colleagues presented a similar case in which surgical treatment was chosen based on the patient's symptoms and prognosis.[14] This diversity in approach is also seen from the fact that Jacquemin et al. used IV steroids,[2] whereas Alalade et al. chose to use IV antibiotics.[11]

From the information gained, this review could conclude that the finding of a clival variation would not affect dental treatment. Moreover, there was no evidence to support any alteration or change in conventional treatment for patients with anatomical variants. However, it is important for dental practitioners to be trained in radiographic interpretation so that they can recognize and diagnose variants properly. There was no significant additional benefit of further testing, which is therefore discouraged. Due to the spontaneity of the effects of CBM and FNM, patients should be made aware of the variant in case of idiopathic complications in the future. However, most of these cases would be expected to remain asymptomatic throughout life. If complications do occur, there are proven surgical and non-surgical treatments that can correct the clival variation and address any secondary effects. Unnecessary testing and unwarranted surgical management of CBM and FNM are not recommended in general dental practice.

Conflicts of Interest: None

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