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Prevalence of the Mandibular Bifid Canal: A Cross Sectional Study in Ecuador

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ABSTRACT

Objectives: To determine the prevalence of the bifid mandibular canal using cone-beam computed tomography (CBCT) in the city of Cuenca.

Materials and Methods: A total of 174 CBCT studies (2022–2025) from an anonymous database were analyzed. Multiplanar reconstructions (coronal, sagittal, and axial views) were evaluated to identify anatomical variations of the mandibular canal. Bifurcations were classified according to Naitoh, considering the origin and trajectory of the accessory canal.

Results: Bifid mandibular canal was identified in 14.4% of the evaluated CBCT scans. The retromolar canal was the most frequent variant. No marked side predominance was observed. A statistically significant association was found between the left-side Naitoh classification and age group ($p = 0.047$); however, the effect size was weak (Cramér's $V = 0.192$).

Conclusions: Bifid mandibular canal was an uncommon anatomical variation in this Ecuadorian sample. CBCT was useful for identifying mandibular canal variations and may support surgical planning. However, the findings should be interpreted with caution because the study was retrospective and based on CBCT scans from a single radiological center.

Keywords: Bifid mandibular canal, Oral surgery, Prevalence, Association, Epidemiology, Anatomy, CBCT.

1. Introduction

The bifid mandibular canal is considered a rare variation, with an occurrence of less than 1% worldwide (1). However, this figure may vary depending on the population studied, as another study conducted in Turkey reported a prevalence of 22.7% (2). Likewise, research carried out in Bosnia and Herzegovina reported a percentage of 9.2% (3).

Knowledge of the mandibular canal is essential for surgical procedures, as it contains sensitive structures (4). Among these structures are the artery, vein, and inferior alveolar nerve, which usually run together within a single canal (5). Additionally, important anatomical variations have been identified in this structure, such as the bifid mandibular canal (6). These

variations must be recognized and studied by the surgeon to reduce the risk of complications during surgical intervention (7).

These variations can directly influence clinical practice, as the presence of a bifid mandibular canal may lead to undesirable incidents during surgery (8). Among the complications mentioned are failure of inferior alveolar nerve anesthesia, intraoperative hemorrhage, paresthesia, or nerve injury (9). These incidents may occur during procedures such as third molar surgery, implant placement, or orthognathic surgeries (10). Therefore, timely identification is necessary to avoid complications and ensure patient safety (11).

The mandibular canal, which contains structures of the nervous and circulatory systems, begins its course at

the mandibular foramen or inferior dental foramen (12). It then travels downward through the cancellous bone, subsequently adopting a horizontal direction below the alveolar processes, at the level of the first and second molars (13). In turn, it divides into terminal branches such as the incisive branch, which runs beneath the incisors, and the mental branch, which emerges through the mental foramen (7).

Various variations of the mandibular canal have been described in the literature (14). These include bifid canals with retromolar, dental, anterior, or buccolingual pathways, as well as the possible presence of accessory canals (12). These variants may alter the usual location of the neurovascular bundle, increasing surgical risk if not previously identified (15).

Several theories explain the formation of the bifid mandibular canal, highlighting the proposal by Chávez-Lomelí, who suggested that during embryological development the inferior alveolar nerve innervates different dental groups, which later fuse to form a single nerve structure (16). In this context, it has been described that these initially independent nerve branches travel through separate bony pathways (17). However, during mandibular ossification these pathways tend to fuse into a single canal; when this fusion is incomplete, bifid or even multiple mandibular canals may arise (18).

Cone-beam computed tomography (CBCT) is a useful imaging modality for identifying this anatomical variation because it allows multiplanar evaluation of the mandibular canal and its possible accessory branches (14). Thanks to these new imaging techniques, visualization of small anatomical structures has become simpler and more precise, facilitating the detection and study of anatomical variations (19).

CBCT also allows evaluation of the mandibular canal in multiplanar sections, including axial, coronal, and sagittal views, as well as three-dimensional reconstructions (14). Cross-sectional and panoramic views observed at different angulations are useful for identifying bifurcations, anomalous pathways, and the relationship of the canal with dental roots or cortical bone (12).

Based on the above, the present study aimed to determine the prevalence of the bifid mandibular canal using CBCT in the city of Cuenca; additionally, to identify the location of the bifid mandibular canal; determine its prevalence in relation to age; quantify its prevalence by sex; and determine its prevalence in relation to the area of residence.

2. Materials and Methods

This study followed a retrospective, cross-sectional design and was conducted in the city of Cuenca, Ecuador. An a priori sample size calculation was performed using G*Power software. The calculation was based on an alpha level of 0.05, statistical power of 80% ($1 - \beta = 0.80$), and an expected medium effect size of $f = 0.25$. Based on these parameters, a minimum sample of 174 CBCT scans was required.

A total of 174 CBCT scans obtained from an anonymized database corresponding to the period 2022–2025 were included. These were available from a radiological center in Cuenca and belonged to patients aged 18–64 years residing in the city. Only records with basic sociodemographic data such as sex, age group, area of residence, and ethnicity were considered.

CBCT scans presenting motion distortion, radiopaque materials, or excessive noise that hindered visualization of the mandibular canal were excluded, as well as those from patients with a history of mandibular surgery, bone pathologies, craniofacial malformations, or any alteration that modified the natural anatomy of the region. Studies with insufficient technical parameters, inadequate sectioning of the area of interest, or duplicate records were also excluded.

The principal investigator was trained and calibrated by an oral and maxillofacial radiologist with more than five years of experience. Calibration was performed using 15 CBCT scans (Newtom Giano HR, Italy), operating from 9 to 42 mA and 90 kV depending on the patient. All digital images were exported to an HP ENVY x360 laptop and evaluated using NEWTOM VIEWER software. The interobserver Kappa value was 0.86. Fifteen scans were evaluated per day on alternate days. All visualization sessions were conducted in a quiet room with dim ambient lighting. Images were analyzed on a 16-inch high-resolution screen with a resolution of 1920×1080 pixels and 32-bit color depth.

Images were exported and stored as Digital Imaging and Communications in Medicine (DICOM) files and analyzed directly on the monitor. Coronal, sagittal, and transverse images reconstructed from tomography were used to evaluate the mandibular canals and their anatomical variations. These variations were classified according to Naitoh's criteria, based on the origin and course of the accessory canal relative to the main mandibular canal, dividing them into four categories:

- Retromolar canal: terminates in the retromolar region (20).
- Dental canal: terminates in the root region of the second or third molar (20).
- Anterior canal: originates from the superior wall of the mandibular canal, with confluent and independent variations (20).
- Buccal or lingual canal: terminates in either of these walls (20).

2.1 Data Collection and Analysis

Relevant data were collected in an Excel table and later transferred to SPSS version 24.0. Depending on the sample distribution and nature, various descriptive and inferential tests were applied.

This research adhered to ethical guidelines such as the Declaration of Helsinki, the International Guidelines

for Biomedical Research in Humans (CIOMS), and Ecuador's Organic Law on Personal Data Protection. It was approved by the Ethics Committee for the Approval of Degree Work Proposals (CEUHE25-158).

3. Results

A total of 174 CBCT scans corresponding to the period 2022–2025, obtained from a radiological center, were analyzed. No scans were excluded, as all met the established inclusion criteria, thus constituting the entire evaluated sample. Regarding the sample characteristics, it consisted of 103 female and 71 male patients, aged between 18 and 64 years. Of these, 112 were of mestizo ethnicity, 32 indigenous, 20 white, and 10 Afro-Ecuadorian; 163 resided in urban areas and 11 in rural areas. This information can be observed in greater detail in Table 1.

Table 1: Sample distribution

		n	%
Canal bifurcation	Yes	25	14.4%
	No	149	85.6%
Location	Not present	149	85.6%
	Right	12	6.9%
	Left	11	6.3%
	Bilateral	2	1.1%
Naitoh right side	Not present	160	92%
	Retromolar	6	3.4%
	Dental	3	1.7%
	Anterior	0	0%
	Buccolingual	5	2.9%
Naitoh left side	Not present	161	92.5%
	Retromolar	8	4.6%
	Dental	1	0.6%
	Anterior	1	0.6%
	Buccolingual	3	1.7%
Sex	Male	71	40.8%
	Female	103	59.2%
Age group	18-24	46	26.4%
	25-34	29	16.7%
	35-44	24	13.8%
	45-54	20	11.5%
	55-64	55	31.6%
Ethnicity	Mixed	112	64.4%
	Indigenous	32	18.4%
	White	20	11.5%
	Afro-Ecuadorian	10	5.7%
Area of residence	Urban	163	93.7%
	Rural	11	6.3%

To determine the possible association between right-

and left-side bifid mandibular canal variants according

to the Naitoh classification and the independent variables, cross-tabulations were performed for sex, age group, ethnicity, and area of residence. Fisher's exact test was used because it is appropriate for analyzing associations between categorical variables, especially when expected frequencies in most cells are less than 5. Additionally, Cramér's V was applied to assess the strength of association in tables larger than 2×2 .

As shown in Table 1, the overall prevalence of bifid mandibular canal was 14.4%. Regarding location, right-side cases were observed in 6.9% of the sample, left-side

cases in 6.3%, and bilateral cases in 1.1%. The retromolar canal was the most frequent subtype on both sides. The sample was predominantly female, with a higher proportion of participants in the 55-64-year age group, mestizo ethnicity, and urban residence. In males the dental canal type bifurcation was more prevalent, whereas in females, equal percentages were observed between the retromolar and buccolingual canals. Based on Fisher's exact test ($p = 0.183$), no association between variables was found (Table 2).

Table 2: Association between right-side bifid mandibular canal variants according to the Naitoh classification and patient sex

			Naitoh right side			
			Not present	Retromolar	Dental	Buccolingual
Sex	Male	n	65	2	3	1
		%	91.5	2.8	4.2	1.4
	Female	n	95	4	0	4
		%	92.2	3.9	0	3.9
	Total	n	160	6	3	5
		%	92	3.4	1.7	2.9

P-value = 0.18.

The bifid canal was more prevalent in the 25-34 age group, with predominance of the retromolar canal

variant (Table 3). Based on Fisher's exact test ($p = 0.196$), no association between variables was found.

Table 3: Association between right-side bifid mandibular canal variants according to the Naitoh classification and patient age group

			Naitoh right side			
			Not present	Retromolar	Dental	Buccolingual
Age group	18-24	n	44	0	0	2
		%	95.7	0	0	4.3
	25-34	n	24	3	2	0
		%	82.8	10.3	6.9	0
	35-44	n	22	1	0	1
		%	91.7	4.2	0	4.2
	45-54	n	18	1	0	1
		%	90	5	0	5
	55-64	n	52	1	1	1
		%	94.5	1.8	1.8	1.8
	Total	n	160	6	3	5
		%	92	3.4	1.7	2.9

P-value = 0.20.

As depicted in Table 4, in the mestizo group, the retromolar canal was more prevalent, in the indigenous group the buccolingual canal predominated, in the Afro-Ecuadorian group the retromolar canal was more

frequent, while no cases were found in the white group. According to Fisher's exact test ($p = 0.443$), no association between the variables was observed.

Table 4: Association between right-side bifid mandibular canal variants according to the Naitoh classification and patient ethnicity

			Naitoh right side				Total
			Not present	Retromolar	Dental	Buccolingual	
Ethnicity	Mixed	n	103	4	3	2	112
		%	92	3.6	2.7	1.8	64.4
	Indigenous	n	28	1	0	3	32
		%	87.5	3.1	0	9.4	18.4
	White	n	20	0	0	0	20
		%	100	0	0	0	11.5
	Afro-Ecuadorian	n	9	1	0	0	10
		%	90	10	0	0	5.7
	Total	n	160	6	3	5	174
		%	92	3.4	1.7	2.9	100

P-value = 0.44.

Regarding the right-side Naitoh classification, no bifid canals were observed among rural participants, while urban participants presented retromolar, dental, and buccolingual variants. Based on Fisher's exact test ($p = 1$), no association between variables was found

(Table 5). Both males and females showed a higher prevalence of the retromolar canal type bifurcation. Based on Fisher's exact test ($p = 0.448$), no association between variables was found (Table 6).

Table 5: Association between right-side bifid mandibular canal variants according to the Naitoh classification and patient area of residence

			Naitoh right side				Total
			Not present	Retromolar	Dental	Buccolingual	
Area of residence	Urban	n	149	6	3	5	163
		%	91.4	3.7	1.8	3.1	93.7
	Rural	n	11	0	0	0	11
		%	100	0	0	0	6.3
	Total	n	160	6	3	5	174
		%	92	3.4	1.7	2.9	100

P-value = 1.00

Table 6: Association between left-side bifid mandibular canal variants according to the Naitoh classification and patient sex

			Naitoh left side					Total
			Not present	Retromolar	Dental	Anterior	Buccolingual	
Sex	Male	n	67	3	1	0	0	71
		%	94.4	4.2	1.4	0	0	40.8
	Female	n	94	5	0	1	3	103
		%	91.3	4.9	0	1	2.9	59.2
	Total	n	161	8	1	1	3	174
		%	92.5	4.6	0.6	0.6	1.7	100

P-value = 0.45.

According to Table 7, the bifid canal was more prevalent in the 35-44 age group, with predominance of

the retromolar and buccolingual variants. Based on Fisher's exact test ($p = 0.047$) and Cramer's V (0.192),

a statistically significant difference between variables was determined, indicating a statistically significant but

weak association between the left-side Naitoh classification and age group.

Table 7: Association between left-side bifid mandibular canal variants according to the Naitoh classification and patient age group

		Naitoh left side					
		Not present	Retromolar	Dental	Anterior	Buccolingual	Total
Age group	18-24	N	46	0	0	0	46
		%	100	0	0	0	26.4
	25-34	N	27	2	0	0	29
		%	93.1	6.9	0	0	16.7
	35-44	N	19	2	0	2	24
		%	79.2	8.3	0	8.3	13.8
	45-54	N	18	1	1	0	20
		%	90	5	5	0	11.5
	55-64	N	51	3	0	1	55
		%	92.7	5.5	0	1.8	31.6
	Total	N	161	8	1	3	174
		%	92.5	4.6	0.6	1.7	100

P-value = 0.05.

Cramér's V = 0.19.

In both mestizo and indigenous groups, the prevalence was higher for the retromolar canal, in the white group the buccolingual canal predominated, while no cases were found in the Afro-Ecuadorian group. Based on Fisher's exact test ($p = 0.526$), no association between variables was found (Table 8). Two rural

participants presented a left-side retromolar canal (Table 9). However, Fisher's exact test showed no statistically significant association between area of residence and left-side bifid mandibular canal variant according to the Naitoh classification ($p = 0.253$).

Table 8: Association between left-side bifid mandibular canal variants according to the Naitoh classification and patient ethnicity

		Naitoh left side					
		Not present	Retromolar	Dental	Anterior	Buccolingual	Total
Ethnicity	Mixed	n	102	7	1	1	112
		%	91.1	6.3	0.9	0.9	64.4
	Indigenous	n	31	1	0	0	32
		%	96.9	3.1	0	0	18.4
	White	n	18	0	0	2	20
		%	90	0	0	10	11.5
	Afro-Ecuadorian	n	10	0	0	0	10
		%	100	0	0	0	5.7
	Total	n	161	8	1	3	174
		%	92.5	4.6	0.6	1.7	100

P-value = 0.53

Table 9: Association between left-side bifid mandibular canal variants according to the Naitoh classification and patient area of residence

			Naitoh left side				
			Not present	Retromolar	Dental	Anterior	Buccolingual
Area of residence	Urban	n	152	6	1	1	3
		%	93.3	3.7	0.6	0.6	1.8
	Rural	n	9	2	0	0	0
		%	81.8	18.2	0	0	0
	Total	n	161	8	1	1	3
		%	92.5	4.6	0.6	0.6	1.7

P-value = 0.25.

4. Discussion

Although a small percentage of the population presents a bifid anatomical variant of the mandibular canal, its correct identification is important for proper treatment planning, thereby reducing the risk of potential complications and injuries during surgical intervention in clinical practice. For this reason, it is necessary to mention that although this anatomical variant can be observed through panoramic radiographs, the imaging visibility obtained is limited; therefore, CBCT may be considered a useful imaging tool for the evaluation of suspected mandibular canal variations, as it provides multiplanar visualization that can support clinical and surgical planning.

The detected prevalence of the bifid mandibular canal was 14.4% in the 174 CBCT scans reviewed in the present study, similar to that reported in a study conducted in Japan, where a prevalence of 15% was found in 252 CBCT scans (5). However, this differs from another study also carried out in Japan, where a prevalence of 65% was found in 122 CBCT scans (20). This value was considerably higher than that obtained in the present study.

Additionally, in a study published in Spain analyzing 500 CBCT scans, a prevalence of 22.6% for this anatomical condition was reported (21). In contrast, another study conducted in Peru, with a sample of 1497 CBCT scans, reported a prevalence of 10.8% (22). Therefore, it should be emphasized that the prevalence of the bifid mandibular canal can vary considerably between regions, making it necessary to understand the epidemiological context in which the dental professional will perform clinical practice.

Regarding the most prevalent canal type, in the present study it was the retromolar canal, with a rate of 3.4% on the right side and 4.6% on the left. This is

similar to findings reported in Saudi Arabia, where the most prevalent variant was also the retromolar canal, with a rate of 28.5% (23). However, both studies differ from another study conducted in Turkey, where the most prevalent canal type was the dental canal at 36.46% (2). These differences may be attributed to variations in the characteristics of each population, as they correspond to different geographical regions and methodologies used in each study.

The prevalence of the bifid mandibular canal in males was 8.5% on the right side and 5.6% on the left, whereas in females it was 7.8% on the right and 8.7% on the left. This is similar to findings reported in Bosnia and Herzegovina, where the prevalence was 3.5% in males and 5.7% in females (3). However, this contrasts with a Brazilian study, which reported a prevalence of 34.8% in males and 27.1% in females (17). This highlights notable heterogeneity among findings reported in the literature, suggesting that more rigorous future studies may be necessary to clarify the epidemiological and clinical landscape regarding sex-based subcategorization of the prevalence of the bifid mandibular canal.

Regarding the clinical implications of these findings, more recent studies have reinforced the importance of proper identification of the mandibular canal and its variations. According to a study conducted in Guatemala, the proximity of the mandibular canal to the roots of molars and premolars represents a significant risk factor for injury during surgical procedures, especially in patients whose inferior alveolar canal is located very close to the apical regions of the lower teeth (24).

This is consistent with findings reported in Ecuador, where it was noted that the three-dimensional relationship between the mandibular canal and

structures such as third molars constitutes a key indicator of risk for damage to the neurovascular bundle during extractions, reinforcing the need for detailed imaging evaluation prior to treatment (25). Therefore, it can be inferred that these studies support the idea that recognizing the bifid mandibular canal not only has diagnostic value but also represents a determining factor in clinical planning, contributing to risk reduction and improved therapeutic outcomes.

For future studies, it would be advisable to work with larger samples that include populations from different regions, which would allow for a more representative understanding of this anatomical variation. Additionally, the development of prospective studies could help improve control of variables and reduce potential biases. It would also be useful to maintain standardized criteria in CBCT analysis and, where possible, relate imaging findings to clinical aspects such as anesthetic response or surgical complications, in order to provide greater relevance to dental practice.

This study has several limitations. First, the sample was obtained from a single radiological center in Cuenca, which limits the generalizability of the findings to the broader Ecuadorian population. Second, because of the retrospective design, the study was limited to the information available in the CBCT database. Third, imaging findings were not correlated with clinical outcomes such as inferior alveolar nerve anesthesia failure, paresthesia, intraoperative hemorrhage, or

surgical complications. Therefore, although the findings have clinical relevance for surgical planning, direct clinical associations could not be established.

5. Conclusions

In conclusion, the bifid mandibular canal was an uncommon anatomical variation in the studied Ecuadorian sample, with an overall prevalence of 14.4%. The retromolar canal was the most frequent subtype, particularly on the left side, although no marked side predominance was observed overall. Most variables analyzed were not significantly associated with the presence or type of bifid mandibular canal. A statistically significant association was observed between age group and the left-side Naitoh classification; however, the magnitude of this association was weak. These findings should be interpreted with caution due to the retrospective design, sample size, and the use of CBCT scans from a single radiological center.

Conflict of Interests

The authors declare that they have no conflicts of interest related to this study.

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