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Cone-beam Computed Tomography Study of the Root Canal Morphology of Lower Incisors

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Abstract

Introduction: The present study aims to evaluate the root canal morphology of permanent lower incisors by cone-beam computed tomography (CBCT) according to Vertucci's classification (1984), and to correlate the findings with sex, age group, and side of the dental arch. **Materials and Methods:** This was a descriptive observational study that used a sample of mandibular CBCT scans performed between 2021 and 2024 at a private dental radiology service. When none of the Vertucci configurations was applicable, type 0 was assigned. **Results:** Type I was the predominant morphological configuration, followed by type III, for all variables analyzed. Regarding sex, type I was more common among females (71.1%), while type III accounted for 21.2% in both males and females. With respect to age, type I was more common among minors (76.8%), and type III among older adults (23.3%). The type I configuration was more frequently observed on the right side of the dental arch (70.3%), and type III on the left side (21.9%). **Conclusion:** The anatomical observations of the lower incisors highlight the need for careful analysis of their internal morphology during endodontic treatment.

Keywords: Anatomy; Cone-beam Computed Tomography; Endodontics; Root Canal

Introduction

The aim of endodontic treatment is to promote cleaning, disinfection, and three-dimensional filling of the root canal system following mechanical and biological principles[1]. Knowledge of root canal morphology and its most frequent variations is extremely important since it will enable successful endodontic treatment, providing curing the disease and preventing reinfection [2].

Despite major advances in the field of root canal treatment in contemporary endodontics, including the use of rotary instruments and more effective filling systems, the internal anatomy of teeth continues to be a critical factor for the success of endodontic treatment. The anatomical variability of root canals such as the presence of accessory canals and a complex root shape has a considerable impact on the treatment process. Thus, despite advances in instrumentation and methodology, professionals must continue to focus on understanding the complexity of tooth anatomy and how it affects the effectiveness of care [3].

The internal morphology of mandibular central incisors can vary significantly, from a single canal to lingual and accessory canals, and knowledge of this is crucial for endodontic treatment planning. Furthermore, the persistence of microorganisms in the root canals, the lack of more advanced resources can often lead to endodontic treatment failure. Therefore, good planning and execution are necessary for successful endodontic treatment [4, 5].

Periapical radiography is the imaging method routinely used to assess the internal morphology of root canals. However, a limitation of this method is that it provides only two-dimensional images of all structures, impairing the diagnosis of some canals that cannot be identified using this technique. A practical example is the lower incisor. This tooth can possess two canals in the buccolingual direction, which are not identified by conventional radiography. One alternative to overcome these limitations is cone-beam computed tomography (CBCT), which provides three-dimensional images with minimal distortion. This technique is extremely useful for localizing and intensifying root canals, permitting the identification of variations in internal anatomy [6].

In view of the above considerations, the present study aims to evaluate the root canal morphology of permanent lower incisors by CBCT according to Vertucci's classification [7], and to correlate the morphology with sex, age group, and side of the dental arch.

Materials and Methods

Ethical aspects

The study was approved by the Ethics Committee of Centro Universitário FIS (UNIFIS) (Opinion number 6.776.530) and was conducted in accordance with the ethical guidelines of Resolution 510/16 of the National Health Council.

Study design and sample selection

This observational descriptive study used data from the image database of a private dental radiology service in Serra Talhada, Pernambuco, Brazil.

The sample consisted of CBCT scans, performed for various reasons, of patients seen for maxillary or mandibular imaging exams between July 2021 and June 2024. For analysis, permanent lower incisors were selected according to previously established eligibility criteria.

Cone-beam computed tomography

Images were acquired with a Carestream CS81003D, set at 90 kVp and 10 mA, with an exposure time of approximately 10 seconds, in a single 360° rotation. The 14-bit CMOS detector captured a 5×5 cm volume, reconstructed with a 75 µm cubic voxel. The tube focal spot was 0.5 mm.

For the acquisition of CBCT images, the patient was placed in the device so that the occlusal plane remained parallel to the ground, following the protocol recommended by the manufacturer. After initial acquisition, the images appear on the computer screen within a few sec and are stored in .xstd format (Xoran extension) for later evaluation.

Inclusion and exclusion criteria

Inclusion criteria

Examinations of patients who exhibited lower incisors in the examinations performed to evaluate the mandible were included.

Exclusion criteria

Endodontically treated teeth, teeth with extensive caries, incomplete root formation, implants, root remnants, and fused roots, missing teeth, deciduous teeth, and teeth with imaging artifacts were excluded from the mandibular evaluation exams. Exams without diagnostic quality, mandibular exams in which all lower incisors were compromised by any of the above criteria, and exams with an insufficient field of view (*i.e.*, exams showing only the maxilla, given that the images were acquired from a radiology clinic database) were excluded.

Exams that presented imaging artifacts in the lower incisor region were excluded from the sample, as these compromised adequate visualization of root morphology. Imaging artifacts were defined as distortions or errors in the reconstructed data that do not correspond to the actual anatomical structures. These artifacts may be caused by patient movement, acquisition system limitations, and, most importantly, the presence of high-density materials, such as metal structures. It was decided not to apply artifact reduction algorithms in order to maintain the standardization of the acquisition protocol and avoid interference with the morphological parameters analyzed. The exclusion of these cases aimed to ensure the accuracy and reliability of the data obtained.

Sample calculation

The sample size calculation was performed with the aim of estimating the prevalence of root canal anatomical configurations in the studied population. The statistical formula for estimating proportions in infinite populations was used.

$$n = \frac{z^2 \cdot p \cdot (1-p)}{d^2}$$

The parameters adopted included a 95% confidence level (z=1.96) and an absolute margin of error of 5% (d=0.05). The expected prevalence of the outcome (p) was based on previous data from the results, which indicated a frequency of approximately 70% for the Vertucci Type I configuration, the most prevalent morphology, and therefore requiring a larger sample size for statistical accuracy. The calculation determined a minimum need for 323 roots.

Calibration

The tomographic images were evaluated by an examiner previously trained and calibrated in performing the proposed CBCT assessment. Calibration consisted of evaluating the tomographic images of 20 upper incisors selected according to the pre-established inclusion and exclusion criteria under the same conditions of visualization. Maxillary teeth were chosen to avoid reducing the number of teeth for morphological analysis since the tomographic scans used during this stage are not part of the final sample of the present study.

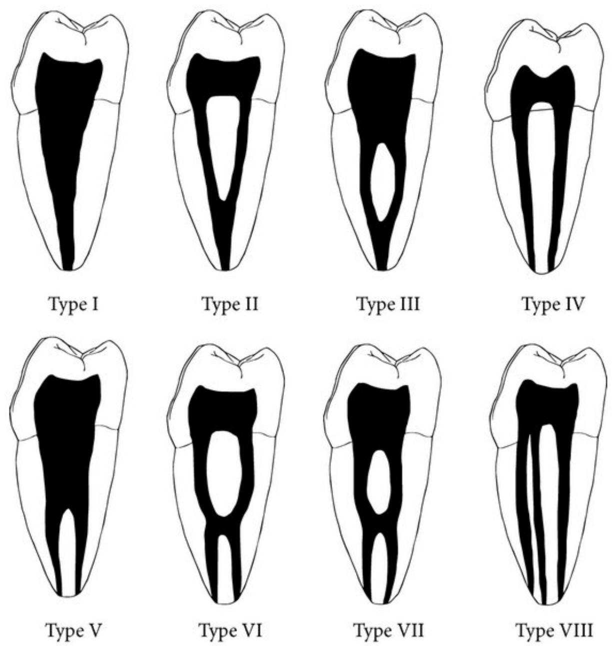

Figure 1. Vertucci classification [7]
Source: Vertucci FJ. Vertucci classification of root canal morphology. [image]. Anatomy Research International. Available at: https://www.researchgate.net/figure/Vertuccis-classification-of-root-canal-morphology-6_fig1_281635285

The teeth evaluated during this stage were reassessed after one week to determine intra-examiner agreement in the morphological types attributed to the root canals according to Vertucci's classification. The data obtained were entered into an Excel spreadsheet (Microsoft Corporation, Redmond, Washington, USA) and subsequently transferred to the Statistical Package for the Social Sciences (SPSS, Version 20, IBM, Armonk, NY, USA) for the determination of intra-examiner agreement using Cohen's kappa test. The intraexaminer kappa agreement was 0.827, classified as "almost perfect".

Evaluation of tomographic images

The root canal morphology of the selected incisors was evaluated in a dark and silent environment with the aid of a 15.6" notebook using the CS 3D Imaging program. Coronal, axial, and sagittal sections were used for evaluation of the root canals in the interface of the program used.

Before evaluation, the images were processed using the same filter (sharpness, brightness, and contrast) to permit better visualization and standardization of the reconstructions. In the window of the axial sections, the examiner determined the section where the long axis of the lower incisor had the largest diameter, which was visualized along its long axis (locator cut). Using the locator cut, the examiner determined the central sagittal section. Using this window of sections, the volume was rotated to align the long axis of the tooth with the vertical plane. The examiner then evaluated the morphology of the canals in the sagittal, coronal, and axial sections and classified them based on Vertucci's classification [7] (Fig. 1), which is the most commonly used system. In cases where the observed morphology did not correspond to any of the types described in Vertucci's classification, the designation "Type 0" was assigned, used only as descriptive convenience for analytical purposes, without representing an extension or modification of the original classification.

Data analysis

For statistical analysis, the data of the tomographic scans were entered into an Excel spreadsheet (Microsoft Corporation, Redmond, Washington, USA) that included patient age and sex, tooth, and type of internal morphological configuration of the root canals according to Vertucci's classification. The data were then exported to SPSS (version 18) for data analysis.

To assess the distribution of patient characteristics, percent frequencies were calculated, and frequency distributions were constructed. For comparison of the distribution of Vertucci configurations between patient profiles, a contingency table was constructed, and the chi-square test for homogeneity was applied. In cases in which the assumptions of the chi-square test were not met, Fisher's exact test was applied. All conclusions were drawn at the 5% significance level.

Results

Among 550 tomographic scans performed for various reasons, 212 scans were excluded (Table 1), remaining 338 scans for evaluation.

A total of 1,138 teeth were evaluated, and 138 were excluded (Table 1). Thus, the sample consisted of 1,000 teeth (497 central incisors and 503 lateral incisors). Most teeth were from female patients (n=608), adults (n=828), and the right side of the dental arch (n=502).

Table 2 presents the distribution of Vertucci root canal configurations according to sex, age group, and dental arch. A higher prevalence of type I was observed in both males and females (68.4% and 71.1%, respectively), followed by type III (21.2% in both groups) (Table 2). The homogeneity test did not show statistical significance (P=0.585), indicating that there was no significant association between the patient's sex and the distribution of Vertucci configurations.

Table 1. Lower incisors and examinations excluded from the sample

Scans excluded from the sample	***n***
Insufficient field of view	189
Presence of at least one of the exclusion criteria attributed to all lower incisors	18
Poor image quality for diagnostic purposes	0 5
Total	0 212
Exclusion criteria for lower incisors excluded from	n
the sample	14
Endodontic treatment	5
Extensive caries	2
Incomplete root formation	7
Implant	4
Root remnant	0
Fused roots	81
Missing	0
Deciduous incisors	25
Imaging artifact	138

Table 2. Distribution of Vertucci's root canal configurations according to sex, age group, and side dental arch

Classification Vertucci	**Sex**		**Age range**			**Side of dental arch**	
	Male	**Female**	**Underage (Up to 17)**	**Adult (18-59)**	**Elderly (60+)**	**Right**	**Left**
	(*n*=392)	**(*n*=608)**	**(*n*=43)**	**(*n*=828)**	**(*n*=129)**	**(*n*=498)**	**(*n*=502)**
Type 0	0 (0.0%) [-]	1 (0,2%) [0.0-0,5]	0 (0.0%) [-]	1 (0.1%) [0,0-0,3]	0 (0.0%) [-]	0 (0.0%) [-]	1 (0,2%) [0.0-0,6]
Type I	268 (68.4%) [63.8-73.0]	432 (71.1%) [67,5-74,7]	33 (76.8%) [64.2-89.4]	585 (70.7%) [67.6-73.8]	82 (63.6%) [55.3-71.9]	350 (70.3%) [66.3-74.3]	350 (69,7%) [65,7-73,7]
Type II	37 (9,4%) [6.5-12.3]	41 (6,7%) [4.7-8.7]	1 (2.3%) [0.0-6.8]	62 (7.5%) [5.7-9.3]	15 (11.5%) [6.0-1.,0]	41(8,2%) [5.8-10.6]	37 (7.4%) [5.1-9.7]
Type III	83 (21.2%) [17.2-25.2]	129 (21.2%) [18.0-24.4]	9 (20.9%) [8.8-33.0]	173 (20.9%) [18.1-23.7]	30 (23.3%) [16.0-30.6]	102 (20.5%) [17.0-24.0]	110 (21.9%) [18.3-25.5]
Type IV	1 (0.3%) [0.0-0.8]	2 (0.3%) [0.0-0.7]	0 (0.0%) [-]	2 (0.2%) [0.0-0.5]	1 (0.8%) [0.0-2.3]	1 (0.2%) [0.0-0.6]	2 (0.4%) [0.0-1.0]
Type V	2 (0.4%) [0.0-1.2]	3 (0.5%) [0.0-1.1]	0 (0.0%) [-]	4 (0.5%) [0.0-1,0]	1 (0.8%) [0.0-2.3]	3 (0.6%) [0,0-1,3]	2 (0.4%) [0.0-1.0]
Type VI	1 (0.3%) [0,0-0,8]	0 (0.0%) [-]	0 (0.0%) [-]	1 (0.1%) [0.0-0.3]	0 (0.0%) [-]	1 (0.2%) [0.0-0.6]	0 (0.0%) [-]
Type VII	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]
Type VIII	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]	0 (0.0%) [-]
***P*-value**	0.585[1]		0.497[1]			0.901[1]	

[1]P-value of Fisher's Exact test, [-] There is no confidence interval, as the prevalence was zero

Table 3. Adjusting the logistic model for a worse ranking

Factor evaluated	**Classification**		**Logistics model parameters**		
	Clinically worse (type III or higher)	**Clinically better (types 0, 1, 2)**	**OR_{adjust}**	**IC(95%)**	***P*-value**
Sex					
Male	87 (22.2%)	305 (77.8%)	0.98	0.72 – 1.33	0.883[2]
Female	134 (22.0%)	474 (78.0%)	1.00	-	-
***P*-value**	0.954[1]				
Age range					
Under 18 years old	9 (20.9%)	34 (79.1%)	1.25	0.54 – 2.88	0.599[2]
18 to 59 years old	180 (21.7%)	648 (78.3%)	1.19	0.77 – 1.84	0.429[2]
60 years or older	32 (24.8%)	97 (75.2%)	1.00	-	-
***P*-value**	0.724[1]				
Arcade					
Right	107 (21.5%)	391 (78.5%)	1.08	0.80 – 1.45	0.638[2]
Left	114 (22.7%)	388 (77.3%)	1.00	-	-
***P*-value**	0.641[1]				

Regarding age group (Table 2), there was a higher prevalence of type I in the groups of minors, adults, and elderly (76.8%, 70.7%, and 63.6%, respectively), followed by type III (20.9% among minors and adults and 23.3% among the elderly). The homogeneity test was not significant (*P*=0.497), suggesting that age did not significantly influence the Vertucci classification in the sample evaluated.

Regarding the dental arch, the teeth of both arches (right and left) exhibited a higher prevalence of Vertucci type I (70.3% and 69.7%, respectively) (Table 2), followed by type III (20.5% on the right and 21.9% on the left). The homogeneity test showed no significance (*P*=0.901), indicating no statistical difference in the distribution of Vertucci configurations between the arches.

The analysis of 95% confidence intervals (95% CI) for the Vertucci classification corroborates the findings of the hypothesis tests, showing the absence of statistically significant differences between the groups evaluated. When examining the sex factor, an extensive overlap was observed between the male and female confidence intervals, especially in the most prevalent configuration, Type I. The interval estimated for males [63.8%-73.0%] contains a large part of the interval observed for females [67.5%-74.7%], indicating that the root anatomy did not present a significant difference between the sexes of this population, a pattern that was repeated for the Type II and III configurations.

Regarding the age range, the precision of the estimates varied depending on the sample size of each subgroup. However, the confidence intervals between adults and the elderly intersected in all classifications, confirming that the observed variations did not reach statistical significance.

The confidence intervals for the right and left sides were virtually identical for most of Vertucci's classifications. Specifically for Type I, the overlap of the intervals was almost total, with limits ranging between [66.3%-74.3%] for the right side and [65.7%-73.7%] for the left, reinforcing the anatomical consistency between the sides. For the more complex classifications (Types IV to VIII), the intervals remained close to zero in all groups, confirming the low prevalence of these morphologies in the studied sample.

To investigate the simultaneous influence of independent variables on anatomical complexity, a binary logistic regression model was fitted, defining the outcome as the presence of configurations classified as "clinically worse" (Vertucci Type III or higher) compared to "clinically better" (Types 0, I, and II). Multivariate analysis revealed that none of the evaluated factors acted as a significant predictor for the occurrence of more complex root morphologies, since all *P*-values remained above the significance level of 5%. Regarding sex, the Adjusted Odds Ratio (OR=0.98) and its respective 95% confidence interval [0.72-1.33] indicated that there was no statistical association between the patient's gender and the risk of presenting complex anatomy. A similar pattern was observed for the age range, where, taking the elderly as a reference, neither those under 18 years of age (OR=1.25; 95% CI: 0.54-2.88), nor adults (OR=1.19; 95% CI: 0.77-1.84) showed significantly increased odds of presenting higher Vertucci classifications. Finally, the location in the dental arch also did not influence the outcome, with the right arch presenting a statistically indistinguishable risk from the left (OR=1.08; 95% CI: 0.800-1.45), confirming the independence between the demographic variables evaluated and the complexity of the internal anatomy in this population (Table 3).

Discussion

The results of the present study widely corroborate literature findings regarding the root anatomy of lower incisors, especially the predominance of Vertucci type I. The majority of the 1.000 teeth evaluated had a single root canal, with a significant prevalence of type I (70.1%), followed by type III (21.2%). This distribution was consistent across sexes, age groups, and dental arches as demonstrated by the lack of statistical significance in the homogeneity tests.

Wessel [8] reported similar results in his study with mandibular incisors, with a predominance of type I root canal configuration in the central (77.32%) and lateral (72.52%) incisors. However, the author also found considerable variations in types II and III, especially in the lateral incisors (27.48%), reinforcing the possible occurrence of two canals. The present study showed a similar distribution of types I and III in both sexes. Furthermore, it is worth noting that the homogeneity test was not significant (*P*=0.497), indicating that there was no statistically significant difference between age groups.

However, a considerable percentage variation was observed between the groups, with a higher frequency of type I among younger individuals (76.8%) compared to older individuals (63.6%). Although this difference did not reach statistical significance, it may represent a clinically relevant trend that deserves attention and investigation in studies with greater sample power. It is worth noting that although the difference in anatomical configuration between age groups did not reach statistical significance, this trend may have a biological basis. Age-related changes in the dentin-pulp complex include the progressive deposition of secondary and tertiary dentin, calcification of the canal walls, and narrowing of the canal lumen. These processes are part of aging and the natural remodeling of dental tissues and can lead to increased morphological complexity or partial obliteration of accessory canals, which can alter the apparent canal configuration observed in imaging exams [9].

Wessel [8] highlighted a greater anatomical asymmetry of the lateral incisors in men, which was not found in a statistically significant manner in our study, possibly because of the larger sample size or the methodology used (volumetric tomography versus direct morphological techniques).

Using diaphanization techniques, Vieira *et al.* [10] identified type I in 64.6% of lower incisors, a rate similar to that found in the present study. Furthermore, the authors observed more complex anatomies such as types III (24%), V (8.3%), and II (2.1%). In contrast, our sample exhibited less anatomical diversity, with type III being the second most prevalent configuration (21.2%) and types V and VII being absent. This divergence might be related to methodological differences and to the sensitivity of the techniques used, since diaphanization permits greater visualization of subtle variations in root morphology, whereas tomography, although highly effective, may not identify very thin or accessory canals.

It is noteworthy that the 21.2% prevalence of Vertucci type III found in the present study has relevant clinical implications, since the second canal may not be detected on conventional radiographic examinations or during initial endodontic access, especially if it is partially obliterated or located lingually. Failure to adequately identify and instrument the second canal can compromise complete debridement of the canal system, increasing the risk of treatment failure. Therefore, the findings of this study reinforce the importance of a careful approach to three-dimensional evaluation and careful exploration of the interior of the pulp chamber, even in teeth with apparently simple anatomy. Strategies such as the use of magnification (magnifying glass or microscope), compensatory grinding with an endo-Z bur or ultrasonic endodontic inserts to remove the lingual shoulder, and manual exploration with K-type #06, #08, or #10 instruments should also be considered to minimize the chance of treatment failure. Furthermore, it is essential to employ irrigation activation techniques (ultrasonic or sonic) to adequately reach both portions of the canal system, especially in the confluence region, and increase disinfection of the root canal system.

The findings of Duque [11] also reinforce the variability of anatomical types. In that study, all methods evaluated revealed a predominance of type I; however, the detection of additional canals decreased with increasing sensitivity of the technique (82% for radiography and 74.1% for diaphanization). These findings agree with our data regarding the predominance of type I; however, underestimation of complex anatomies must be considered when exclusively using tomographic examinations.

Giovanaz [12] identified 52.12% of teeth with type I configuration and 20% with type III, in addition to 6.66% of anatomical configurations that did not fit within the Vertucci categories. Although we did not identify these atypical variations, the similar distribution of types I and III reinforces the reliability of the findings. The absence of non-Vertucci categories in our sample may be attributed to the exclusion of teeth with incomplete images or artifacts, which could have excluded cases of unusual anatomy.

Leoni *et al.* [13] also demonstrated a high prevalence of the type I configuration in central (76.67%) and lateral (73.26%) incisors, as well as the relevance of type III. A similar pattern was observed in our study, with a high prevalence of type in all age groups and arches. However, our study addresses additional variables such as age and laterality, with statistical tests showing that these characteristics did not significantly influence anatomical distribution.

Alvarez and Albergaria [14] identified 83% of incisors with a single canal and 17% with additional canals. The type I configuration was the most common, followed by types II, III, IV, and V. Similarly, our study found a higher frequency of type I, followed by type III; the other types were absent, or their frequency was very low. The lower prevalence of more complex types may be attributed to population differences or even limitations in detecting these variations in imaging examinations, despite the high resolution of tomography.

In summary, the results obtained in this study confirm the high prevalence of the type I configuration in lower incisors reported in the national and international literature. The constancy of this pattern highlights the importance of prior anatomical knowledge for the success of endodontic treatment since type I tends to be more predictable and technically accessible. Furthermore, by providing data specifically from individuals in Northeast Brazil, this study adds valuable regional evidence to the literature. Considering that anatomical variations can be influenced by ethnic and geographic factors, the present findings contribute to filling a gap in current knowledge and may assist in more precise clinical and imaging planning for patients in this population.

It is important to practice that, the expressive prevalence of the type III configuration (21.2%) reinforces the need for attention on the part of dentists, especially regarding the possibility of additional canals not identified in conventional clinical examinations. Within this context, CBCT is a valuable tool for identifying anatomical variations and for accurate treatment planning. However, it is worth noting that the higher prevalence of type I (70.1%) observed in this study may be related to the intrinsic resolution limitation of CBCT compared to methods such as micro-computed tomography (micro-CT) and diaphanization. The voxel size used in this study (75 µm) provides adequate resolution for clinical endodontic evaluation; however, it is considerably larger than the voxel size typically used in micro-CT (10–20 µm). This difference in spatial resolution may hinder the visualization of fine anatomic details, such as narrow accessory canals, apical deltas, or isthmuses, leading to an underestimation of root canal complexity and a relative overrepresentation of simpler configurations such as Vertucci type I. These more sensitive techniques detect subtle morphological variations with greater accuracy, which may explain the lower frequencies of type I reported by Giovanaz *et al.* [12] and Vieira *et al.* [10].

The present findings highlight the clinical importance of using CBCT as a complementary diagnostic tool in endodontic practice, especially in cases where conventional radiographs do not clearly reveal the complexity of the root canal. Three-dimensional evaluation allows clinicians to better anticipate anatomical variations, plan conservative yet complete access cavities, and avoid procedural errors such as undetected canals or inadequate instrumentation. Furthermore, identifying potential secondary canals before treatment can improve the quality of instrumentation and obturation, ultimately increasing treatment success rates and long-term tooth preservation. Therefore, CBCT evaluation should be considered valuable, especially in teeth with suspected complex anatomy or in retreatment cases where previous failure may be related to undetected canals [15].

This study presents some limitations that should be considered. Because it was a retrospective analysis using a convenience sample from a single private imaging center, no a priori sample size calculation was performed. The number of cases was determined by the availability of CBCT scans that met the inclusion criteria. Therefore, the external validity of the findings may be limited, and caution is advised when generalizing these results to other populations with different demographic or ethnic characteristics.

Other issuesis the lack of detailed demographic information, such as ethnicity or geographic background. These data were not available in the CBCT records retrieved from the radiology service, as the scans were anonymized and used exclusively for image-based analysis. Although this limits the ability to explore possible associations between root canal morphology and demographic factors, the approach ensured ethical compliance and patient confidentiality. Another limitation is that central and lateral mandibular incisors were analyzed together. Although some studies have suggested that lateral incisors may present greater morphological variability, both tooth types share similar anatomical features and are frequently evaluated jointly in population-based studies. The present investigation aimed to describe the overall internal morphology pattern of mandibular incisors rather than to compare specific tooth types. Nevertheless, future studies with larger and stratified samples are encouraged to further explore potential differences between central and lateral incisors.

Furthermore, although widely accepted, the Vertucci classification does not include certain morphological variations, such as fins, isthmuses, and C-shaped canals, which can be visualized by CBCT, which may limit the complete representation of root anatomy [16-18]. Future studies may benefit from the use of more recent or complementary classifications capable of more comprehensively describing these variations detectable by advanced imaging methods. Likewise, it is recommended that future research include a validation subsample, using micro-CT or clearing techniques, in order to quantify the degree of underdetection and improve the accuracy of findings obtained by CBCT. This type of study would help consolidate more precise imaging protocols for the three-dimensional analysis of the root canal system. Finally, it should be noted that the available literature specifically addressing the internal morphology of mandibular incisors is limited. As a result, some of the references used in this study include academic theses and non–peer-reviewed sources. Although these works provide valuable descriptive data, their inclusion may reduce the overall strength of the evidence base. This limitation reflects the current scarcity of peer-reviewed publications on the topic and underscores the need for further studies with broader and more standardized methodologies.

Conclusion

The anatomical variations identified in lower incisors highlight the need for a careful and individualized endodontic approach based on the thorough analysis of root canal morphology. Although often considered to have a simple anatomy, lower incisors can exhibit complex internal configurations that must not be neglected, irrespective of sex, age group, or side of the dental arch where the tooth is located.

Recognizing these variations is essential for effective endodontic treatment planning and execution, enabling complete instrumentation and disinfection of the root canals.

Therefore, detailed anatomical assessment not only increases the chances of clinical success but also contributes to the preservation of long-term oral health.

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Conflict of interest

None.

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Authors' contributions

Conceptualization: KFSP; Methodology: NMDO/IFPJ/DMAS; Formal Analysis and Investigation: NMDO; Writing-Original Draft Preparation: WTN/JMIM/GPG/CNPS/VGBF/VGBF; Writing-Review and Editing: LFSE/AMSPG/KDAC A/BLCT.; Supervision: WTN/JMIM/GPG. All authors read and approved the final manuscript.

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