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ORIGINAL ARTICLE

# Root canal anatomy of mandibular incisors with Vertucci's type III configuration: a micro-CT evaluation


## ABSTRACT

***Aim:*** *To evaluate the root canal anatomy of mandibular incisors with Vertucci's type III configuration.*
***Methodology:*** *Forty mandibular incisors were scanned using a micro-CT to measure canal and dentin volume, bifurcation and merging levels, minor and major diameters, long-short diameter ratio, dentin thickness, degree of curvatures and number of foramens.*
***Results:*** *The apical third showed lower volume of canal and dentin. The bifurcation with the formation of buccal and lingual canals presented a mean of 3.75 mm extension. The cement-enamel junction, bifurcation and merging levels showed major diameter (P < 0.05). The round shaped canals were found in buccal (67.5%), lingual (85%) and apical sections (55%). In apical section dentin thickness ranged from 1.02 mm to 0.52 mm. No specimen showed root curvature and 82.5% of mandibular incisors presented single apical foramen.*
***Conclusion:*** *The morphologic aspects of root canal bifurcation and merging in mandibular incisors Vertucci's type III do not present a consistent pattern.*



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## Introduction

The knowledge of the root canal anatomy configuration is fundamental for the diagnosis and execution of endodontic therapy. As important as knowing the most prevalent anatomy types is the ability to diagnose the possible variations, which can be quite complex, therefore, more difficult to the dentist than the periapical radiography suggests (1). Frequently root canals show a complex anatomic configuration with variations that can be related to the curvature, cross section shape, additional canals, fins, deltas, intercanal connections and accessory canals (2-6). The pattern of a single root canal with a continuous taper, roundness and a single apical foramen is the exception rather than the frequent condition (2, 4). So, the various pathways of canals along the root should be considered and during endodontic preparation the original characteristics of the root canals should be preserved as much as possible (7).

A single root and a single canal have been described as the more usual configuration of mandibular incisors (4-6, 8-11), thus the presence of oval, long oval, and ribbon-shaped canals are very common (2). But the prevalence of two canals should be also considered because canals may divide and rejoin, especially due a bifurcation that occur mainly in the middle third of root. According several authors, the Vertucci type III is the most common anatomical variation found in this type of teeth (4-6, 11-16). In this root canal variation, a single canal splits at the middle root third creating a buccal and a lingual canal. These two canals usually join at the apical third and end in a single foramen (6, 12, 16, 17).

In order achieve the goal of endodontic treatment and to reduce the bacterial load, the morphological characteristics of this dental group should be described in depth. To date, there is limited information about the anatomical parameters of type III mandibular incisors including apical diameters and root thickness. This information can provide anatomical parameters and no micro-CT study showing detailed description of the extension and diameters of bifurcations that may occur at different root levels. Thus, the aim of this study was to evaluate the root canal anatomy of mandibular incisors with Vertucci's type III configuration using the Micro-CT as the analytic tool to measure canal and dentin volume, bifurcation and merging levels, minor and major diameters, long-short diameter ratio, dentin thickness, degree of curvatures and number of foramens.

## Methodology

After the approval of this research project by the local ethics committee (protocol 1.051.377) one hundred and eighty extracted human mandibular central and lateral incisors without previous endodontic treatment, root fracture, root resorption, calcification and complete rhizogenesis, extracted for reasons not related to this study from a Brazilian subpopulation were collected in the Human Teeth Bank of the Federal University of Paraná. The teeth were stored in 10% buffered formalin solution for up to a year. The gender and age were unknown. Digital images (Kodak RVG 500, Eastman Kodak, Rochester, NY, USA) were taken in mesio-distal direction and fifty-seven teeth showing a single canal in the coronal third that divides into two canals and merging into a single canal at apical third were selected for this study.

The samples were scanned using a Skyscan 1174 micro-CT (Bruker-microCT, Kontich, Belgium) to confirm the presence of the anatomical configuration of interest. The parameters used were 50kV, 800µA, 0.7 step size rotation and 16.8µm voxel resolution. The digital data were further elaborated by reconstruction software NRecon v1.6.4.8 (Bruker). From the reconstruction of the three-dimensional models referring to the root canals of the mandibular incisors, by using CTAn v.1.12 and CTVol v.2.2.1 (Bruker-micro CT), morphologic evaluations were made to confirm the Vertucci's type III configuration (11). After the micro-CT diagnosis, 17 teeth were discarded because not present the anatomical configuration Vertucci's type

III, and the final sample was comprised of 40 mandibular incisors.
The CTAn software was used to evaluate the canal and dentine volume, the data was expressed in $mm^3$ in four segments (0-1 $mm^3$, 1-4 $mm^3$, 4-7 $mm^3$ e 7-10 $mm^3$). For the two-dimensional analysis, the CTAn and DataViewer (Bruker-microCT) software's were used to evaluate the root length, root canal bifurcation, merging levels and its extension.
In addition, the minor and major diameters and long-short diameter ratio[2] were measured at the cement-enamel junction level, bifurcation level, middle sections of buccal and lingual canals, merging level and at 1mm below the root apex. The buccal, lingual, mesial and distal dentin thickness in the middle sections of the buccal and lingual canals were also measured. The degree of the root canal curvatures and number of apical foramens were also included in the analysis.

*Statistical Analysis*
The volumetric and diameter data were analyzed statistically with the D'Agostino and Pearson tests for verification of normality. The comparison between the segments was performed with the Kruskal-Wallis and Dunn's tests for multiple comparisons ($P<0.05$). The statistical analysis was carried out with the GraphPad Prism 8 (La Jolla, CA, U.S).

## Results

Considering the volume of root canal and dentin, the apical root segment showed less volume ($P<0.05$), There was no statistically significant difference between the evaluated segments of 4-7mm and 7-10mm just for root canal volume. Table 1 shows the data of root canal and dentin volume in the different thirds.
The root length showed a mean of 12.51mm and the canal bifurcation and merging point varied. Representative images of these variations are shown in Figure 1.
The area of the root where a buccal and a lingual canal could be found presented an extension of 3.75mm (±1.61 mm), ranging from 1.16 mm to 6.76 mm. The bifurcation and merging point values taking the apex as the reference were 9.92 mm (±2.03 mm) and 6.08mm (± 1.71 mm), respectively.
The median of the root canal buccolingual diameter at the cementoenamel junction was similar ($P > 0.05$) to the bifurcation level (1.74 mm). This diameter significantly decreases in both buccal and lingual canals to 0.48mm (0.33-0.63) and 0.38 mm (0.32-0.50). These values increased ($P<0.05$) at the merging level (1.61mm) and decrease significantly ($P<0.05$) towards the apex. The average diameter at this level (1 mm) were 0.35mm (0.20–0.71 mm).
The cement-enamel junction showed the largest diameter in mesiodistal direction with 0.44mm and gradually decreased in the following sections until the lower diameter ($P<0.05$) with 0.17 mm at 1 mm below apex section. The major and minor diameters are presented in table 2.
Regarding the transversal cross-section of the canals, the measurement of the major and minor diameter ratios showed long oval-shape at levels that had a single canal, except for the apical millimeter, which had a round shape in 55% of the sample. In

**Table 1**

**Median and 25% and 75% percentile of volume ($mm^3$) of root canal and dentin volume at different evaluated levels**

| | 0-1 mm | 1-4 mm | 4-7 mm | 7-10 mm |
|---|---|---|---|---|
| **Canal** | $0.05^a$ (0.03-0.06) | $0.26^b$ (0.17-0.37) | $0.57^c$ (0.43-0.77) | $0.95^c$ (0.66-1.28) |
| **Dentin** | $1.13^a$ (0.92-1.44) | $15.65^b$ (13.17-17.97) | $31.84^c$ (27.87-33.52) | $43.66^d$ (39.63-47.90) |

**Different superscript letters at each line indicate significant difference (P<0.05).*

**Table 2**

**Median, 25% and 75% percentiles of buccolingual and mesiodistal diameters (mm) evaluated at cement-enamel junction (CEJ) level, bifurcation, middle sections of vestibular and lingual canals, merging and 1mm below the apical apex**

| | Buccolingual | Mesiodistal |
|---|---|---|
| **CEJ** | 1.54[a] (1.21-1.78) | 0.44[a] (0.37-0.58) |
| **Bifurcation** | 1.74[a] (1.38-2.10) | 0.32[ab] (0.27-038) |
| **Mid. Buccal canal** | 0.48[b] (0.33-0.63) | 0.26[bc] (0.21-0.31) |
| **Mid. Lingual canal** | 0.38[b] (0.32-0.50) | 0.26[bc] (0.23-0.31) |
| **Merging** | 1.61[a] (1.45-1.93) | 0.22[c] (0.17-0.29) |
| **1 mm apical** | 0.35[b] (0.27-0.43) | 0.17[d] (0.13-0.21) |

*Different superscript lowercase letters in each column indicate statistical differences (P<0.05).*

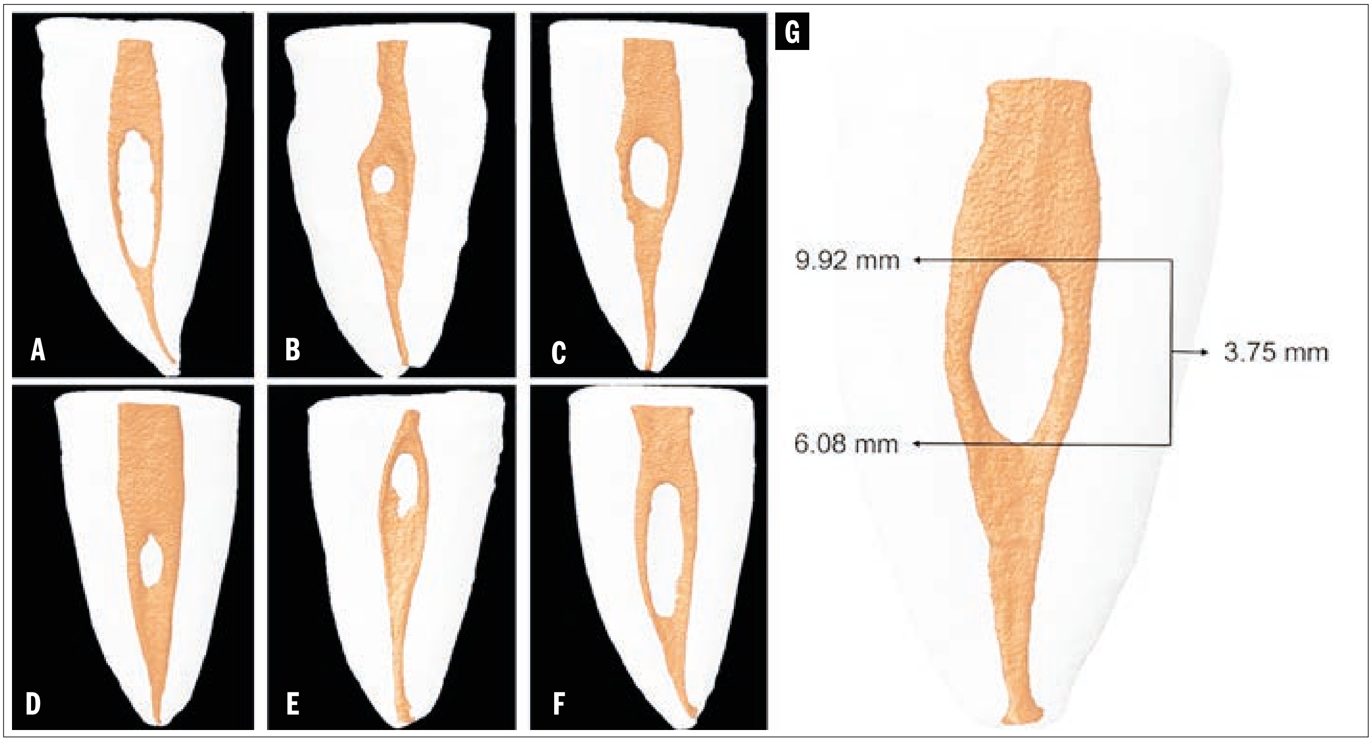



**Figure 1**
Representative tridimensional reconstructions of mandibular incisors showing different positions and extension of bifurcation and rejoin of Vertucci's type III root canals **(A-F)**. The values represent mean of bifurcation and rejoin from apex and extension of buccal and lingual canals **(G)**.

bifurcated sections, most of the buccal and lingual canals showed round shape in axial sections. The percentage and number of long oval canals at different root canal levels are shown in table 3.

In the middle section of two canals, it was found similar dentin thickness for the buccal and lingual, with mean of 1.85mm and 1.87 mm, respectively, as well as in the mesiodistal direction of the buccal (1.16 mm) and lingual canal (1.12 mm). Considering dentin between canals, it was found thickness of 1.32 mm. In the apical millimeter, the mean lingual dentin was higher than the buccal and mesiodistal dentin thickness, 1.02 mm, 0.70 mm, and 0.52 mm, respectively (Figure 2).

The roots showed a mean curvature of 8.85 degrees (±3.70) in the buccolingual direction and 11.53 degrees (±4.13) in the mesiodistal direction. The curvature values in degrees are shown in Figure 3. Regard-

**Figure 2**
Tridimensional reconstruction of representative sample showing axial cross sections of bifurcation, vestibular and lingual canals, merging and 1mm below the apical apex. The mean and standard deviation of buccal, lingual, mesial and distal dentin thickness in the middle sections of the buccal and lingual canals and at the apical apex section are also shown.

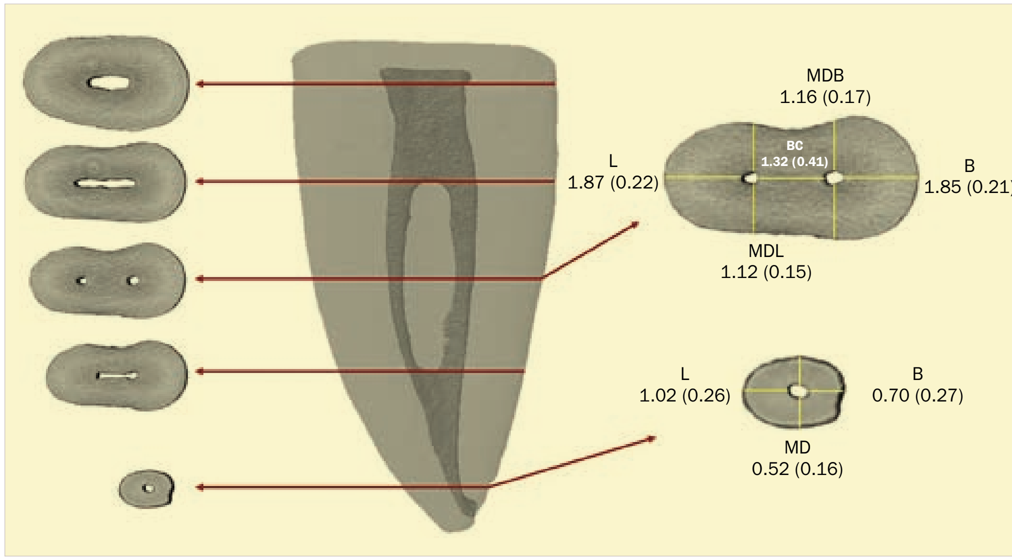



**Table 3**

**Percentage and number (n) of long oval canals evaluated at cement-enamel junction (CEJ) level, bifurcation, middle sections of vestibular and lingual canals, merging and 1 mm below the apical apex**

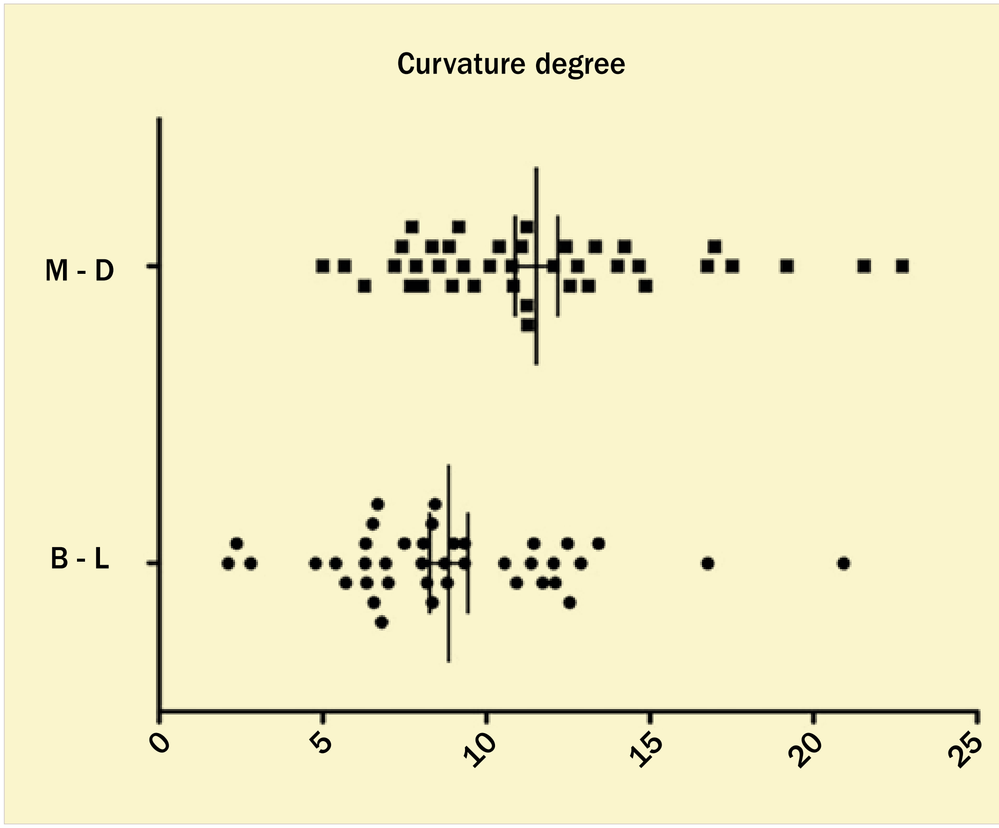
| Level | 0-2 | >2-4 | >4-6 | >6-8 | >8-10 | >10 | Total long oval canals |
|---|---|---|---|---|---|---|---|
| CEJ | 12.5 (5) | 60 (24) | 25 (10) | 2.5 (1) | 0 (0) | 0 (0) | 87.5 (35) |
| Bifurcation | 0 (0) | 22.5 (9) | 32.5 (13) | 35 (14) | 7.5 (3) | 2.5 (1) | 100 (40) |
| Mid. Buccal canal | 67.5 (27) | 30 (12) | 2.5 (1) | 0 (0) | 0 (0) | 0 (0) | 32.5 (13) |
| Mid. Lingual canal | 85 (34) | 15 (6) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 15 (6) |
| Merging | 2.5 (1) | 2.5 (1) | 15 (6) | 40 (16) | 22.5 (9) | 17.5 (7) | 97.5 (39) |
| 1 mm apical | 55 (22) | 35 (14) | 5 (2) | 2.5 (1) | 2.5 (1) | 0 (0) | 45 (18) |

ing the number of foramina, 82.5% of the specimens (n=33) showed only one major foramen, but, in 10% of the samples (n=4) 2 apical foramina were found, in 5% (n=2) 3 apical foramina and 2.5% (n=1) 4 apical foramina.

## Discussion

The type III configuration in mandibular incisors has been reported as the second most prevalent type, its prevalence may be influenced by ethnicity. Martins et al. (10) observed the Vertucci's type III configuration in 5.7% in the Brazil population, respectively, whereas the Syria ethnicity group presented 48.7% and Nigeria ethnicity group presented only a prevalence of 2.3% and the overall prevalence was 21.9% for mandibular central incisors and 26.0% for lateral incisors Shemesh et al. (11) found a higher prevalence of 33.7% and 31.9 in the Israeli population. In this study, mandibular incisors were collected from the Brazilian population, in which the type III variation is not uncommon and

**Figure 3**
The degree of root canal curvatures in the mesiodistal (M-D) and buccolingual (B-L).




can be present ranged from 5,7% to 28% (4, 6, 10, 16).

Previous studies using different methods observed that the internal root canal configuration of central and lateral mandibular incisors was similar (4, 9-12, 18), and according to Wu et al. (19), most of subjects with complicated root canals in permanent mandibular central incisors had bilaterally complicated root canal configurations. Root canals of mandibular incisors are similar bilaterally (15, 16). So, in this study, there was no distinction between them and the sample selection.

Vertucci type III configuration (12) is characterized by one canal leaving from the pulp chamber, which is divided into two within the root, and then merged to exit as one canal, however, this configuration does not always follow the same pattern, a great variability of the location and extension of the bifurcations and rejoins were observed in the three-dimensional images of the samples in this study. Whereas the mandibular incisors have an average length of around 21 mm, measured from the apex to the incisal edge (4), and root length of mean 12.51 mm as found in this study, we observed that, in the most samples, the canal bifurcation started in the cervical third and rejoin in the middle third of the root, showing buccal and lingual canals located mainly in the middle third of the root, in disagreement with results of Shemesh et al. (11), that found that both in central and lateral mandibular incisors the separation into two canals was in the middle third of the root. However, it is important to point that the authors considered a mean among II, III, IV and V types. Martins et al. (20) reported that bifurcation may also to occur at any root level. The great variation in the location of the bifurcation represents an additional challenge for accessing the lingual canal during endodontic treatment, which may be the greatest cause of failure in endodontic treatment in this dental group.

In this study, the septum formed between bifurcation and rejoin showed a mean of

3.75 mm, with minimum of 1.16 mm and maximum of 6.76 mm, but according to Shemesh et al. (11) in one-third of the cases, the septum was smaller than 1mm. It is important to say that in our findings there was variation in the level and extension of the bifurcation, which may start in the cervical or middle third and rejoin in the cervical, middle or apical third of the root canal. The knowledge of canals bifurcation and the location of the separation is fundamental for endodontic outcome, because missed and untreated canals were associated with the presence of apical periodontitis (21). Evaluating the anatomical root structures is essential before starting an endodontic treatment, the clinician must perform radiographs with variations in the horizontal angle, and when in doubt regarding the morphology of the root canal, more accurate imaging methods, such as Cone-beam computed tomography (CBCT), which provides a more accurate and detailed investigation of root anatomy (22), can be requested. Sahoo et al. reported endodontic treatment in a Vertucci type III root canal, in which it was only possible to diagnose this anatomy after performing a CBCT scan (23).

Our results showed a smaller volume of canal and dentin in the apical root third, which was increased in the cervical direction, but we cannot compare these data, because there is few available information about the root canal volume in mandibular incisors. One study evaluated the total volume of root canal, however, it has made no distinction to configuration type of the canal (4), whereas, in the only study that evaluated the volume of type III root canals, this was done only in the apical third 6 and presented higher volume than we found in our study. A small root canal volume consequently allows a small volume of irrigant solution, which may compromise disinfection and favor hard tissue accumulation during the shaping procedures, so the continuous refreshment of solution is necessary because greatly increases the effectiveness of irrigation (24).

The diameter of the root canal is a variable that influence the shaping and cleaning procedures. In this study, it was observed that the mesiodistal diameter increases progressively from the 1mm apical section (0.17 mm) to the CEJ (0.44 mm). However, the buccolingual diameter must be highlighted because it presented sudden variations along the canal, a high diameter (1.54 mm) was found in the CEJ section, similar the bifurcation section (1.74 mm), but significantly reduces in the buccal (0.48 mm) and lingual (0.38 mm) canals, then it significantly increases in rejoin section (1.61 mm) and again significantly decreases at 1mm apical section (0.35 mm). This variation in diameters will influence the selection of instruments to perform endodontic treatment, which require instruments with a lower taper. A smaller buccolingual diameter observed in the CEJ level, than in the section of root canal bifurcation, confirm the presence of a prominent bulge of dentin in the CEJ area, which makes the detection difficult and debridement of a lingual canal. The ideal coronary access is not obtained with a lingual approach, but when used the access from the lingual, it should be moved as far toward the incisal as possible (25). However, one should always consider the presence of a bifurcated canal and, clinically, perform a modified coronal access, extending the access cavity lingually, in an oval shape, to facilitate the location of the lingual canal.

Wu et al. (2) defined as long oval canal when the cross-sectional ratio of long to short canal diameter was 2, following this proposal, in this study it was found predominantly long oval canals in the CEJ level (87.5%) as well as in the bifurcation (100%) and rejoin sections (97.5%), however between these levels the buccal and lingual showed round shape in 67.5% and 85%, respectively. Previous studies showed at 1mm short of the apical foramen the minor diameter raging from 0.21 mm to 0.25 mm and major diameter raging from 0.37 mm to 0.49 mm for general mandibular incisors (2, 4, 12) and 0.22 mm and 0.41 mm, respectively, for type III anatomy (6). These data were similar those found in our study (0.17 mm – 0.35 mm), but the high major diameter observed was 0.71 mm. So, it should be considered the prevalence of higher apical diameters than 0.35 mm at the 1mm apical level, where canal shaping is usually ended. Therefore, an instrument with an apical diameter of at least 0.35 mm is required to touch all the root canal walls in the apical region. Another important point to consider is that 45% of the samples presented long-oval shape, corroborating with Milanezi et al. (6) that found 37.5% of oval-shaped canals in the 1mm apical level of type III anatomy and it was more prevalent in comparison to type I with 16.7%. This data may explain the difference between our results and Wu et al. (2) study that found only 10% of oval canals in this same root position.

Mechanical preparation of long oval-shaped canals could represent a challenge for clinicians. Recent studies have shown that different contemporary endodontic instrument systems were not able to provide optimal shaping ability in both oval-shaped canals (26) and long oval-shaped canals (27) of mandibular incisors, these studies used instruments with different tapers and tip size #25 and #30, respectively. In this study, the type III canals showed a variation in diameter and cross section along the root, which can make difficult the properly shaping and cleaning.

The increase of apical enlargement promotes important outcomes such as significantly reduction in percentage of unprepared canal areas (28) and less hard tissue debris accumulation (29) due the improvement of the flushing action of irrigants by deeper penetration in the root canal system. Furthermore, in infected root canals the enlargement of the apical preparation promotes greater intracanal bacterial reduction (30). However, during treatment, the clinician must take into account that, the expectation of using instruments with large tip and taper to shape and touch all canals walls and providing a round preparation could lead to accidents such as stripping or perforation due the flat characteristic of the root. The bifurcation section may be a potential risk area because the average of dentin thickness on both the mesial and distal walls shows 1.16 mm for the buccal canal and 1.12 mm for the lingual canal. Furthermore, even after apical enlargement canals with anatomical complexity may not be completely free from packed hard tissue debris (28, 29) and bacterial cells (30).

Cleanliness of untouched canal areas by instruments depends on irrigants action (27), so the constant refreshment and agitation of the irrigant with complementary methods such as passive ultrasonic irrigation and mechanical irrigant agitation devices, increases the effectiveness of the solutions and improves canal debridement (31, 32). Bao et al. (32) showed that the XP-endo Finisher allowed to remove biofilm from hard-to-reach areas in the root canal system. Ultrasonic tips like Flatsonic and Clearsonic as an auxiliary method for the rotary or reciprocate instrumentation of oval-shaped canals increases canal volume and surface, reducing the non-instrumented areas of the root canal system (33).

The teeth presented a low degree of curvature, both in the buccolingual and mesiodistal direction, only 1.2% of the sample presented curvature greater than 20 degrees. Despite we found 82.5% of sample a single apical foramina and a cone beam computed tomography study showed 100% of in mandibular incisors (21), it was observed in this study one tooth with an apical delta (four foramina), also reported in a previous study (4), so the presence of multiple foramina should also be considered in mandibular incisors with type III canal configuration.

With advances in digital imaging, instrumentation and anatomical studies, the endodontic treatment of root canals with anatomical complexities has become more predictable. In the case of lower incisors, the clinician must be aware of possible anatomical variations, always take radiographs with variation in the horizontal angle, extend the access to the cavity in the lingual direction and probe an additional canal, and also consider CBCT, which is a useful technique for endodontic diagnosis and treatment.

The limitations of this study limitations stem from both the sample size and the narrow focus on specific categories of teeth. However, it’s important to view this as an initial study that lays out the criteria for future research targeting the endodontic management of root canal anatomy of Vertucci's type III mandibular incisors and the morphological variations that may occur. Future studies will be necessary to evaluate the shaping of these canals in order to suggest the appropriate tip and taper of the instrument for this anatomical condition.

## Conclusion

The morphologic aspects of root canal bifurcation and rejoin in mandibular incisors Vertucci's type III do not present a consistent pattern. In this anatomical configuration, oscillation occurs in the largest diameter and cross-sectional shape along the root canal.

## Clinical relevance

The Vertucci type III is the most common anatomical variation found in mandibular incisors.

## Conflict of interest

The authors deny any conflicts of interest related to this study.

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