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Root canal conicity estimation of primary maxillary central and lateral incisors—A study by Nano-CT

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Abstract

Aim: The objective of the study was to estimate the conicity of the root canals of maxillary central and lateral incisors by computed nanotomography (Nano-CT).

Design: This in vitro study included nine extracted primary maxillary central incisors and 12 maxillary lateral incisors, which were subjected to Nano-CT analysis. The resulting images of each tooth were reconstructed using the OnDemand3D software, and root canal area, volume, and taper analysis were performed using the free FreeCAD 0.18 software for the 3D computer-aided design (CAD) model. Data were statistically analysed using the Stata v14.0 software, adopting a significance level of 5%.

Results: The results presented the mean value of the diameter and area of the root canal of primary central and lateral incisors. In addition, the taper values for both dental groups between points D0-D5, D5-D7, and D7-D10 were determined. Considering the diameters obtained over the entire length of the root, with a length of 12 mm, a conical model was constructed.

Conclusion: Detailed knowledge of root morphology of maxillary central and lateral incisors of primary dentition by means of Nano-CT is important to achieve faster, more accurate, and efficient endodontic treatments.

KEYWORDS

computed nanotomography, morphological study, primary teeth, root canal conicity

1 | INTRODUCTION

The primary dentition has thinner layers of enamel and dentin compared with the permanent teeth, and these tissues have a lower level of mineralization.[1] Thus, the progression of dental caries is faster and more aggressive.[2] At the same time, soon after complete root formation, this structure undergoes a physiological resorption process that, along with the development of the permanent successor germ, causes changes in the root canal system of the primary teeth.

Pulp pathology has great repercussions on the body, because when not properly treated, it can cause infectious foci in the craniofacial complex.[3] For young children, the risk of spreading the infection is even greater since the immune system is not fully developed[4] and the bone has wider marrow spaces.[5] Given these factors and considering the functional, morphological, and aesthetic importance of primary teeth maintenance until normal exfoliation, endodontic treatment of primary teeth is important and necessary.

Successful treatment of pulp diseases in primary dentition will depend primarily on the paediatric dentist's knowledge of pulp tissue biology and primary teeth morphology, especially of the root canal, for an appropriate choice of materials and techniques to be used.[6] It is important to develop a complete understanding of the three-dimensional morphologic characteristics of root canal system and the changes occurred during root canal preparation. The best endodontic treatment is soundly based on a detailed background knowledge of the internal anatomy of the teeth.[7]

Several anatomical variations occur in the root canals, which contribute to the failure of pulp therapy, especially in teeth with pulp necrosis.[6] Multiple researches have been conducted to provide a more detailed description of the morphology and anatomical variations of permanent teeth.[8,9] The literature on primary dentition, however, is limited, and almost all studies are performed on posterior teeth.[10-12]

The morphological study of primary teeth comprises knowing the morphology of the pulp chamber, root structure, and root canals, as well as the specific measures of length and diameter of each dental group, and their variations, which will influence the effectiveness of the endodontic treatment.[11,13,14] The detailed and quantitative data on the morphological characteristics of primary teeth in different dental groups, however, are scarce.[13]

Several techniques were used to evaluate root and root canal morphology in primary dentition, such as whitening technique, radiographs, microscope, cone-beam computed tomography, and computed microtomography (μCT).[10] There are no studies on root canal diameter in the literature using nano-computed tomography (nano-CT), however. Nano-CT is an ultra-high spatial resolution CT technology for 3D imaging and represents a technical advancement of the established micro-CT systems.[15,16] Nano-CT devices, which use a nano-focal spot source (<400 nm), allow clear visualization of structures at a cellular level. Sub-micrometre resolution images are obtained due to the excellent contrast resolution of the flat-panel detector. Also, the data acquisition process is very stable and the scans are obtained faster compared with micro-CT methods.[15,16]

Therefore, the objective of this study was to estimate the conicity of the root canals of the maxillary central and lateral incisors by computed nanotomography (Nano-CT) in order to develop unique instruments for these specific teeth.

Why this paper is important to paediatric dentists?

- A conical model for primary maxillary central and lateral incisors was constructed.
- Computed nanotomography is first used to determine the morphology and to estimate the conicity of the root canals of primary teeth.
- The purpose of this study is to collect information about the different anatomical details that can evidence the necessity of developing new specific endodontic instruments to primary teeth.

2 | MATERIAL AND METHODS

The present research protocol was approved by the *Comité Institucional de Etica en Investigación del Instituto de Medicina Tropical 'Daniel Alcides Carrión' de la Universidad Nacional Mayor de San Marcos* IMT 'DAC' (UNMSM; CIEI protocol 2020-006).

Then, the in vitro, descriptive, longitudinal, experimental, and prospective study included a total of nine maxillary central incisors and 12 maxillary lateral incisors extracted for reasons unrelated to this study, which were stored in 0.1% thymol solution. A pilot study was conducted using teeth for each type, considering the variability of the measurements and root resorption. The difference in diameters was taken into account to assess the taper, with an alpha error of 0.05, power of 0.80, and unknown standard deviation. Stata v14 software (Stata Corp) was used for the sample size calculation. The estimated sample size for the maxillary central and lateral incisors was 8 and 10, respectively.

The teeth included in the study were from primary dentition and have no evidence of root resorption or resorption not exceeding 1/3 root length, no evidence of root fracture, dental anomaly of shape, size, and structure, no previous endodontic treatment, internal resorption, or obliteration of the canal.

2.1 | Dental preparation

The tooth preparation process consisted of washing with water and brush, and if necessary, an ultrasonic scraper was used. Subsequently, the teeth were submerged in saline for 30 minutes to remove surface residues and then stored in formaldehyde.

2.2 | Nano-CT scan analysis

For this analysis, the teeth were mounted on a pink wax cube and scanned with Nano-CT equipment (Phoenix.m. General Electric) using 70 kVp and 200 mA. The exploration was performed in 360° of rotation around the vertical axis with 1.0° of rotation and resolution of 69.02 μm, with a 0.1-mm distance copper filter in the axial and coronal planes. The

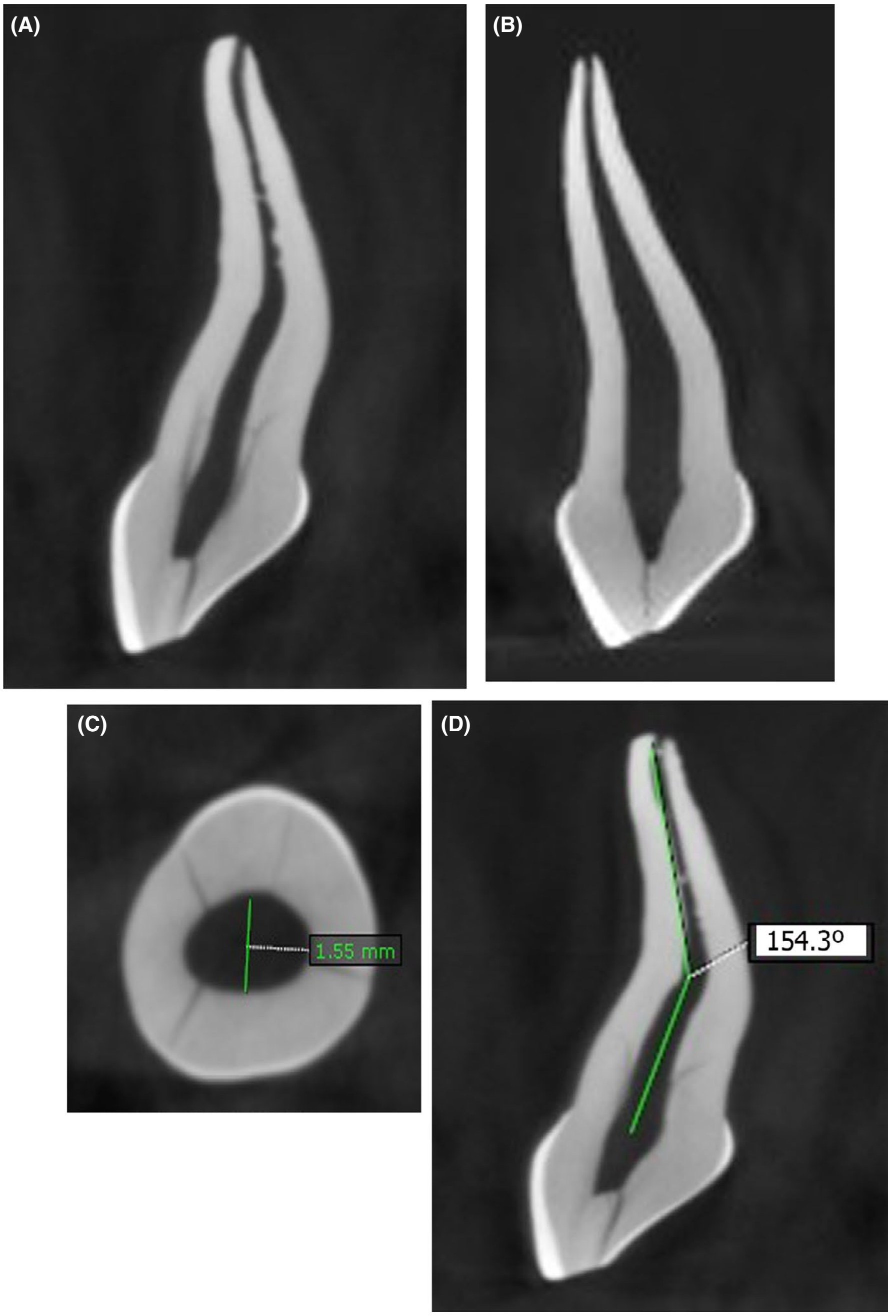

FIGURE 1 Nano-CT sagittal views of maxillary (A) and lateral (B) incisors. (C) Coronal view measuring duct diameter. (D) Axial view showing the angulation of the incisors, to shelter the germ of the permanent tooth

resulting images of each maxillary central incisor and lateral incisor were reconstructed in the OnDemand3D software (Cybermed, Seoul, South Korea). Root canal conicity, area, and volume analysis were performed using the free FreeCAD 0.18 software for the computer-aided design (CAD) 3D model.

2.3 | Teeth morphology analysis

To analyse the morphology of the pulp chamber, the height from the ceiling to the floor of the pulp chamber was evaluated by making a longitudinal section.

For root canal morphology analysis, the root canal conicity was estimated considering the following values and parameters: 1- root canal length, from cervical to apical region; 2-. larger area of constriction at the cervical level, considering the enamel-cement junction as a cervical reference point; and 3- most apical extreme of the root considered as the apical reference point. The variables considered were the number of root canals present in each root and the diameter of the root canal. The largest and smallest diameters every millimetre along the root canal, the thickness of the inner and outer face of the root dentin, and the circularity of the root canal were measured, and an estimate of the amount of root resorption of each root was recorded.

TABLE 1 Diameter of maxillary central incisors in (mm) from 0 to 12 mm from the cervical line (D0-D12)

	N	Mean	Standard deviation	Minimum	Maximum	Median
D0 (0 mm)	9	1.58	0.24	1.13	1.97	1.63
D1 (1 mm)	9	1.47	0.23	0.94	1.66	1.57
D2 (2 mm)	9	1.23	0.19	0.82	1.47	1.27
D3 (3 mm)	9	1.01	0.20	0.53	1.27	1.03
D4 (4 mm)	9	0.88	0.23	0.40	1.11	0.94
D5 (5 mm)	9	0.71	0.22	0.30	1.05	0.68
D6 (6 mm)	9	0.55	0.17	0.22	0.82	0.58
D7 (7 mm)	9	0.43	0.16	0.13	0.75	0.43
D8 (8 mm)	9	0.39	0.12	0.16	0.62	0.39
D9 (9 mm)	8	0.37	0.11	0.16	0.58	0.36
D10 (10 mm)	6	0.36	0.07	0.29	0.49	0.35
D11 (11 mm)	1	0.24	0.03	0.21	0.28	0.25
D12 (12 mm)	1	0.18	0.05	0.14	0.24	0.18

Figure 1 illustrates Nano-CT views of maxillary and lateral incisors used for analysis and measurements.

2.4 | Statistical analysis

For statistical analysis, data were entered into Stata v14.0 software. Measurement reproducibility of the largest and smallest diameters of the root canal was tested by the intraclass correlation coefficient (ICC = 0.981), and 30% of the total sample measurements were repeated after an interval of 15 days. Data were submitted to descriptive statistical analysis. The normality and homogeneity of the variables were evaluated by the Shapiro-Wilk test, and accordingly, the regression formula was used to predict the primary teeth conicity. To measure the smallest length and diameter of the root canals and pulp chamber, the selected statistical tests were measures of central tendency. Comparison of the cervical (D0-D5), middle (D5-D7), and apical (D7-D10) thirds was performed with the Kruskal-Wallis test. Multiple comparison tests were performed by Dunn's procedure to identify tertiary pairs with significant differences. A significance level of 5% ($P < .05$) was considered for statistical test results.

3 | RESULTS

The mean diameter of the maxillary central incisor root canal in the cervical region D0 (0 mm) was 1.58 ± 0.24 mm, whereas the mean diameter of the deepest longitude (at 12 mm from the cervical line) was 0.18 ± 0.05 mm. Only two of the evaluated teeth had a length greater than 10 mm (Table 1).

The mean diameter of the maxillary lateral incisor root canal at the cervical region D0 (0 mm) was 1.47 ± 0.13 mm, whereas the mean diameter of the deepest longitude (at 12 mm from the cervical line) was 0.19 ± 0.03 mm. Of the evaluated teeth, 9 had a length >10 mm (Table 2).

The mean values of the diameters obtained at points D0 (0 mm), D5 (5 mm), D7 (7 mm), and D10 (10 mm) of maxillary central incisors were 1.58, 0.71, 0.43, and 0.36 mm, respectively. The medians were 1.63, 0.68, 0.43, and 0.35 mm at points D0, D5, D7, and D10, respectively. The differences between the four points are statistically significant ($P = .0001$). In post hoc analysis by Dunn's test, it was observed that there are significant differences between point D0 and points D5, D7, and D10 (P-values of .05441, .0002, and .000, respectively). No significant differences could be observed between points D5 and D7 (P-value of .2993), between points D5 and D10 (P-value of .670), and between points D7 and D10 (P-value = 1.0000; Table 3), however.

For the maxillary lateral incisor, the mean values of the diameters obtained at points D0 (0 mm), D5 (5 mm), D7 (7 mm), and D10 (10 mm) were 1.47, 0.75, 0.50, and 0.33 mm, respectively. The medians were 1.68, 0.76, 0.50, and 0.24 mm at points D0, D5, D7, and D10, respectively. The differences between the four points are statistically significant (P-value = .0001). Post hoc analysis by Dunn's test showed significant differences between point D0 and points D7 and D10 (P-values of .000 for both). It was not possible to observe significant differences between points D0 and D5 (P-value = .0755), between points D5 and D7 (P-value = .0755), and between points D7 and D10 (P-value = .2092; Table 4), however.

The mean value of root canal area of maxillary central incisors at cervical line D0 (0 mm) was 2.02 ± 0.59 mm^2,

TABLE 2 Diameter of maxillary lateral incisors in (mm) from 0 to 12 mm from the cervical line (D0-D12)

	N	Mean	Standard deviation	Minimum	Maximum	Median
D0 (0 mm)	12	1.47	0.13	1.21	1.68	1.50
D1 (1 mm)	12	1.47	0.12	1.26	1.73	1.43
D2 (2 mm)	12	1.21	0.10	1.06	1.38	1.21
D3 (3 mm)	12	1.04	0.12	0.87	1.33	1.0
D4 (4 mm)	12	0.86	0.10	0.73	1.01	0.85
D5 (5 mm)	12	0.75	0.05	0.68	0.87	0.76
D6 (6 mm)	12	0.62	0.04	0.57	0.70	0.63
D7 (7 mm)	12	0.50	0.03	0.42	0.55	0.50
D8 (8 mm)	12	0.44	0.06	0.35	0.57	0.44
D9 (9 mm)	12	0.42	0.06	0.30	0.50	0.40
D10 (10 mm)	9	0.33	0.03	0.26	0.37	0.24
D11 (11 mm)	6	0.23	0.05	0.17	0.29	0.23
D12 (12 mm)	3	0.19	0.03	0.17	0.23	0.19

TABLE 3 Diameter of maxillary central incisors (mm) in points D0, D5, D7, and D10

	N	Mean	Standard deviation	Minimum	Maximum	Median	*P*_value[a]
D0 (0 mm)	9	1.58	0.24	1.13	1.97	1.63	
D5 (5 mm)	9	0.71	0.22	0.30	1.05	0.68	.0001
D7 (7 mm)	9	0.43	0.16	0.13	0.75	0.43	
D10 (10 mm)	6	0.36	0.07	0.29	0.49	0.35	

[a]Kruskal-Wallis equality-of-populations rank test.

TABLE 4 Diameter of maxillary lateral incisors (mm) in points D0, D5, D7, and D10

	N	Mean	Standard deviation	Minimum	Maximum	Median	*P*_value[a]
D0 (0 mm)	12	1.47	0.13	1.21	1.68	1.50	
D5 (5 mm)	12	0.75	0.05	0.68	0.87	0.76	.0001
D7 (7 mm)	12	0.50	0.03	0.42	0.55	0.50	
D10 (10 mm)	9	0.33	0.03	0.26	0.37	0.24	

[a]Kruskal-Wallis equality-of-populations rank test.

whereas the mean area at deepest length D12 (12 mm of the cervical line) was 0.02 ± 0.01 mm^2 (Table 5).

The mean value of the root canal area of maxillary lateral incisors at the cervical line D0 (0 mm) was 1.73 ± 0.31 mm^2, whereas the mean area at the deepest length D12 (12 mm of the cervical line) was 0.03 ± 0.01 mm^2 (Table 6).

The mean values of the maxillary central incisor areas obtained at points D0, D5, D7, and D10 were 2.02, 0.43, 0.17, and 0.10 mm^2, respectively. The medians were 2.08, 0.36, 0.15, and 0.09 mm^2 at points D0, D5, D7, and D10, respectively. The differences between the four points are statistically significant (*P*-value = .0001). Performing post hoc analysis by Dunn's test showed that there are significant differences between point D0 and points D5, D7, and D10 (*P*-values of .005, .0002, and .000, respectively). No significant differences could be observed between points D5 and D7 (*P*-value of .3230), between points D5 and D10 (*P*-value of .0742), and between points D7 and D10 (*P*-value = 1.0000; Table 7), however.

The mean values of the maxillary lateral incisor areas obtained at points D0, D5, D7, and D10 were 1.73, 0.45, 0.20, and 0.09 mm^2, respectively. The medians were 1.77, 0.46, 0.20, and 0.09 mm^2 at points D0, D5, D7, and D10, respectively. The differences between the four points are statistically significant (*P*-value = .0001). Performing post hoc analysis by Dunn's test, it was observed that there are no significant differences between points D0 and D5 (*P*-value = .0753), between points D5 and

TABLE 5 Area in maxillary central incisors in (mm^2) from 0 to 12 mm of the cervical line (D0-D12)

	N	Mean	Standard deviation	Minimum	Maximum	Median
D0 (0 mm)	9	2.02	0.59	1.00	3.07	2.08
D1 (1 mm)	9	1.74	0.48	0.69	2.16	1.93
D2 (2 mm)	9	1.22	0.34	0.53	1.71	1.26
D3 (3 mm)	9	0.83	0.29	0.22	1.28	0.83
D4 (4 mm)	9	0.64	0.28	0.12	0.97	0.70
D5 (5 mm)	9	0.43	0.25	0.07	0.87	0.36
D6 (6 mm)	9	0.26	0.14	0.04	0.53	0.26
D7 (7 mm)	9	0.17	0.12	0.01	0.45	0.15
D8 (8 mm)	9	0.14	0.09	0.01	0.36	0.13
D9 (9 mm)	8	0.11	0.07	0.02	0.27	0.10
D10 (10 mm)	6	0.10	0.04	0.05	0.18	0.09
D11 (11 mm)	1	0.04	0.01	0.03	0.06	0.05
D12 (12 mm)	1	0.02	0.01	0.01	0.04	0.02

TABLE 6 Area of maxillary lateral incisors in (mm^2) from 0 to 12 mm from the cervical line (D0-D12)

	N	Mean	Standard deviation	Minimum	Maximum	Median
D0 (0 mm)	12	1.73	0.31	1.15	2.22	1.77
D1 (1 mm)	12	1.71	0.29	1.25	2.35	1.61
D2 (2 mm)	12	1.17	0.20	0.88	1.50	1.16
D3 (3 mm)	12	0.87	0.22	0.59	1.39	0.82
D4 (4 mm)	12	0.59	0.14	0.42	0.80	0.56
D5 (5 mm)	12	0.45	0.07	0.36	0.59	0.46
D6 (6 mm)	12	0.31	0.04	0.26	0.38	0.31
D7 (7 mm)	12	0.20	0.03	0.14	0.24	0.20
D8 (8 mm)	12	0.16	0.05	0.10	0.26	0.15
D9 (9 mm)	12	0.14	0.05	0.07	0.20	0.14
D10 (10 mm)	9	0.09	0.02	0.05	0.11	0.09
D11 (11 mm)	6	0.05	0.02	0.02	0.07	0.04
D12 (12 mm)	3	0.03	0.01	0.02	0.04	0.03

D7 (P-values = .0753), and between points D7 and D10 (P-value = .2089). Differences are statistically significant between point D0 and points D7 and D10 (P-values of .000 for both) and between points D5 and D10 (P-value = .0003; Table 8).

To calculate the taper, the following formula was used:

$$C = \frac{d_2 - d_1}{L}$$

According to Gergi et al,[17] the taper determination is more accurate in the first 3 mm of the cone. With this procedure, the following results were found:

The taper values obtained in the maxillary central incisors between points D0-D5, D5-D7, and D7-D10 were 17%, 14%, and 2%, respectively. The smallest diameters of the cone formed between points D0-D5, D5-D7, and D7-D10 were 0.71, 0.43, and 0.36 mm, respectively, whereas the largest diameters were 1.58, 0.71, and 0.43 mm, respectively (Table 9; Figure 2A).

The taper values obtained in the maxillary lateral incisors between points D0-D5, D5-D7, and D7-D10 were 15%, 13%, and 6%, respectively. The smallest diameters of the cone formed between points D0-D5, D5-D7, and D7-D10 were 0.75, 0.50, and 0.33 mm, respectively, whereas the largest diameters were 1.47, 0.75, and 0.50 mm, respectively (Table 10, Figure 2B).

TABLE 7 Area of maxillary central incisors in (mm^2) in points D0, D5, D7, and D10

	Mean	Standard deviation	Min-Max	Median	*P*-value[a]
D0	2.02	0.59	1.00-3.07	2.08	.0001
D5	0.43	0.25	0.07-0.87	0.36	
D7	0.17	0.12	0.01-0.45	0.15	
D10	0.10	0.04	0.05-0.18	0.09	

[a]Kruskal-Wallis equality-of-populations rank test.

TABLE 8 Area of maxillary lateral incisors in (mm^2) in points D0, D5, D7, and D10

	Mean	Standard deviation	Min-Max	Median	*P*-value[a]
D0	1.73	0.31	1.15-2.22	1.77	.0001
D5	0.45	0.07	0.36-0.59	0.46	
D7	0.20	0.03	0.14-0.24	0.20	
D10	0.09	0.02	0.05-0.11	0.09	

[a]Kruskal-Wallis equality-of-populations rank test.

For the reconstruction of the 3D image, the FreeCAD 0.18 program (free program for the computer-aided design (CAD) 3D model) was used, considering the diameters obtained over the entire length of the tooth root, with a length of 12 mm. For the construction of the cone, the same procedures were used, using points D0, D5, and D10 with a height of 12 mm, and the respective tapers, with lengths of 5, 7, and 10 mm (Figure 3A, B).

4 | DISCUSSION

This study aimed to determine the root morphology of primary central and lateral maxillary incisors and to measure the mean conicity along the root canal of these teeth, providing a conical model of three-dimensional reconstruction at three different root levels.

The detailed knowledge of root canal morphology and conicity demonstrated in this study is of clinical and scientific relevance. Nano-CT images offered a valuable mathematical modelling of tooth morphology. The cones built were based on canal diameter, conicity, and degree of physiological resorption, and correspond, respectively, to the presence of half resorbed root, one third, or absence of rhizolysis.

The conical models support the clinician for the appropriate choice of endodontic instruments, so that they are able to act on the entire length of the root canal. Selecting an instrument that is compatible with the root canal diameter, including the apical third, allows its active tip to act on all walls, removing the infected dentin. The study helps with the choice of the best instrument, even in the presence of rhizolysis, since the findings provide the diameter and taper values corresponding to the presence of one third (D7) or half (D5) of resorbed roots.

Given the particularities of primary teeth, such as physiological resorption process, less thick dentin structure, with higher tubule density[18] and with less mineral content,[19,20] and the presence of the permanent tooth germ in close contact, care should be taken during pulp therapy. Maxillary primary incisors have relatively longer root length compared with crown length.[13] In addition, due to the presence of the successor permanent tooth close to the apical third and to allow its development, the roots of the primary teeth present a radicular dilaceration into buccal direction.[13,21] Jung et al,[13] using cone-beam computed tomography, demonstrated that the degree of laceration was 26.3° for primary maxillary central incisors and 16.5° for maxillary lateral incisors, and was located approximately at half of the root length. This curvature was evidenced in this study, which was remarkable in teeth that had not undergone rhizolysis. Interestingly, from the data obtained, it was possible to demonstrate that the diameter and conicity of the root canal decreased dramatically from this angle.

The average root length of primary maxillary central and lateral incisors is 10.52 and 10.79 mm, respectively,

TABLE 9 Taper of maxillary central incisor until middle third (D0-D5), apical third (D5-D7), and apex (D7-D10)

	L	d_3	d_1	Taper (taper)	%	Code (ISO)[a]
D0-D5	5	1.58	0.71	0.174	17	07017
D5-D7	2	0.71	0.43	0.14	14	04014
D7-D10	3	0.43	0.36	0.02	2	03502

[a]IS0 6877 l995.

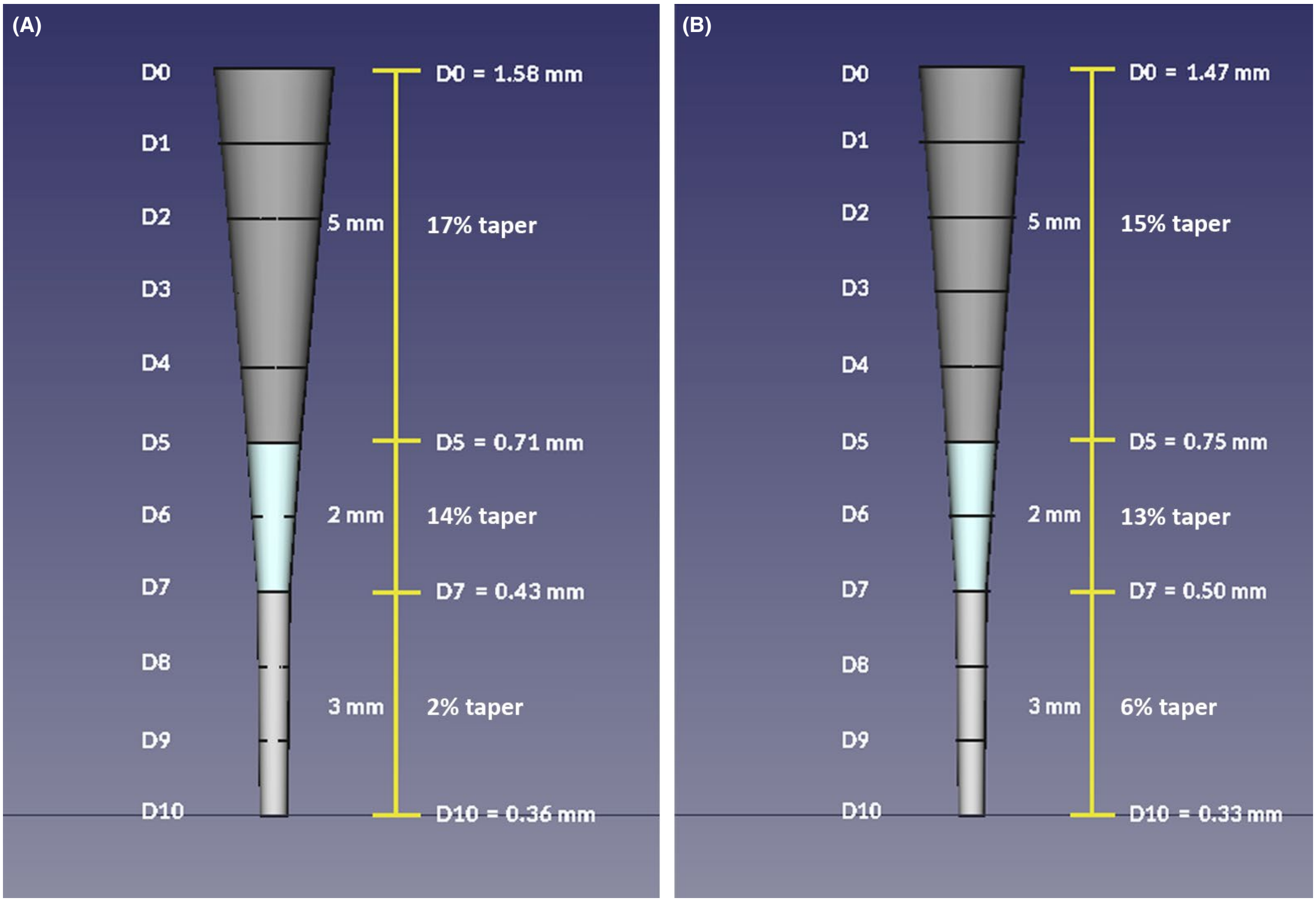

FIGURE 2 Creation of 3D surface of the maxillary central (A) and lateral (B) incisor ducts

TABLE 10 Taper of maxillary lateral incisor until middle third (D0-D5), apical third (D5-D7), and apex (D7-D10)

	L	d_3	d_1	Taper (taper)	%	Code (ISO)[a]
D0-D5	5	1.47	0.75	0.144	15	07515
D5-D7	2	0.75	0.50	0.125	13	05013
D7-D10	3	0.50	0.33	0.056	6	03006

[a]IS0 6877 1995.

as previously described[13], agreeing with this study that found most root canal measuring between 10 and 11 mm. According to Gaurav et al[14], these measures, however, were smaller, being a mean of 8.14 mm for maxillary incisors. Regarding the diameter at the enamel-cement junction, a slight variation is detected between both studies: 1.58 and 1.47 mm for maxillary central and lateral incisors, respectively, in our study, compared with a mean of 2.10 mm for maxillary incisors found by Gaurav et al. The diameter of canals at middle third was also different, with almost twice the values found here, considering the measures at point D5. These divergences, in addition to the different imaging techniques used (cone-beam computerized tomography—CBCT versus Nano-CT), can be partially justified by the reference points adopted in each research protocol. Comparisons with the study of Jung et al[13] were limited because they considered the external surface for root measurements, presenting some incompatible values.

To the best of our knowledge, this is the first study that examined the morphology of anterior primary teeth every millimetre along the root canal, making difficult a direct comparison with the literature.

There is increasing scientific evidence in the literature from both in vitro[22-24] and clinical[25,26] studies evaluating different instruments and systems for biomechanical root canal preparation in primary dentition. Specifically, in anterior teeth, only Subramaniam et al[22] evaluated the effectiveness of hand and rotary files for smear layer removal in root canals of primary teeth by scanning electron microscope (SEM). The systems employed in this study, which included nickel-titanium (NiTi) and stainless-steel manual files and rotary NiTi files (Hero Shaper), involve the use of at least

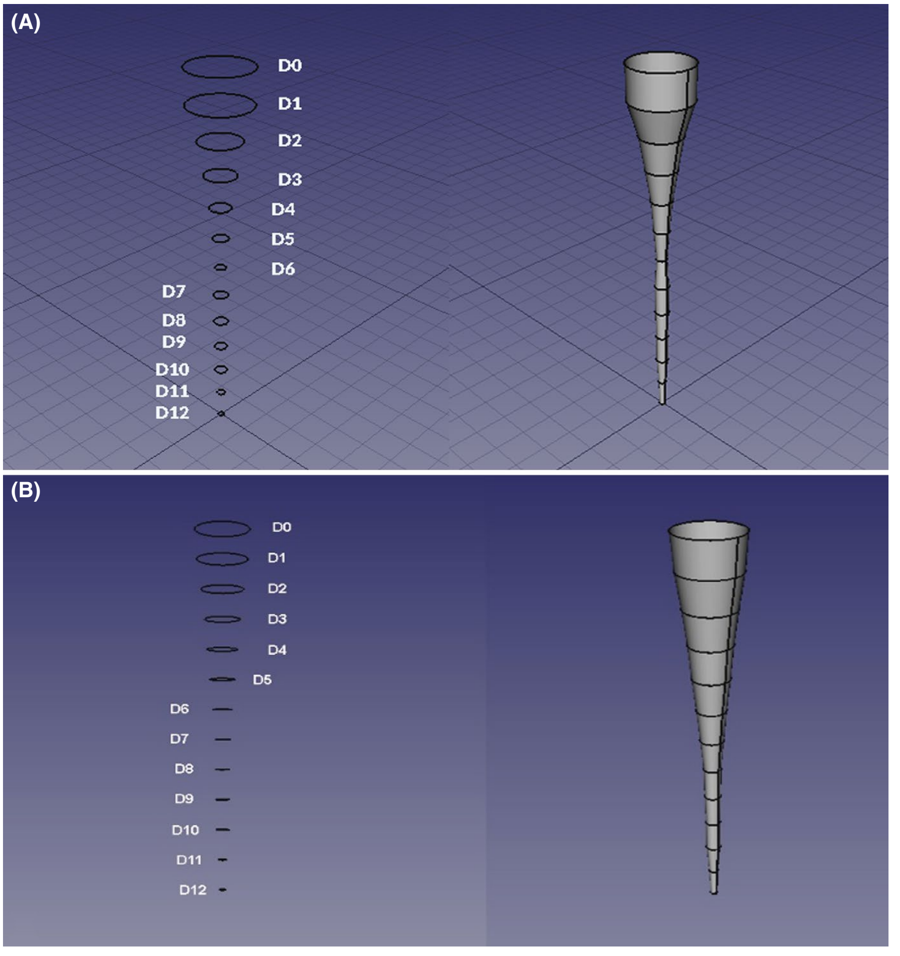

FIGURE 3 Conical shape of maxillary central (A) and lateral (B) incisors constructed (mm)

three instruments of different diameters (15, 20, 25, and 30) for canal preparation, and they have a single taper of 2% (manual) or taper of 4 and 6% (rotational).[22] Two ProTaper Universal systems employ 7 files, S1, S2, F1, F2, F3, F4, and F5, and 17, 20, 20, 25, 30, 40, and 50 tips, respectively, and taper of 2%-11%, 4%-11.5%, 7%, 8%, 9%, 6%, and 5%, respectively. Profile systems recommend the use of 6 files, namely 40/06, 30/06, 25/06, 20/06, 25/04, and 20/04, in the crown-apex direction.[27]

Even if you choose an instrument that has maximum compatibility with the canal diameter, that instrument will not follow its conicity, however. Taking into account the data obtained in this study, it can be suggested that the available systems are not ideal for primary teeth, which may lead to insufficient or excessive wear, including root perforation, over-instrumentation, or not determining the conical shape in the canal to favour the obturation step. Considering the apical third of the root canal, it was demonstrated that maxillary central and lateral incisors (ICS and ILS) presented apical diameter (D10) of 0.36 and 0.33 mm and taper (D7-D10) of 2% and 6%, respectively. Thus, the first files to be used would not be acting effectively on the dentin wall to its apical limit. In the presence of the rhizolysis process, this deficiency would be even greater.

For primary teeth, due to its peculiarities, disinfection of the root canal system is more dependent on mechanical preparation, since irrigating solutions that have toxic potential should be avoided and irrigation is restricted to the use of more biologically compatible solutions, which in turn have limited antimicrobial effect, reducing the risk of damage to adjacent structures. Additionally, the conical shape determined during root canal preparation will assist in the canal filling step, which must respect the working length limit, avoiding inadvertent apical extrusion of material, especially in the primary teeth, to avoid additional damage to the permanent germ.

Briefly, given the different tapers in the apical, middle, and cervical thirds, and their respective diameters along the root canal of the anterior primary teeth, narrow files would be leaving infected areas and large files would cause excessive wear, and the amount of infected dentin removed along the canal would be irregular.

According to Siqueira et al,[28] anaerobic bacteria are able to penetrate into the dentinal tubules to varying lengths, reaching deep layers. Ricucci & Siqueira,[29] by means of a histological study on teeth with periapical lesion, demonstrated that the canal walls are covered by bacterial biofilm and that the underlying dentinal tubules are heavily invaded and colonized by microorganisms at varying depths. Thus, it is estimated that a 0.1 mm thickness of infected root dentin should be removed during biomechanical preparation.

The purpose of this study is to develop unique rotary instruments according to the diameter of the canal at the boundary of the rhizolysis bevel and the conicity of the primary teeth, so that the instrument acts on the entire length of the canal, on all walls, and wearing out a minimum, regular and sufficient amount of tissue to remove infected dentin.

Detailed knowledge of the root morphology of the central and lateral maxillary incisors by means of Nano-CT is important to achieve faster, more accurate, and efficient endodontic treatments.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

G.T.R. and L.A.B.S. conceived the ideas; D.J.B.V. and L.R.R.S. collected the data; G.T.R., M.P.L., and P.N.F. analysed the data; and G.T.R., M.P.L., and R.A.B.S. led the writing.

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