CLINICAL RESEARCH

Worldwide Prevalence of the Lingual Canal in Mandibular Incisors: A Multicenter Cross-sectional Study with Meta-analysis

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SIGNIFICANCE

The prevalence of lingual root canals in mandibular incisors was investigated in 44 countries. The overall percentage was 21.9% and 26.0% in the central and lateral incisor, respectively. The outcomes varied according to geographic location, ethnicity, age, and gender.

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ABSTRACT

Introduction: This cross-sectional study assessed the influence of patient demographics on the worldwide prevalence of a lingual canal in mandibular incisors. **Methods:** Twenty-six thousand four hundred mandibular incisors were evaluated using cone-beam computed tomography imaging by precalibrated observers from 44 countries. A standardized screening method was employed to collect data on the presence of a lingual canal, the anatomic configuration of the root canal, and number of roots. Patient demographic information (age, sex, and ethnicity) was also recorded. Multiple intra and interrater tests assessed the reliability of the observers and groups, and a meta-analysis was used to examine differences and heterogeneities ($\alpha = 5\%$). **Results:** The prevalence of the lingual canal in mandibular central and lateral incisors varied from 2.3% (0.06%–4.0%; Nigeria) to 45.3% (39.7%–51.0%; Syria) and from 2.3% (0.06%–4.0%; Nigeria) to 55.0% (49.4%–60.6%; India), respectively. Ethnicity had a significant impact on the prevalence of the lingual canal, with African, Asian, and Hispanic groups having the lowest proportions ($P < .05$), while Caucasians, Indians, and Arabs showed the highest ($P < .05$) for both incisor groups. Additionally, males had a significantly higher odds ratio for both the central (1.334) and lateral (1.178) incisors, while older patients had a lower prevalence for both tooth groups ($P < .05$). The side and tooth group did not influence on the outcomes. **Conclusions:** The prevalence of lingual root canals in mandibular incisors varies significantly based on geographic location, ethnicity, age, and gender. The overall prevalence was 21.9% for mandibular central incisors and 26.0% for lateral incisors. *(J Endod 2023;■:1–17.)*

KEY WORDS

Anatomy; cone-beam computed tomography; cross-sectional study; endodontics; incisors; meta-analysis

The primary objective of root canal therapy is to ensure effective debridement and disinfection of the canal space. In order to achieve this goal, a thorough understanding of the most common root canal configurations and their possible variations in the tooth undergoing treatment is essential. Failure to accurately diagnose the anatomy can result in incomplete treatment of the canal space, which in turn increases the risk of developing periapical pathology[1].

Extensive anatomic investigations[2-6] have contributed to a thorough understanding of the morphology of both mandibular central and lateral incisors. The central incisor typically exhibits an overall length of 20.8 mm, while the lateral incisor tends to be longer (22.1 mm)[7]. Although the majority of studies report both incisors as being single-rooted teeth in 100% of cases[8], a few studies have also documented the prevalence of 2 roots in 0.1%[3] and 0.3%[6] of specimens. Additionally, while the roots are typically straight, an apical curvature to the buccal side in central incisors or to the distal side in lateral incisors has been reported[7]. The internal morphology of both mandibular incisors is largely influenced by the presence of a longitudinal root depression on both proximal sides of their roots. This depression can cause a reduction in mesiodistal root thickness, resulting in an internal dentinal bridge that may divide the pulp

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space into two root canals[9]. Even though there are other important morphological aspects of the internal root canal system, such as the position of the apical foramen and the frequency of accessory canals and apical ramifications, the most clinically significant anatomical variation in this group of teeth is the presence of 2 root canals.

A previous systematic review using cone-beam computer tomography (CBCT) assessments[10] reported an overall prevalence of a lingual canal of 20.4% and 25.3% for the mandibular central and lateral incisors, respectively. This review also revealed significant variation in the prevalence of lingual canal among diverse geographic regions, with East Asia exhibiting the lowest percentages (central incisor: 7.6%; lateral incisor: 17.2%) and Europe displaying the highest (central incisor: 36.8%; lateral incisor: 37.5%), indicating a substantial difference of about 20%–30% between these regions. These results highlight the relevance of geographic location as a possible factor in the prevalence of a second canal in mandibular incisors, emphasizing that the proportion documented in one region may not necessarily apply to another region. However, the current knowledge regarding the influence of demographic factors on the proportion of lingual canal in mandibular incisors is limited, as the previously mentioned review was only able to gather data from 9 countries representing 3 continents. Furthermore, inadequate information supplied by the pooled studies prevented the examination of important variables, such as ethnicity, age, or tooth side. These gaps in the literature highlight the need for further investigation to address these missing data and better comprehend the influence of demographic factors on the proportion of the lingual canal in different geographic regions.

While evidence strongly suggests that geographic region plays a significant role in the prevalence of a second canal in mandibular incisors, there is limited information available for most of the world's populations. Additionally, there is a gap in knowledge regarding other possible demographic factors that could impact its prevalence. Thus, this study aims to investigate the influence of several factors such as tooth type, geographic location, ethnicity, sex, age and side, plus CBCT scanner voxel size, and field-of-view (FOV), on the worldwide prevalence of a lingual canal in central and lateral mandibular incisors. The null hypothesis being tested is that there is no difference in lingual canal prevalence when considering the previously mentioned variables.

MATERIALS AND METHODS

Research Protocol, Study Outcomes, and Sample Size Calculation

This cross-sectional study research protocol underwent a review process and was granted approval by the Ethics Committee of Faculdade de Medicina Dentária da Universidade de Lisboa, receiving the registration number CE-FMDUL202239, and followed the preferred reporting items for epidemiologic cross-sectional studies on root and root canal anatomy using CBCT technology[11]. The data collection was carried out by analyzing pre-existing CBCT imaging volumes, following the position statement of the American Association of Endodontists[12]. The CBCT examinations assessed in this study were conducted for treatment planning or surgical purposes. No CBCT volumes were obtained specifically for the purpose of this study, and patient identification was not accessed during the analysis.

Forty-four field observers from 5 continents and 44 different countries were involved in determining the proportion of the lingual canal (primary outcome) and the percentages of a second root and root canal configuration (secondary outcome) in both permanent central and lateral mandibular incisors (Table 1). All observers received written instructions on the study outcomes, definitions of anatomic landmarks, CBCT screening methodology, deadlines, bibliographic references, and exemplifications through sagittal views of CBCT scans. In addition, a tutorial video demonstrating the step-by-step protocol to be followed in the 3D volumes was prepared by the study coordinator (J.M.) and reviewed by two external nonobserver reviewers (M.A.V. and J.B.I.) to obtain scientific consensus. This

TABLE 1 - Geographic Location of the Assessed Sub-populations, CBCT Scanner Brand and Scanning Details, and Reasons for Teeth Exclusion

Region	City	Continent	CBCT database	Observer	CBCT model (Brand)	CBCT settings (μm, kV, mA)	CBCT FOV	Visualization software	Date of CBCT exam acquisition	Teeth excluded (reasons)
Argentina	Salta	America	IC/PC	P.E.	CS 8100 (Carestream, Atlanta)	75, 60-80, 2-15	Large	CS 3D Imaging (Carestream)	2021-2022	54 RCT
Australia	Melbourne	Oceania	IC	F.C.	Accuitomo 80 (Morita, Kyoto, Japan) i-CAT FLX (i-CAT, Hatfield, England)	80-160, 86-90, 6-8 200, 120, 5	Small	InteleViewer (InteleRad, Montreal, Canada)	2011-2022	23 artefacts 118 RCT 35 open apex 60 unclear number
Azerbaijan	Baku	Asia	AI	N.B.	Promax 3D (Planmeca, Helsinki, Finland)	200, 90, 5-6	Small Large	Romexis (Planmeca)	2016-2022	20 artefacts 10 RCT
Belgium	Brussels	Europe	PC	M.Z.	Newtom Giano (Newtom, Verona, Italy)	150, 90, 4	Small Large	NNT (Newtom)	2016-2022	6 artefacts
Brazil	Campinas	America	PC	L.B.	i-CAT FLX (i-CAT, Hatfield, England)	200, 90, 5	Large	i-CAT Vision (i-CAT)	2017-2022	17 artefacts
Canada	Toronto	America	IC/PC	E.L.	CS 9300 (Carestream, Atlanta)	90, 84, 5	Small	Invivo (Anatomage, Santa Clara, USA)	2010-2020	0
Chile	Santiago do Chile	America	IC	M.A.	CS 8100 (Carestream, Atlanta)	150, 82, 5	Large	CS 3D Imaging (Carestream)	2016-2022	115 artefacts 230 RCT 77 open apex
China	Suzhou	Asia	AI	F.P.	Kavo 3D eXame (Kavo Sybron, Munich, Germany)	200, 120, 4	Large	eXame vision (Kavo)	2017-2022	3 RCT 5 artefacts
Colombia	Bogota	America	IC/PC	C.E.	Promax 3D (Planmeca, Helsinki, Finland)	75, 90, 14	Small	Romexis (Planmeca)	2017-2022	0
Costa Rica	San Jose	America	PC	W.V.	X Mind Trium (Acteon, Merignac, France)	200, 85-90, 8	Large	X Mind Trium (Acteon)	2022	0
Ecuador	Quito	America	PC	J.C.	Scanora 3Dx (Soredex, Helsinki, Finland)	150-200, 90, 6	Large	On demand (Soredex)	2022	60 artefacts
Egypt	Cairo	Africa	PC	M.B.A.	Promax 3D (Planmeca, Helsinki, Finland)	150, 90, 12	Large	Romexis (Planmeca)	2017-2022	58 artefacts 330 RCT 23 open apex
England	London	Europe	PC	T.P.	CS 8100 (Carestream, Atlanta)	75-150, 90, 3-6	Small Large	CS 3D Imaging (Carestream)	2019-2022	52 artefacts
France	Paris	Europe	PC	F.S.	Orthophos SL (Dentsply, Ballaigues, Switzerland)	160, 85, 6	Small Large	Sidexis 4 (Dentsply)	2020-2022	10 artefacts
Germany	Bab Kreuznach	Europe	PC	H.H.	X800 (Morita, Kyoto, Japan) CS 9300 (Carestream, Atlanta) Kavo OP 3D Pro (Kavo	80, 100, 7 90, 84-90, 5-8 85, 90, 6	Small Large	i-Dixel (Morita) CS 3D Imaging (Carestream) OnDemand 3D (Kavo)	2012-2022	0

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TABLE 1 - Continued

Region	City	Continent	CBCT database	Observer	CBCT model (Brand)	CBCT settings (μm, kV, mA)	CBCT FOV	Visualization software	Date of CBCT exam acquisition	Teeth excluded (reasons)
					Sybron, Munich, Germany)					
Greece	Athens	Europe	IC	A.C.	Newtom VGI (Newtom, Verona, Italy)	150, 110, 8	Large	NNT (Newtom)	2022	0
Hungary	Budapest	Europe	PC	G.B.	Promax 3D (Planmeca, Helsinki, Finland) CS 9300 (Carestream, Atlanta) Vatech Green (Vatech, Gyeonggi-do, Korea)	200, 84, 15 200, 60-90, 2-15 200, 6-99, 9-16	Large	Romexis (Planmeca) CS 3D Imaging (Carestream) Vatech MAR (Vatech)	2018-2022	0
Iceland	Hafnarfjördur	Europe	PC	M.R.	i-CAT FLX (i-CAT, Hatfield, England)	200, 120, 4	Large	i-CAT Vision (i-CAT)	2017-2021	12 artefacts 8 RCT
India	Palakkad	Asia	PC	J.K.	Newtom Giano (Newtom, Verona, Italy)	150, 90, 4-9	Small Large	NNT (Newtom)	2018-2022	10 artefacts 12 open apex
Israel	Jerusalem	Asia	AI	A.S.	Alioth (Asahi Roentgen, Kyoto, Japan)	155, 85, 6	Large	RadiAnt Dicom Viewer (Medixant, Pozlan, Poland)	2018-2020	22 artefacts
Italy	Rome	Europe	IC	R.C.	Accuitomo 170 (Morita, Kyoto, Japan)	200, 88, 8	Small	i-Dixel (Morita)	2021-2022	0
Jamaica	Kingston	America	PC	S.T.	OP 300 (Kavo, Charlotte)	85, 57-90, 4-16	Large	Invivo (Anatomage, Santa Clara, USA)	2021-2022	30 artefacts
Japan	Tokyo	Asia	AI	S.M.	Accuitomo F17 (Morita, Kyoto, Japan)	80, 90, 7	Small Large	Infinitt Pacs (Infinitt Medical, Phillipsburg, USA)	2018-2022	4 artefacts
Kuwait	Salmiya	Asia	PC	H.O.	Promax 3D (Planmeca, Helsinki, Finland)	150, 90, 10	Small Large	Romexis (Planmeca)	2018-2022	266 artefacts
Kyrgyzstan	Bishkek	Asia	PC	Ar.M.	Promax 3D (Planmeca, Helsinki, Finland)	75-150, 90, 8-10	Small Large	Romexis (Planmeca)	2022	25 artefacts 6 open apex
Malaysia	Kuala Lumpur	Asia	AI	A.P.	Promax 3D (Planmeca, Helsinki, Finland)	200, 60-120, 1-14	Small Large	Romexis (Planmeca)	2019-2022	0
Mexico	León	America	IC/PC	R.A.	OP 300 (Kavo, Charlotte) Promax 3D (Planmeca, Helsinki, Finland)	75-200, 85-120, 8-12	Small Large	OnDemand 3D (Kavo) Romexis (Planmeca)	2016-2022	40 artefacts
Nigeria	Lagos	Africa	PC/AI	O.O.	CS 8100 (Carestream, Atlanta)	150, 90, 3	Small	CS 3D Imaging (Carestream)	2018-2022	17 artefacts 2 fractured teeth
Pakistan	Karachi	Asia	PC	M.N.	Promax 3D (Planmeca, Helsinki, Finland) CS 9600 (Carestream, Atlanta)	180-200, 85-90, 4-6	Large	Romexis (Planmeca) CS 3D Imaging (Carestream)	2018-2021	37 artefacts
Paraguay	Asunción	America	IC	C.H.	Imax 3D (Owandy, Beaubourg, France)	170, 84, 5	Large	CS 3D Imaging (Carestream)	2019-2022	36 artefacts 110 RCT

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TABLE 1 - Continued

Region	City	Continent	CBCT database	Observer	CBCT model (Brand)	CBCT settings (μm, kV, mA)	CBCT FOV	Visualization software	Date of CBCT exam acquisition	Teeth excluded (reasons)
Peru	Lima	America	IC	C.N.	OP 300 (Kavo, Charlotte)	200, 57-90, 4-16	Large	OnDemand 3D (Kavo)	2021	5 artefacts
Portugal	Lisbon	Europe	PC	J.M.	Promax 3D (Planmeca, Helsinki, Finland)	200, 84, 15	Large	Romexis (Planmeca)	2019-2022	22 artefacts
Romania	Bucharest	Europe	PC	S.N.	Promax 3D (Planmeca, Helsinki, Finland)	200, 85, 12	Large	Romexis (Planmeca)	2022	0
Russia	Yekaterinburg	Asia	PC	E.L.	CB 500 (Gendex, Hatfield, England)	200, 120, 3-8	Small Large	i-CAT Vision (i-CAT)	2021-2022	63 RCT 10 artefacts
Saudi Arabia	Riyadh	Asia	AI	H.A.	Promax 3D (Planmeca, Helsinki, Finland)	200, 84, 15	Large	Romexis (Planmeca)	2022	0
South Africa	Durban	Africa	PC	H.S.	CS 8100 (Carestream, Atlanta)	75-150, 90, 3	Small Large	CS 3D Imaging (Carestream)	2017-2022	7 artefacts
South Korea	Seoul	Asia	AI	S.C.	Alphard 300 (Asahi Roentgen Ind, Kyoto, Japan)	200, 60-100, 2-15	Large	Zetta PACS Viewer (Asahi)	2018-2022	0
Spain	Barcelona	Europe	PC	J.G.	CS 8100 (Carestream, Atlanta) Promax 3D (Planmeca, Helsinki, Finland)	150-200, 84-90, 4-6	Large	InteleViewer (InteleRad, Montreal, Canada)	2016-2022	40 artefacts
Syria	Damascus	Asia	PC	Z.A.	Viso G5 (Planmeca, Helsinki, Finland)	200, 60-120, 1-16	Large	Romexis (Planmeca)	2018-2022	40 absence of teeth
Thailand	Bangkok	Asia	AI	D.B.	Accuitomo 170 (Morita, Kyoto, Japan)	125, 90, 5	Small	OneVolumeViewer (Morita)	2021-2022	24 artefacts 30 RCT 16 open apex
Turkey	Bolu	Europe	AI	A.K.	5G XL (Newtom, Verona, Italy)	100-200, 110, 3-6	Small Large	(Newtom, Verona, Italy)	2019-2022	15 artefacts 35 RCT 16 open apex
Uruguay	Montevideo	America	IC	I.M.	Tropypan (Trophy, Atlanta) CS 9000 (Carestream, Atlanta)	100-150, 70-90, 3-10	Small Large	Trophy Imaging (Trophy) CS 3D Imaging (Carestream)	2020-2022	47 artefacts 117 RCT 9 open apex
USA	Vista	America	PC	Ad.M.	CS 9000 (Carestream, Atlanta)	76, 80-85, 10	Small	CS 3D Imaging (Carestream)	2022	3 artefacts
Venezuela	Caracas	America	PC	C.B.	CS 9000 (Carestream, Atlanta)	76, 60-90, 2-15	Small	CS 3D Imaging (Carestream)	2012-2022	60 artefacts 17 open apex

CBCT, cone-beam computer tomography; IC, imaging center; PC, private clinic; AI, academic institution; RCT, root canal treated.

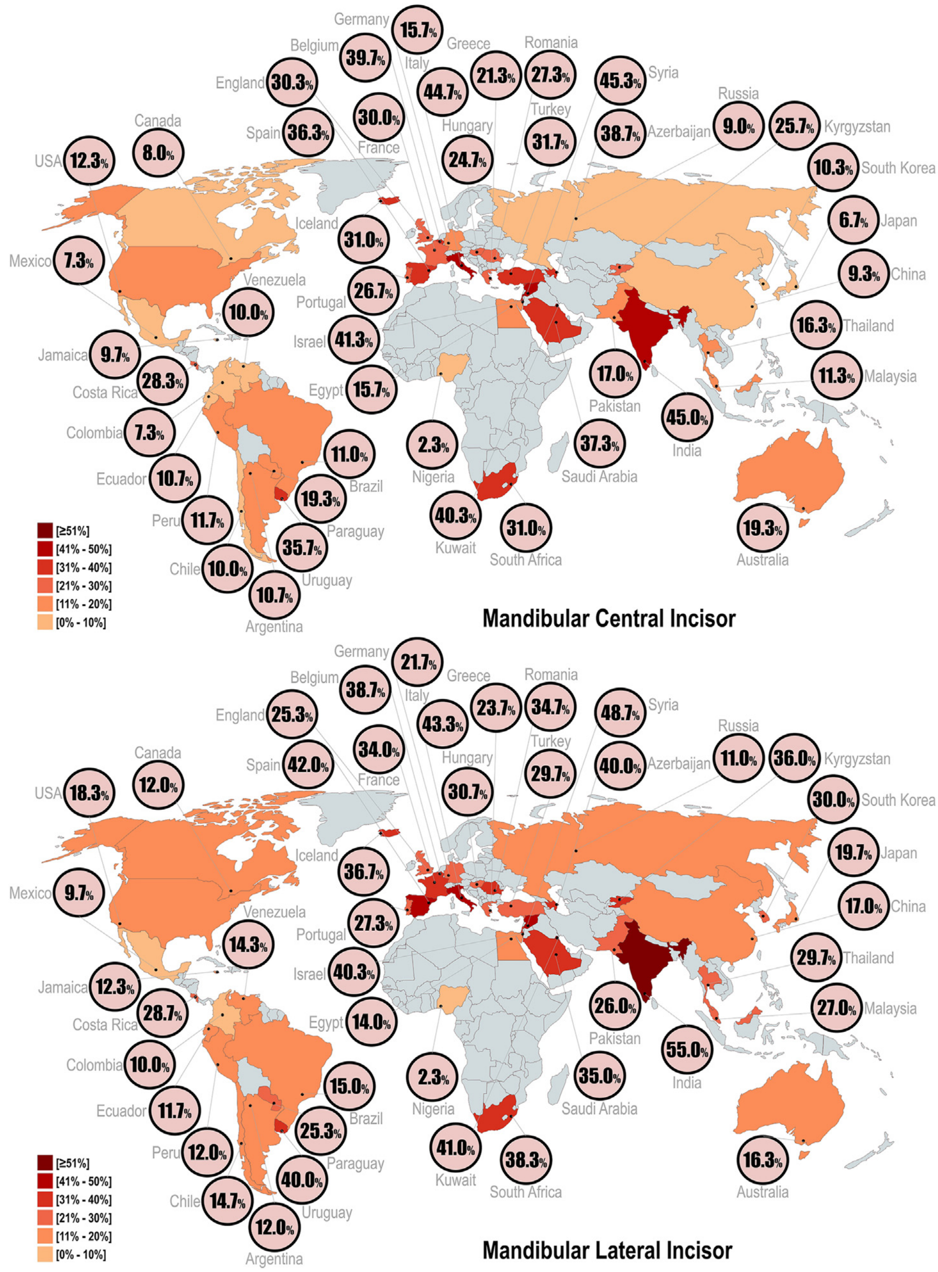

FIGURE 1 – Global prevalence of the lingual canal in mandibular central (*top*) and lateral (*bottom*) incisors. The *color scale* indicates the percentage of teeth with a lingual canal. The highest prevalence was observed in the southern and Middle East regions of the Asian continent and Europe for both tooth types.

information was used to calibrate all field observers simultaneously.

The final sample size was determined (https://sample-size.net/) based on a pilot assessment of 35 teeth in all 44 regions. To test the null hypothesis, regions with the highest discrepancy in primary outcome results were compared (Nigeria vs Syria for both groups of teeth). A confidence level of 95%, a power of 80%, and an effect size of 43.0% and 46.3% for the prevalence of a second canal in central and lateral incisors, respectively, were considered. As a result, a final sample size of 19 and 17 teeth was calculated. However, to ensure greater statistical power and compensate for the fact that all regions were not compared to each other, the final sample size was increased to 300 teeth per group and per region.

Sample Selection, Data Acquisition, and Screening Method

To ensure representation of the sub-population being assessed, a convenience sample of patients who attended health centers in the regions of interest was included in this study. Only 1 observer was permitted per region, but multiple CBCT devices were allowed, including both small and large FOV volumes and CBCT scanner brands, as long as the voxel size was equal to or less than 200 μm. Each observer was instructed to review pre-existing CBCT datasets in a consecutive manner following an alphabetic or numeric chart order until the sample size of 300 incisors per group was achieved. Demographic information, such as sex and age, was also collected. Teeth that met the exclusion criteria, such as those with

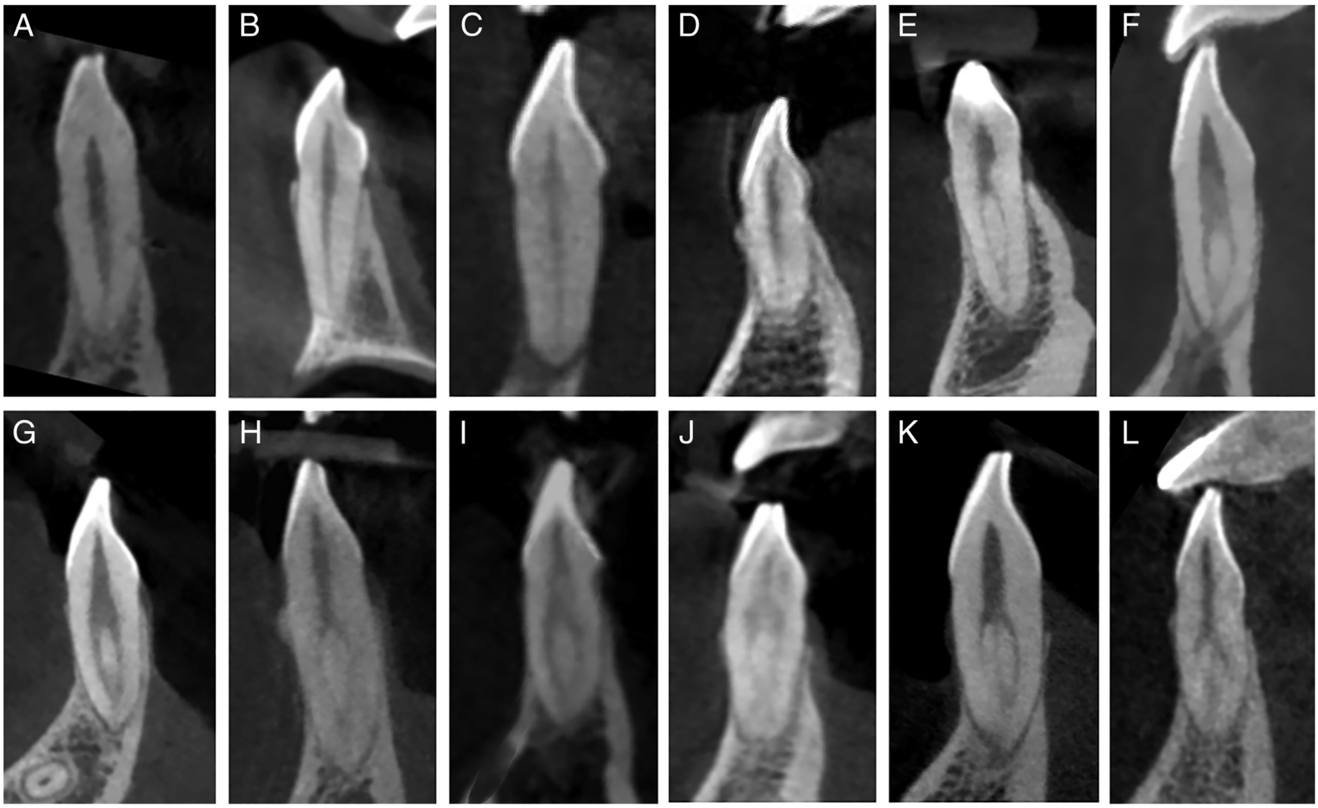

FIGURE 2 – Representative images of various root canal anatomic configurations found in different countries. The configurations include a single canal noted in Belgium (*A*), Argentina (*B*), Syria (*C*), and Malaysia (*D*); two independent canals with single exit observed in England (*E*), Turkey (*F*), South Africa (*G*), France (*H*), and Peru (*I*); two independent canals with multiple exit recorded in Portugal (*J*); more than two canals observed in Brazil (*K*); and a 2-rooted incisor found in Spain (*L*).

incomplete root formation or root resorption, severe decay, previous root canal treatment, uncertainty in tooth numbering, lack of demographic information, compromised imaging visualization due to artifacts, or unsalvageable roots (including root fractures), were not included in the study. Table 1 summarizes the number and the reasons for exclusions in each region.

The method for CBCT volume assessment involved aligning the long axis of the tooth being analyzed with the reference lines of the visualization software in three dimensions, followed by an anatomic interpretation on the coronal, sagittal, and axial planes. To enhance image quality and interpretation, observers were permitted to adjust visualization settings, such as enabling noise reduction or specific filters. Each selected tooth was recorded with the following information: tooth number (according to the Universal Numbering System), number of roots (1 or 2), presence of a lingual canal (yes/no) (primary outcome), and canal configuration. The latter was classified as single canal, 2 independent canals (multiple foramina), 2 confluent canals (single foramen), or more than 2 root canals. Additionally, pertinent demographic data including sex (male or female), age, and ethnic group (pertaining to the ethnic group of patients attending the health center unit and not necessarily the country) were also documented for each case. It is important to note that the ethnic group classification was based on the patient profiles within the health center unit, rather than representing the entire country's ethnic composition. The classification encompassed three categories: "all (ethnicity)" when all patients belonged to a specific ethnic group, "mostly (ethnicity)" when the vast majority of individuals were from a particular ethnic group, with only a few exceptions from other ethnicities, and "mixed (ethnicity)" when multiple ethnicities were observed, irrespective of the presence or absence of a dominant ethnic group.

If any difficulty or uncertainty arose during the classification of anatomical parameters, observers were instructed to contact the study coordinator to reach a final consensus. To prevent individual assessment bias, all participants were blinded to the results of the other observers. The data were collected in a single Excel sheet (Microsoft Office v15.0.5537, Redmond, WA) using a predetermined template that was equal for all observers. The sheet was designed to enable crosschecking and double-checking of the most critical information and to allow for export to statistical software. Any nonconformities were sent back to the observer with a clarification request and correction if necessary. The results of the check for dataset nonconformities are presented in Supplemental Table S1. The two external nonobserver reviewers regularly monitored the initially set intermediate and final deadlines to ensure that the field observers were working at an equal pace and were committed to achieving the objectives.

Reliability Measurements

Five measurements of individual and group reliability were performed in this study. Prior to final data collection, both intra and interrater reliability tests were conducted. Intrarater reliability was evaluated by comparing the scores of 2 assessments conducted on the same regional dataset within a 1-month interval, with a total of 35 mandibular central incisors and 35 mandibular lateral incisors (11.7% of selected specimens) being screened

TABLE 2 - Patient Demographics and Morphological Characteristics of the Mandibular Central Incisor Root Canal System

	Demographics					Anatomic configuration					
Region	Sample size (patients)	Ethnic groups	Average age (y) [range]	Proportion of males	Proportion of females	Sample size (teeth)	Two roots	Single canal	Two independent canals (multiple exits)	Two confluent canals (single exit)	More than two canals
Argentina	151	Mixed (Hispanic and American Natives)	48 (22-76)	74 (49.0%)	77 (51.0%)	300	0 (0%)	268 (89.3%)	—	32 (10.7%)	—
Australia	185	Mixed (Asians and Caucasians)	49 (9-87)	76 (41.1%)	109 (58.9%)	300	0 (0%)	242 (80.7%)	1 (0.3%)	57 (19.0%)	—
Azerbaijan	152	Mostly Caucasians	44 (14-70)	78 (51.3%)	74 (48.7%)	300	4 (1.3%)	184 (61.4%)	10 (3.3%)	106 (35.3%)	—
Belgium	154	Mixed (Asians, Caucasians and Africans)	51 (15-79)	54 (35.1%)	100 (64.9%)	300	0 (0%)	181 (60.3%)	9 (3.0%)	110 (36.7%)	—
Brazil	151	Mixed (Caucasians (non-hispanic) with Africans, American Natives and Asians)	40 (16-85)	48 (31.8%)	103 (68.2%)	300	1 (0.3%)	267 (89.0%)	11 (3.7%)	17 (5.7%)	5 (1.6%)
Canada	153	Mixed (Caucasian, Asian and African-Canadian)	33 (10-73)	76 (49.7%)	77 (50.3%)	300	0 (0%)	276 (92.0%)	1 (0.3%)	23 (7.7%)	—
Chile	153	Mostly Caucasians (Hispanic origin)	39 (10-77)	49 (32.0%)	104 (68.0%)	300	0 (0%)	270 (90.0%)	1 (0.3%)	29 (9.7%)	—
China	300	Asians (Han ethnicity)	36 (14-78)	140 (46.7%)	160 (53.3%)	300	1 (0.3%)	272 (90.6%)	8 (2.7%)	20 (6.7%)	—
Colombia	156	Mostly Caucasians (Hispanic origin)	55 (18-84)	58 (37.2%)	98 (62.8%)	300	0 (0%)	278 (92.7%)	4 (1.3%)	18 (6.0%)	—
Costa Rica	152	Mostly Caucasians (Hispanic origin)	37 (24-49)	42 (27.6%)	110 (72.4%)	300	0 (0%)	215 (71.7%)	4 (1.3%)	81 (27.0%)	—
Ecuador	151	Mostly Caucasians (Hispanic origin)	52 (19-86)	53 (35.1%)	98 (64.9%)	300	0 (0%)	268 (89.3%)	5 (1.7%)	27 (9.0%)	—
Egypt	155	Africans (Egyptians)	44 (23-77)	71 (45.8%)	84 (54.2%)	300	0 (0%)	253 (84.3%)	3 (1.0%)	44 (14.7%)	—
England	153	Mostly Caucasians	63 (20-86)	63 (41.2%)	90 (58.8%)	300	0 (0%)	209 (69.7%)	4 (1.3%)	87 (29.0%)	—
France	154	Mostly Caucasians	48 (15-86)	73 (47.4%)	81 (52.6%)	300	0 (0%)	210 (70.0%)	1 (0.3%)	89 (29.7%)	—
Germany	164	Caucasians	57 (12-85)	51 (31.1%)	113 (68.9%)	300	0 (0%)	253 (84.4%)	4 (1.3%)	43 (14.3%)	—
Greece	151	Caucasians	48 (10-86)	69 (45.7%)	82 (54.3%)	300	8 (2.7%)	236 (78.7%)	27 (9.0%)	37 (12.3%)	—
Hungary	155	Mostly Caucasians	47 (15-81)	67 (43.2%)	88 (56.8%)	300	0 (0%)	226 (75.4%)	1 (0.3%)	73 (24.3%)	—
Iceland	300	Mostly Caucasians	33 (16-76)	138 (46.0%)	162 (54.0%)	300	0 (0%)	207 (69.0%)	3 (1.0%)	90 (30.0%)	—
India	291	Asians (Indian origin)	39 (21-71)	135 (46.4%)	156 (53.6%)	300	1 (0.3%)	165 (55.0%)	18 (6.0%)	117 (39.0%)	—
Israel	171	Mixed (Jewish, Arabs and Africans)	34 (15-64)	84 (49.1%)	87 (50.9%)	300	0 (0%)	176 (58.7%)	—	124 (41.3%)	—
Italy	155	Mostly Caucasians	31 (14-96)	69 (44.5%)	86 (55.4%)	300	0 (0%)	166 (55.3%)	—	134 (44.7%)	—
Jamaica	154	Mixed (Africans, Asians and Caucasians)	31 (16-61)	43 (27.9%)	111 (72.1%)	300	0 (0%)	271 (90.3%)	—	29 (9.7%)	—
Japan	300	Asians	53 (20-87)	126 (42.0%)	174 (58.0%)	300	0 (0%)	280 (93.4%)	1 (0.3%)	19 (6.3%)	—
Kuwait	153	Mixed (Asians and Caucasians)	42 (12-78)	67 (43.8%)	86 (56.2%)	300	0 (0%)	179 (59.7%)	10 (3.3%)	111 (37.0%)	—
Kyrgyzstan	155	Mostly Asians	38 (9-77)	50 (32.3%)	105 (67.7%)	300	0 (0%)	223 (74.4%)	24 (8.0%)	52 (17.3%)	1 (0.3%)

(*continued on next page*)

TABLE 2 - Continued

	Demographics					Anatomic configuration					
Region	**Sample size (patients)**	**Ethnic groups**	**Average age (y) [range]**	**Proportion of males**	**Proportion of females**	**Sample size (teeth)**	**Two roots**	**Single canal**	**Two independent canals (multiple exits)**	**Two confluent canals (single exit)**	**More than two canals**
Malaysia	264	Mostly Asians	38 (15-77)	116 (43.9%)	148 (56.1%)	300	0 (0%)	266 (88.6%)	2 (0.7%)	32 (10.7%)	—
Mexico	152	Mostly Caucasians (Hispanic origin)	43 (10-76)	53 (34.9%)	99 (65.1%)	300	4 (1.3%)	278 (92.6%)	5 (1.7%)	17 (5.7%)	—
Nigeria	152	Africans	42 (14-83)	74 (48.7%)	78 (51.3%)	300	0 (0%)	293 (97.7%)	—	7 (2.3%)	—
Pakistan	154	Asians	35 (16-65)	75 (48.7%)	79 (51.3%)	300	0 (0%)	249 (83.0%)	—	51 (17.0%)	—
Paraguay	155	Mostly Caucasians (Hispanic origin)	45 (13-82)	65 (41.9%)	90 (58.1%)	300	0 (0%)	242 (80.7%)	—	58 (19.3%)	—
Peru	152	Mixed (Hispanic origin and American Natives)	35 (16-87)	64 (42.1%)	88 (57.9%)	300	0 (0%)	265 (88.3%)	3 (1.0%)	32 (10.7%)	—
Portugal	152	Mostly Caucasians	50 (19-82)	41 (27.0%)	111 (73.0%)	300	0 (0%)	220 (73.4%)	4 (1.3%)	76 (25.3%)	—
Romania	153	Mostly Caucasians	42 (12-73)	64 (41.8%)	89 (58.2%)	300	0 (0%)	218 (72.7%)	1 (0.3%)	81 (27.0%)	—
Russia	151	Mixed (Russians, Ukrainians, Tatars, Bashkirs, Jews, Belarusians and Kazakh)	32 (12-73)	55 (36.4%)	96 (63.6%)	300	0 (0%)	273 (91.0%)	4 (1.3%)	23 (7.7%)	—
Saudi Arabia	154	Mostly Arabs	38 (16-83)	72 (46.8%)	82 (53.2%)	300	0 (0%)	188 (62.6%)	8 (2.7%)	104 (34.7%)	—
South Africa	152	Mixed (Asians of Indian origin, Caucasians and Africans)	45 (10-92)	73 (48.0%)	79 (52.0%)	300	0 (0%)	207 (69.0%)	3 (1.0%)	90 (30.0%)	—
South Korea	300	Asians	34 (12-84)	163 (54.3%)	137 (45.7%)	300	0 (0%)	269 (89.7%)	—	31 (10.3%)	—
Spain	152	Caucasians	40 (15-87)	70 (46.1%)	82 (53.9%)	300	3 (1.0%)	191 (63.7%)	16 (5.3%)	93 (31.0%)	—
Syria	151	Arabs	41 (16-74)	67 (44.4%)	84 (55.6%)	300	0 (0%)	164 (54.7%)	—	136 (45.3%)	—
Thailand	163	Asians	46 (11-85)	73 (44.8%)	90 (55.2%)	300	0 (0%)	251 (83.7%)	1 (0.3%)	48 (16.0%)	—
Turkey	157	Mostly Caucasians	34 (14-68)	61 (38.9%)	96 (61.1%)	300	0 (0%)	205 (68.4%)	1 (0.3%)	94 (31.3%)	—
Uruguay	154	Mixed (Hispanic origin and Africans)	47 (12-82)	60 (39.0%)	94 (61.0%)	300	2 (0.7%)	193 (64.3%)	9 (3.0%)	98 (32.7%)	—
USA	173	Mostly Caucasians	58 (13-93)	61 (35.3%)	112 (64.7%)	300	0 (0%)	263 (87.6%)	2 (0.7%)	35 (11.7%)	—
Venezuela	184	Mostly Caucasians (Hispanic origin)	50 (13-84)	66 (35.9%)	118 (64.1%)	300	0 (0%)	270 (90.0%)	—	30 (10.0%)	—
Total	7.694	Multi-ethnic	—	3.227 (41.9%)	4.467 (58.1%)	13.200	24 (0.2%)	10280 (77.9%)	209 (1.6%)	2705 (20.5%)	6 (0.05%)

TABLE 3 - Patient Demographics and Morphological Characteristics of the Mandibular Lateral Incisor Root Canal System

	Demographics					Anatomic configuration					
Region	**Sample size (patients)**	**Ethnic groups**	**Average age (y) (range)**	**Proportion of males**	**Proportion of females**	**Sample size (teeth)**	**Two roots**	**Single canal**	**Two independent canals (multiple exits)**	**Two confluent canals (single exit)**	**More than two canals**
Argentina	151	Mixed (Hispanic and American Natives)	48 (22-76)	73 (48.3%)	78 (51.7%)	300	0 (0%)	264 (88.0%)	—	36 (12.0%)	—
Australia	187	Mixed (Asians and Caucasians)	50 (9-87)	83 (44.4%)	104 (55.6%)	300	0 (0%)	251 (83.7%)	1 (0.3%)	48 (16.0%)	—
Azerbaijan	153	Mostly Caucasians	44 (14-70)	80 (52.3%)	73 (47.7%)	300	0 (0%)	180 (60.0%)	2 (0.7%)	118 (39.3%)	—
Belgium	153	Mixed (Asians, Caucasians and Africans)	51 (15-79)	53 (34.6%)	100 (65.4%)	300	1 (0.3%)	184 (61.3%)	5 (1.7%)	111 (37.0%)	—
Brazil	151	Mixed (Caucasians (non-hispanic) with Africans, American Natives and Asians)	40 (16-85)	48 (31.8%)	103 (68.2%)	300	2 (0.7%)	255 (85.0%)	16 (5.4%)	28 (9.3%)	1 (0.3%)
Canada	154	Mixed (Caucasian, Asian and African-Canadian)	33 (10-73)	75 (48.7%)	79 (51.3%)	300	1 (0.3%)	264 (88.0%)	3 (1.0%)	33 (11.0%)	—
Chile	152	Mostly Caucasians (Hispanic origin)	40 (10-80)	47 (30.9%)	105 (69.1%)	300	0 (0%)	256 (85.4%)	1 (0.3%)	43 (14.3%)	—
China	300	Asians (Han ethnicity)	36 (14-78)	140 (46.7%)	160 (53.3%)	300	0 (0%)	249 (83.0%)	11 (3.7%)	40 (13.3%)	—
Colombia	162	Mostly Caucasians (Hispanic origin)	55 (18-84)	65 (40.1%)	97 (59.9%)	300	0 (0%)	270 (90.0%)	5 (1.7%)	25 (8.3%)	—
Costa Rica	151	Mostly Caucasians (Hispanic origin)	37 (24-49)	42 (27.8%)	109 (72.2%)	300	0 (0%)	214 (71.3%)	3 (1.0%)	83 (27.7%)	—
Ecuador	151	Mostly Caucasians (Hispanic origin)	52 (19-86)	56 (37.1%)	95 (62.9%)	300	0 (0%)	265 (88.3%)	—	35 (11.7%)	—
Egypt	154	Africans (Egyptians)	44 (16-77)	69 (44.8%)	85 (55.2%)	300	0 (0%)	258 (86.0%)	2 (0.7%)	40 (13.3%)	—
England	154	Mostly Caucasians	63 (20-86)	62 (40.3%)	92 (59.7%)	300	0 (0%)	224 (74.6%)	5 (1.7%)	71 (23.7%)	—
France	153	Mostly Caucasians	49 (15-86)	73 (47.7%)	80 (52.3%)	300	1 (0.3%)	198 (66.0%)	5 (1.7%)	97 (32.3%)	—
Germany	177	Caucasians	58 (12-85)	58 (32.8%)	119 (67.2%)	300	1 (0.3%)	235 (78.4%)	4 (1.3%)	61 (20.3%)	—
Greece	150	Caucasians	48 (10-86)	67 (44.7%)	83 (55.3%)	300	10 (3.0%)	229 (76.3%)	32 (10.7%)	39 (13.0%)	—
Hungary	155	Mostly Caucasians	47 (15-81)	65 (41.9%)	90 (58.1%)	300	1 (0.3%)	208 (69.3%)	3 (1.0%)	89 (29.7%)	—
Iceland	300	Mostly Caucasians	33 (16-76)	138 (46.0%)	162 (54.0%)	300	0 (0%)	190 (63.4%)	4 (1.3%)	106 (35.3%)	—
India	291	Asians (India origin)	39 (21-71)	135 (46.4%)	156 (53.6%)	300	0 (0%)	135 (45.0%)	29 (9.7%)	136 (45.3%)	—
Israel	171	Mixed (Jewish, Arabs and Africans)	34 (15-64)	84 (49.1%)	87 (50.9%)	300	0 (0%)	179 (59.7%)	—	121 (40.3%)	—
Italy	157	Mostly Caucasians	32 (14-93)	69 (43.9%)	88 (56.1%)	300	0 (0%)	170 (56.7%)	—	130 (43.3%)	—
Jamaica	152	Mixed (Africans, Asians and Caucasians)	31 (16-61)	41 (27.0%)	111 (73.0%)	300	0 (0%)	263 (87.7%)	—	37 (12.3%)	—
Japan	300	Asians	53 (20-87)	126 (42.0%)	174 (58.0%)	300	2 (0.7%)	241 (80.3%)	5 (1.7%)	54 (18.0%)	—
Kuwait	156	Mixed (Asians and Caucasians)	42 (12-78)	66 (42.3%)	90 (57.7%)	300	0 (0%)	177 (59.0%)	18 (6.0%)	105 (35.0%)	—
Kyrgyzstan	154	Mostly Asians	37 (9-77)	51 (33.1%)	103 (66.9%)	300	0 (0%)	192 (64.0%)	22 (7.3%)	86 (28.7%)	—
Malaysia	264	Mostly Asians	38 (15-77)	116 (43.9%)	148 (56.1%)	300	3 (1.0%)	219 (73.0%)	12 (4.0%)	69 (23.0%)	—

(*continued on next page*)

TABLE 3 - Continued

	Demographics					Anatomic configuration					
Region	Sample size (patients)	Ethnic groups	Average age (y) (range)	Proportion of males	Proportion of females	Sample size (teeth)	Two roots	Single canal	Two independent canals (multiple exits)	Two confluent canals (single exit)	More than two canals
Mexico	152	Mostly Caucasians (Hispanic origin)	43 (17-76)	52 (34.2%)	100 (65.8%)	300	7 (2.3%)	271 (90.4%)	7 (2.3%)	22 (7.3%)	—
Nigeria	154	Africans	42 (9-81)	75 (48.7%)	79 (51.3%)	300	0 (0%)	293 (97.7%)	—	7 (2.3%)	—
Pakistan	151	Asians	35 (16-65)	74 (49.0%)	77 (51.0%)	300	0 (0%)	222 (74.0%)	—	78 (26.0%)	—
Paraguay	154	Mostly Caucasians (Hispanic origin)	45 (13-82)	65 (42.2%)	89 (57.8%)	300	0 (0%)	224 (74.7%)	—	76 (25.3%)	—
Peru	151	Mixed (Hispanic origin and American Natives)	35 (15-87)	65 (43.0%)	86 (57.0%)	300	0 (0%)	264 (88.0%)	1 (0.3%)	35 (11.7%)	—
Portugal	153	Mostly Caucasians	50 (19-82)	41 (26.8%)	112 (73.2%)	300	0 (0%)	218 (72.6%)	2 (0.7%)	80 (26.7%)	—
Romania	157	Mostly Caucasians	43 (12-73)	65 (41.4%)	92 (58.6%)	300	0 (0%)	196 (65.4%)	1 (0.3%)	103 (34.3%)	—
Russia	151	Mixed (Russians, Ukrainians, Tatars, Bashkirs, Jews, Belarusians and Kazakh)	32 (12-73)	56 (37.1%)	95 (62.9%)	300	0 (0%)	267 (89.0%)	7 (2.3%)	26 (8.7%)	—
Saudi Arabia	154	Mostly Arabs	39 (17-81)	76 (49.4%)	78 (50.6%)	300	0 (0%)	195 (65.0%)	6 (2.0%)	99 (33.0%)	—
South Africa	155	Mixed (Asians of Indian origin, Caucasians and Africans)	45 (10-92)	76 (49.0%)	79 (51.0%)	300	0 (0%)	185 (61.7%)	4 (1.3%)	111 (37.0%)	—
South Korea	300	Asians	34 (12-84)	163 (54.3%)	137 (45.7%)	300	0 (0%)	210 (70.0%)	—	90 (30.0%)	—
Spain	152	Caucasians	40 (15-87)	71 (46.7%)	81 (53.3%)	300	0 (0%)	174 (58.0%)	20 (6.7%)	104 (34.6%)	2 (0.7%)
Syria	151	Arabs	41 (16-74)	67 (44.4%)	84 (55.6%)	300	0 (0%)	154 (51.3%)	—	146 (48.7%)	—
Thailand	174	Asians	46 (11-85)	73 (41.9%)	101 (58.1%)	300	0 (0%)	211 (70.3%)	5 (1.7%)	84 (28.0%)	—
Turkey	157	Mostly Caucasians	33 (14-68)	60 (38.2%)	97 (61.8%)	300	1 (0.3%)	211 (70.4%)	4 (1.3%)	85 (28.3%)	—
Uruguay	153	Mixed (Hispanic origin and Africans)	48 (12-82)	62 (40.5%)	91 (59.5%)	300	4 (1.3%)	180 (60.0%)	16 (5.3%)	104 (34.7%)	—
USA	197	Mostly Caucasians	59 (13-93)	66 (33.5%)	131 (66.5%)	300	0 (0%)	245 (81.6%)	2 (0.7%)	53 (17.7%)	—
Venezuela	212	Mostly Caucasians (Hispanic origin)	50 (13-85)	79 (37.3%)	133 (62.7%)	300	0 (0%)	257 (85.7%)	—	43 (14.3%)	—
Total	7.781	Multi-ethnic	—	3.268 (42.0%)	4.513 (58.0%)	13.200	34 (0.3%)	9.747 (73.8%)	263 (2.0%)	3.187 (24.1%)	3 (0.02%)

twice in each region regarding the presence of a lingual canal (primary outcome). Each observer's individual reliability was determined using Cohen's kappa value. For interrater reliability, all 44 field observers evaluated the same 18 mandibular central incisors from 14 CBCT volumes (not included in any regional dataset) regarding the presence of a lingual canal (primary outcome), with the percentage of agreement and intraclass correlation coefficient used to determine group reliability. Additionally, each individual result was compared to a consensus classification obtained by 2 experienced external evaluators (the non-observer reviewers) using the Cohen's kappa test. The lower acceptable limit was defined as 0.61 (substantial agreement[13]) for both intraclass correlation coefficient and Cohen's kappa value, and the observers were asked to review the study protocol and repeat the evaluations if this limit was not reached. Both intra and interrater analyses followed the predefined CBCT screening methodology and were conducted during the same time interval by all field observers.

Statistical Analysis

Due to the multicenter nature of this study, a meta-analysis based on random-effects model[14] was conducted using the OpenMeta [Analyst] v.10.10 software (http://www.cebm.brown.edu/openmeta/). The primary outcome (prevalence of a lingual root canal) for both groups of teeth was expressed as odds ratios and untransformed proportions with 95% confidence interval (CI) forest plots. To investigate potential sources of heterogeneity, metaregression was also performed. The level of statistical significance was set at 5%.

RESULTS

The total sample size of this study comprises 26,400 mandibular teeth, with 13,200 from each type of tooth (central and lateral incisors). The data on central incisors were obtained from 7694 patients (3,227 males and 4,467 females), whereas the data on lateral incisors were gathered from 7,781 patients (3,268 males and 4,513 females). The prevalence of the lingual canal in the mandibular central incisor worldwide was found to be 21.9% (95% CI, 18.4%–25.4%), with a range of 2.3% (95% CI, 0.06%–4.0%) in Nigeria to 45.3% (95% CI, 39.7%–51.0%) in Syria. For the lateral incisor, the global proportion was 26.0% (95% CI, 22.1%-29.9%), ranging from 2.3% (95% CI, 0.06%-4.0%) in Nigeria to 55.0% (95% CI, 49.4%–60.6%) in India. The difference in the overall prevalence between the 2 teeth was not considered statistically significant ($P > .05$) (Fig. 1, Supplemental Fig. S1). The prevalence of 2 confluent canals merging into a single foramen was the most common multiple root canal anatomic configuration (central incisor: 20.5%; lateral incisor: 24.1%), while the occurrence of more than 2 root canals or double-root anatomy was a rare finding (Fig. 2, Tables 2 and 3).

The statistical analysis revealed significant differences in the presence of the lingual canal among different global regions. The central incisor showed the lowest prevalence in the eastern Asian continent with 12.4% (95% CI, 8.5%–16.3%), while the southern and Middle East areas of the Asian continent showed the highest prevalence with 37.8% (95% CI, 29.4%–46.2%) ($P < .05$). Similarly, for the lateral incisor, the lowest prevalence was observed in Oceania with 16.3% (95% CI, 12.2%–20.5%), while the southern and Middle East areas of the Asian continent showed the highest prevalence with 40.8% (95% CI, 33.7%–47.9%) ($P < .05$) (Fig. 3).

The analysis of ethnic groups, which excluded data from mixed sub-populations, showed significant differences between the groups ($P < .05$). The proportions of the lingual canal were lowest among Africans, Asians, and Hispanics; while Caucasians, Indians, and Arabs had the highest proportions for both teeth (Fig. 4).

Males had a higher prevalence of lingual canals compared to females (central: 24.5% [95% CI, 20.5%–28.5%] vs 20.1% [95% CI, 16.7%–23.5%]; lateral: 27.7% [95% CI, 23.5%–31.9%] vs 24.9% [95% CI, 20.9%–29.0%]), but these differences were not statistically significant ($P > .05$) (Supplemental Fig. S2). However, males had a significantly higher odds ratio of having a lingual canal compared to females ($P < .05$) for both central (1.334 [95% CI, 1.146–1.552]) and lateral (1.178 [95% CI, 1.052–1.318]) incisors (Supplemental Fig. S3).

The evaluated teeth exhibited the lowest prevalence of lingual canals in patients aged over 61 years ($P < .05$) and the highest prevalence in the 21–40 years age group ($P < .05$) (Supplemental Fig. S4), while the prevalence was found to be similar for the left and right sides ($P > .05$) (Supplemental Fig. S5).

Intrarater and external observer consensus reliability tests indicated that all observers achieved substantial (0.61–0.80) to perfect (1.00) agreements. The interrater test showed that the group achieved almost perfect agreement (0.831) with a high percentage of agreement (95.7%). The nonconformities in the dataset ranged from 0% to 1.28% (Supplemental Table S1).

Regarding the possible influence of voxel size on the outcomes, a metaregression using the worldwide data revealed an Omnibus P value of 0.011 and 0.009 for the central and lateral incisors, respectively. These results did not allow for the exclusion of voxel size as a possible source of heterogeneity at this stage. However, further analysis was conducted by subdividing the overall data into geographic regions in order to control for the impact of voxel size interpretation, which was previously considered a statistically significant variable. The results showed an Omnibus P value of 0.078 for the central incisor and 0.310 for the lateral incisor, indicating that voxel size can be excluded as a possible source of heterogeneity in the results.

A metaregression was also conducted to evaluate the impact of the FOV size on the outcomes. The Omnibus P values, based on the worldwide data, were found to be 0.161 and 0.114 for central and lateral incisors, respectively. However, when data were further analyzed by subdividing it into geographic regions (as a confounding variable), the P values increased significantly, nearly reaching a score of 1 (central: 0.935; lateral: 0.953). These analyses collectively indicate that the FOV size can be excluded as a potential source of heterogeneity.

DISCUSSION

Previous studies have reported differences in mineralized tissues or organs among ethnic groups. African men, for example, have been found to have greater bone mineral mass and bone density, longer femurs, and a lower spine-to-femur ratio compared to Caucasian men[15]. Additionally, East Asians have been shown to have a higher mediolateral dimension of the tibia bone compared to Caucasians[16]. Ethnic differences in dental and alveolar arches have also been reported, with Africans having wider and longer arches than Caucasians[17] and Caucasians, Arabians, and Asians exhibiting different arch forms[18,19]. Ethnic characteristics can also influence the shape of teeth crowns and roots[20]. For instance, the *radix entomolaris* in mandibular first molars and single-rooted configuration in mandibular second molars are most commonly found in East Asians[8,21]. Moreover, differences in the root canal system space have been reported not only between sub-populations from different geographic regions but also between various ethnic and age groups, indicating that demographic factors significantly influence the internal anatomy of teeth[21]. The current study demonstrated significant variations in the prevalence of lingual canals in mandibular incisors among individuals belonging to

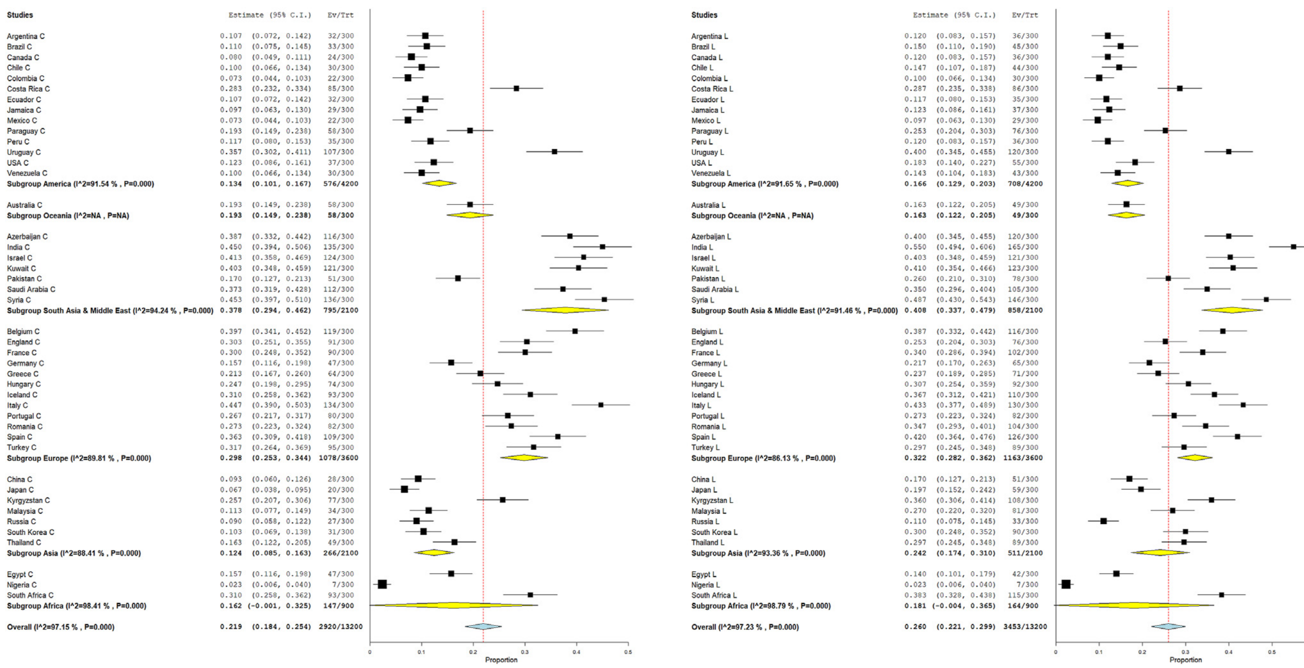

FIGURE 3 – Proportion forest plots depicting the prevalence of the lingual root canal on the mandibular central (*left*) and lateral (*right*) incisors across various geographic regions. The plot shows the point estimate for each region as a square, with the size of the square proportional to the weight assigned to that study. The *horizontal line crossing each square* represents the 95% confidence interval (CI) for the point estimate. Regions with lower proportions, such as East Asia, Oceania, and America, are depicted toward the bottom of the plot, while those with higher proportions, such as Europe and South Asia and Middle East, are shown toward the top.

different geographic regions, ethnicities, sexes, and age groups. However, no significant differences were observed between tooth groups or sides, thereby partly refuting the null hypothesis.

Notwithstanding the prevalence of a particular anatomical dental feature may vary within a given region or country population, which may be related to the representativeness of the sub-population under analysis, the global assessment of multiple studies is expected to be consistent. Previous studies with a CBCT resolution equivalent to that of the present investigation (≤200 μm voxel size) have reported on the prevalence of the lingual canal of the mandibular central incisor in Belgium, Italy, Portugal and Israel, with percentages of 38.5%[22], 45.0%[23], 27.4%,[10] and 40.5%[5], respectively. These percentages are similar to those found in the present study for the same

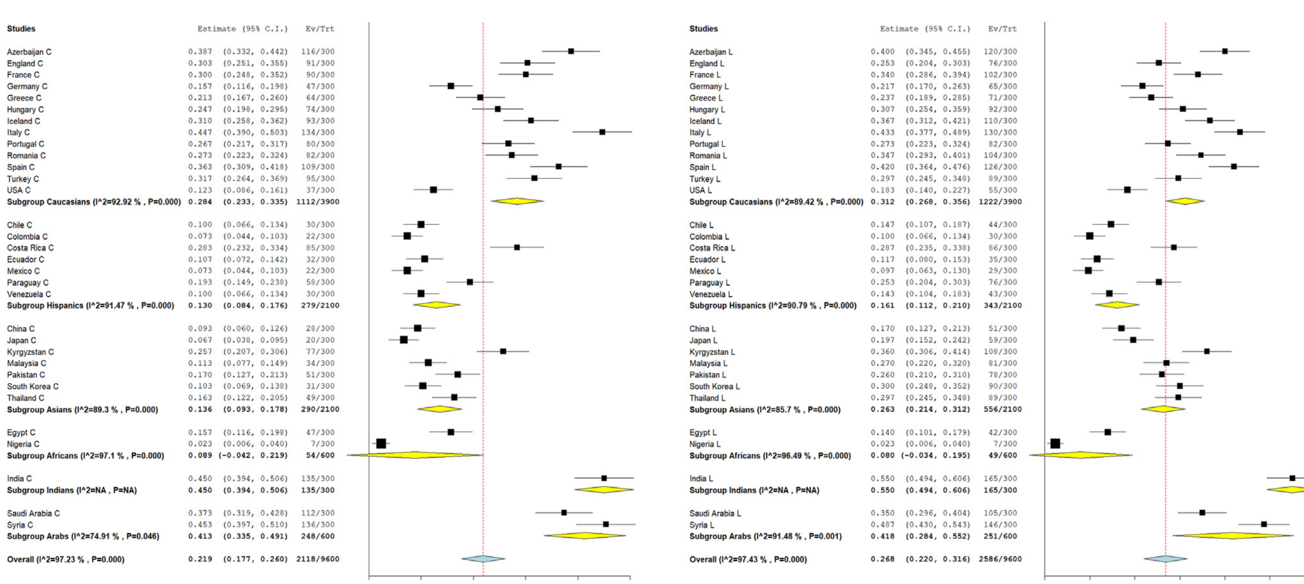

FIGURE 4 – The proportion forest plots show the prevalence of lingual root canals on the mandibular central (*left*) and lateral (*right*) incisors by ethnic group. The analysis revealed that Hispanics, Asians, and Africans had the lowest percentages of lingual canals; while Arabs, Indians, and Caucasians had the highest.

countries (39.7%, 44.7%, 26.7%, and 41.3%). In previous studies conducted in South America, specifically in Chile[22] and Brazil[24], higher percentages of lingual canal prevalence in mandibular incisors were reported compared to the present research (10.0% and 11.0%). However, these results are still consistent with the evidence suggesting lower proportions in South America when compared to the previously mentioned European and Middle Eastern countries. China is one of the few countries that have previously published lingual canal prevalence data, with documented percentages of 6.7%[25], 8.9%[26], and 15.7%[2], which are consistent with the 9.3% reported in the present study.

For many of the countries included in this investigation, previous data are unavailable, making direct comparisons with previous studies impossible. However, an overall analysis of a previous systematic review[10] reported significantly higher percentages in the European continent and significantly lower percentages in East Asia, which is consistent with the outcomes reported herein. In addition, the present investigation has contributed to a better understanding of lingual canal prevalence on a global scale by revealing higher percentages in southern and Middle East Asia and lower percentages in the American continent (Figs. 1 and 3). Results for the African continent were more mixed, with the homogenous sub-Saharan Nigerian sub-population displaying the lowest prevalence (2.3%) of the 44 countries analyzed. However, the other two African countries (Egypt and South Africa) showed higher percentages (15.7% and 31.0%, respectively). It is important to note that these countries may have been influenced by other ethnic groups, as Egyptians have cultural ties with Arabian nations (which are associated with higher percentages as shown in Fig. 4), and the South African sample included individuals of Caucasian and Indian ancestry (as well as African individuals), which are groups that typically display higher prevalence rates (Fig. 4). The results of the present study are consistent with a previous systematic review[10], which suggested that Asian patients have a significantly lower prevalence of lingual canals in mandibular central incisors compared to non-Asian individuals. However, with the present data, it is now possible to identify which specific sub-groups make up these two major ethnic groups (Fig. 4). These findings and the corresponding analysis can be extended to the prevalence of the lingual canal in the mandibular lateral incisor, with similar conclusions being drawn.

Anthropological data can provide insights into the reasons for the observed differences between geographic regions and ethnic groups discussed earlier. The human species can be traced back to a region in central Africa near Nairobi, Kenya, from where it spread out to colonize the world. The migration routes taken by early humans may help explain the origin of ethnic groups and the differences between them. It is believed that early humans dispersed through two major migratory pathways: the northern route via the Levant corridor, which followed the Nile River, Sinai Peninsula, and the Levantine corridor to the east end of the Mediterranean Sea and then split into two branches, 1 heading to Europe and the other to Asia, leaving behind the African branch; and the southern route, which passed through the Horn of Africa and across the Bad-el-Mandeb strait into southern Arabia before splitting into the two branches mentioned earlier[20]. These two major migratory routes gave rise to three major ethnic groups in the early stages of mankind: Africans, who remained in Africa; Caucasians, who migrated to Europe; and Asians, who migrated to eastern Asia. The southern and Middle East regions of the Asian continent, where the three major ethnic groups converge, are considered a region of turbulence where influential ethnic sub-groups such as Arabs, Indians, or Indo-Iranians emerged[20,27]. Taking into account the migration routes and formation of the three major ethnic groups; it can be hypothesized that the higher prevalence of a lingual canal in mandibular incisors in Caucasians may have emerged through a genetic mutation and/or adaptation to the local environment during the migratory process towards Europe. It is important to note that ethnic sub-groups, such as Arabs and Indians, despite having mixed genetics due to their connections to all three major ethnic branches and their geographical location, have been genetically linked to the Caucasian major group[27] and not the Asian major group. This can partly explain why their lingual canal prevalence is similar to that of Caucasians. The Asian major group migrated to Eastern Asia and later to Oceania and the American continent via Alaska, leading to ethnic sub-groups such as Tibetans, Japanese, Eskimos, Australian Aborigines, and North and South Amerinds (indigenous peoples of the Americas)[27]. This may partially explain the lower prevalence of mandibular incisor lingual canals in Asians and Hispanics—who evolved from the Caucasian major group that migrated from Europe in the 16th century and have a strong influence from other groups such as the original South Americans—as well as in the countries where the Asian major branch migrated and expanded.

Overall, there was a 4.4% (central incisor) and 2.8% (lateral incisor) higher prevalence of lingual canal in males than females, although the difference was not statistically significant (Supplemental Fig. S2). However, males had significantly higher odds of having lingual canal (1.334 and 1.178) than females (Supplemental Fig. S3). This difference does not seem to have as much clinical relevance as the ones observed among geographic regions or ethnic groups and, therefore, both sexes should be treated similarly in a clinical setting. The tendency for males to have a higher number of canals has been previously reported[28] and may be partially explained by sexual dimorphism, with males having larger teeth[29]. This may be due to the influence of the Y chromosome, which leads to superior enamel and dentin formation compared to the X chromosome[30].

In mandibular incisors, which usually have ovoid-shaped root canals[7], calcification patterns in the middle-center of the canal can result in a two-canals configuration[9]. This may increase the number of root canals, but over time, the calcification process can cause the smaller canals to become obliterated[9] or too small to be detected using CBCT imaging[28]. This can lead to a reduction in the number of root canals in elderly patients. Despite previous differences noted between central and lateral incisors, there seems to be no significant impact on the presence or absence of a lingual root canal when comparing the two tooth groups (Supplemental Fig. S1). The present study found higher proportions of lingual canals in the 21–40 age group, while the older age group (>61 years) had lower percentages of lingual canals for both tooth groups (Supplemental Fig. S4), which is consistent with previous research on other types of teeth[28]. These differences in lingual canal proportions across the four age groups may be attributed to dynamic changes in the root canal system. In general, wider root canal spaces are found in younger individuals[9,31], which tend to become narrower over time due to both physiological and pathological calcification processes[9,32].

This study accepted a maximum CBCT voxel size of 200 μm, which has been previously considered as the upper limit for minimizing heterogeneity in identifying lingual canals in mandibular incisors[10] and other root canal morphologies[28]. The metaregression analysis of global results, which only included countries using a single CBCT scanner to screen teeth, was unable to rule out voxel size as a possible source of heterogeneity. However, upon closer examination, it was found that lower resolution (<100 μm) single scanner assessments were unevenly distributed, with the majority of studies coming from America ($n = 6$) and Asia ($n = 1$; region with lower proportions) and only 1 from Africa (mixed results) and Europe (region with higher percentages). On the other hand, some continents that used multiple voxel size scanners, like America, showed consistent outcomes. Therefore, a regional meta-regression analysis was conducted, which excluded CBCT scanner voxel size as a possible source of heterogeneity, consistent with previous findings[10,28]. In this case, CBCT settings related to both voxel size and FOV were discarded as potential confounder variables.

This study has relevant strengths, primarily stemming from the utilization of CBCT imaging as the assessment tool. CBCT provides a three-dimensional perspective of both the internal and external structures of the teeth, offering valuable insights into real-world practice. Additionally, the substantial sample size consisting of 26,400 mandibular incisors obtained from 15,475 patients across 44 different countries is unparalleled in the endodontic literature. One of the limitations of this study was the restricted number of evaluations conducted in Africa, particularly in the sub-Saharan region,and Oceania, which are currently areas with limited knowledge. Therefore, further studies in these regions are needed to enhance our understanding. Another limitation pertained to the definition of ethnic groups based on patients' profiles. Conducting genetic tests on the extensive number of individuals assessed would have been impracticable. However, despite this limitation, the similarity in results observed among sub-populations with the same ethnic group provides evidence supporting the reliability of this approach. Other research constrain, which is common in multicenter studies, is the possibility of bias arising from different observers and, in this case, from different CBCT scanners. To minimize the potential for observer bias, five individual and group reliability measurements were conducted, spanning 4 months to ensure reliable anatomic assessment from the 44 observers over an extended data collection period of 5 months. Following an appropriate learning and calibration period, the high performance on these tests (Supplemental Table S1) demonstrated that all participants were considering similar anatomic concepts, thus enhancing the accuracy of the evidence obtained. Furthermore, in addition to accurate classification, it is crucial to ensure trustworthy data recording, particularly when dealing with a large amount of repetitive data collection. To evaluate the potential catalog bias of each observer, a dataset nonconformities check was performed, measuring the percentage of nonconformities observed. The low percentages obtained from this assessment (Supplemental Table S1) suggest that the participants maintained a reliable data record even for scores that were not double-checked. Ultimately, this stringent approach to anatomical concepts and precise data recording can be considered a major strength of the current study, along with the comprehensive global knowledge gained from a worldwide assessment that included previously nonevaluated regions and a meta-analysis statistical approach to explore differences, confounders, and heterogeneities[14]. Regrettably, we were unable to incorporate more than one observer per country. However, future investigations could address this by involving two observers per region, thereby necessitating consensus between them. Although this approach may require additional efforts to ensure observer calibration, it has the potential to further enhance the reliability of the study's outcomes. In this study, the meta-analysis was chosen as the statistical method due to the consistent assessment methodology implemented across all participating centers. It is worth noting that the meta-analysis has been effectively employed in previous multi-center epidemiological studies with similar characteristics[14,21,28,33]. Regarding the CBCT scanners used in the study, it was not possible to utilize the same scanner with identical settings in all regions. However, it was ensured that all scanners employed had sufficient resolution for the study's objectives, as previously discussed.

CONCLUSIONS

The findings of this study indicate that the prevalence of lingual root canals in mandibular central and lateral incisors varies significantly based on geographic location, ethnicity, age, and gender. The overall prevalence was 21.9% for mandibular central incisors and 26.0% for lateral incisors. The study revealed that Hispanics, Asians, and Africans had the lowest prevalence; while Arabs, Indians, and Caucasians showed the highest. The southern and Middle East regions from Asia and Europe had higher percentages compared to America and East Asia. Males were found to have a higher likelihood of presenting with a lingual canal than females. Older patients were found to have lower percentages of lingual canals. The side (left and right) and the tooth group (central and lateral) did not have a significant impact on the prevalence of lingual root canals.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

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

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found in the online version at www.jendodon.com (https://doi.org/10.1016/j.joen.2023.05.012).

REFERENCES

1. Karabucak B, Bunes A, Chehoud C, et al. Prevalence of apical periodontitis in endodontically treated premolars and molars with untreated canal: a cone-beam computed tomography study. J Endod 2016;42:538–41.
2. Han T, Ma Y, Yang L, et al. A study of the root canal morphology of mandibular anterior teeth using cone-beam computed tomography in a Chinese subpopulation. J Endod 2014;40:1309–14.
3. Kayaoglu G, Peker I, Gumusok M, et al. Root and canal symmetry in the mandibular anterior teeth of patients attending a dental clinic: CBCT study. Braz Oral Res 2015;29.
4. Leoni GB, Versiani MA, Pecora JD, Damiao de Sousa-Neto M. Micro-computed tomographic analysis of the root canal morphology of mandibular incisors. J Endod 2014;40:710–6.
5. Shemesh A, Kavalerchik E, Levin A, et al. Root canal morphology evaluation of central and lateral mandibular incisors using cone-beam computed tomography in an Israeli population. J Endod 2018;44:51–5.
6. Zhengyan Y, Keke L, Fei W, et al. Cone-beam computed tomography study of the root and canal morphology of mandibular permanent anterior teeth in a Chongqing population. Ther Clin Risk Manag 2016;12:19–25.
7. Versiani M, Pereira MR, Pécora J, Sousa Neto MD. Root canal anatomy of maxillary and mandibular teeth. In: Versiani MBB, Sousa-Neto MD, editors. The Root Canal Anatomy in Permanent Dentition. Switzerland: Springer International Publishing; 2019. p. 181–240.
8. Martins JNR, Marques D, Silva E, et al. Prevalence studies on root canal anatomy using cone-beam computed tomographic imaging: a systematic review. J Endod 2019;45:372–86.
9. Thomas RP, Moule AJ, Bryant R. Root canal morphology of maxillary permanent first molar teeth at various ages. Int Endod J 1993;26:257–67.
10. Martins JNR, Marques D, Leal Silva EJN, et al. Influence of demographic factors on the prevalence of a second root canal in mandibular anterior teeth–a systematic review and meta-analysis of cross-sectional studies using cone beam computed tomography. Arch Oral Biol 2020;116:104749.

11. Martins JNR, Kishen A, Marques D, et al. Preferred reporting items for epidemiologic cross-sectional studies on root and root canal anatomy using cone-beam computed tomographic technology: a systematized assessment. J Endod 2020;46:915–35.

12. American Association of Endodontics. In: Glossary of Endodontic Terms. 9th ed. Chicago, IL: American Association of Endodontics; 2016.

13. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.

14. Basagana X, Pedersen M, Barrera-Gomez J, et al. Analysis of multicentre epidemiological studies: contrasting fixed or random effects modelling and meta-analysis. Int J Epidemiol 2018;47:1343–54.

15. Gerace L, Aliprantis A, Russell M, et al. Skeletal differences between black and white men and their relevance to body composition estimates. Am J Hum Biol 1994;6:255–62.

16. Shao H, Chen C, Scholl D, et al. Tibial shaft anatomy differs between Caucasians and East Asian individuals. Knee Surg Sports Traumatol Arthrosc 2018;26:2758–65.

17. Lombardo L, Coppola P, Siciliani G. Comparison of dental and alveolar arch forms between different ethnic groups. Inter Orthod 2015;13:462–88.

18. Gafni Y, Tzur-Gadassi L, Nojima K, et al. Comparison of arch forms between Israeli and North American white populations. Am J Orthod Dentofacial Orthop 2011;139:339–44.

19. Kook YA, Nojima K, Moon HB, et al. Comparison of arch forms between Korean and North American white populations. Am J Orthod Dentofacial Orthop 2004;126:680–6.

20. Hanihara T. Geographic structure of dental variation in the major human populations of the world. In: Scott R, Irish J, editors. Anthropological Perspectives on Tooth Morphology. Genetics, Evolution, Variation. 1st ed. New York: Cambridge University Press; 2013. p. 479–509.

21. Martins JNR, Nole C, Ounsi HF, et al. Worldwide assessment of the mandibular first molar second distal root and root canal: a cross-sectional study with meta-analysis. J Endod 2022;48:223–33.

22. Martínez I, Torres A, Jacobs R, et al. Root canal morphology of mandibular incisors using cone-beam computed tomography in two population samples: a cross-sectional study. Austin J Radiol 2018;5:1083.

23. Valenti-Obino F, Di Nardo D, Quero L, et al. Symmetry of root and root canal morphology of mandibular incisors: a cone-beam computed tomography study *in vivo*. J Clin Exp Dent 2019;11:e527–33.

24. Candeiro GTM, Monteiro Dodt Teixeira IM, Olimpio Barbosa DA, et al. Vertucci's root canal configuration of 14,413 mandibular anterior teeth in a Brazilian population: a prevalence study using cone-beam computed tomography. J Endod 2021;47:404–8.

25. Zhao Y, Dong YT, Wang XY, et al. [Cone-beam computed tomography analysis of root canal configuration of 4 674 mandibular anterior teeth]. Beijing Da Xue Xue Bao Yi Xue Ban 2014;46:95–9.

26. Liu J, Luo J, Dou L, Yang D. CBCT study of root and canal morphology of permanent mandibular incisors in a Chinese population. Acta Odontol Scand 2014;72:26–30.

27. Scott GR, Anta A, Schomberg R, Rúa C. Basque dental morpholgy and the "Eurodont" dental pattern. In: Scott GR, Turner I, editors. The Anthropology of Modern Teeth: Dental Morphology and its Variation in Recent Human Populations. Cambridge: Cambridge University Press; 1997.

28. Martins JNR, Zhang Y, von Zuben M, et al. Worldwide prevalence of a lingual canal in mandibular premolars: a multicenter cross-sectional study with meta-analysis. J Endod 2021;47:1253–64.

29. Lakhanpal M, Gupta N, Rao N, Vashisth S. Tooth dimension cariations as a gender determinant in permanent maxillary teeth. JSciMed Dent 2013;1:1014–9.

30. Alvesalo L. The expression of human sex chromossome genes in oral and craniofacial growth. In: Scott GR, Irish J, editors. Anthropological Perspectives on Tooth Morphology. Genetics, Evolution, Variation. 1st ed. New York: Cambridge University Press; 2013. p. 92–107.

31. Gani OA, Boiero CF, Correa C, et al. Morphological changes related to age in mesial root canals of permanent mandibular first molars. Acta Odontol Latinoam 2014;27:105–9.

32. Johnstone M, Parashos P. Endodontics and the ageing patient. Aust Dent J 2015;60(Suppl 1):20–7.

33. Cesaroni G, Forastiere F, Stafoggia M, et al. Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE project. BMJ 2014;348:f7412.