Maxillary incisor internal root anatomy evaluated by cone-beam computed tomography in a population of the Autonomous City of Buenos Aires, Argentina

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ABSTRACT
In the field of anthropology, discrete traits are considered as minimal epigenetic variations. However, they can elicit complications in endodontic therapy. Thorough understanding of root canal morphology is essential to achieving predictable results in endodontic practice, and may be attained by using cone-beam computed tomography (CBCT) scans. The aim of the present study was to research the internal root anatomy of maxillary central and lateral incisors in vivo and quantify its variation in a population of the Autonomous City of Buenos Aires, Argentina. A total 697 CBCT scans from a pre-existing database were observed, and the configuration type for each tooth was determined according to Vertucci's classification. The data were described by absolute frequencies and percentages with 95% confidence intervals (CI). The CI was estimated by the Wilson Score method. Chi-square test (χ^2) was used for comparing frequencies, with a 5% significance level. 238 CBCT scans met the inclusion criteria, resulting in 761 teeth assessed. Vertucci Type I configuration was observed in 760 teeth (99.9%) and the Type II was found in only one tooth (0.1%), in which the anatomy was compatible with dens in dente. When differences were analyzed according to sex, all the teeth in all women had Vertucci Type I configuration. In men, all maxillary central incisors were Vertucci Type I. Of 151 maxillary lateral incisors, 150 had Vertucci Type I configuration (99.3%) and 1 had Type II (0.7%). Conclusions: Maxillary incisor internal root anatomy prevalence was estimated from CBCT scans for the first time in an Argentine population. 99.9% of the sample presented Vertucci Type I configuration, and 0.1% had Vertucci Type II configuration. The clinical finding of maxillary incisors with anatomical complexity should be considered as a possibility in endodontic practice.

Received: December 2020; Accepted: June 2021.

Keywords: *cone-beam computed tomography - endodontics - anatomy - morphology - root canal.*

Anatomía radicular interna de incisivos superiores evaluados mediante tomografía cone-beam en una población de Buenos Aires, Argentina

RESUMEN
En el ámbito de la antropología, los rasgos discretos son considerados variaciones epigenéticas mínimas, pero pueden traer complicaciones en la terapia endodóntica. Comprender la morfología del conducto radicular es fundamental para lograr resultados predecibles en la práctica endodóntica, y esto puede lograrse mediante el uso de la tomografía cone-beam (CBCT). El objetivo de este trabajo fue investigar de manera in vivo la anatomía radicular interna de incisivos centrales y laterales superiores, y cuantificar su variación en una población de la Ciudad Autónoma de Buenos Aires, Argentina. 697 CBCTs de una base de datos preexistente fueron analizadas, y se consignó para cada pieza el tipo de configuración basada en la clasificación de Vertucci. Los datos se describieron mediante frecuencias absolutas y porcentajes con intervalos de confianza al 95% (IC95). Los IC95 fueron estimados mediante el método score de Wilson. Para la comparación de frecuencias se utilizó la prueba de Chi-cuadrado (χ^2), con un nivel de significación de 5%. 238 CBCTs cumplieron con los criterios de inclusión, resultando en 761 piezas evaluadas. Se encontró un Vertucci tipo I en 760 piezas (99,9%) y se halló Vertucci tipo II en una sola pieza dentaria (0,1%), que mostraba anatomía compatible con dens in dente. Diferenciando por sexos, todas las mujeres para todas las piezas mostraron Vertucci tipo I. Los varones en sus incisivos centrales superiores poseían Vertucci tipo I en todas las piezas, y de los 151 incisivos laterales superiores, 150 mostraron tipo I de Vertucci (99,3%) y 1, tipo II (0,7%). Conclusión: La prevalencia de anatomía dentaria interna fue estimada por primera vez en una población argentina mediante CBCTs. El 99,9% de la muestra presentó un Vertucci tipo I, y el 0,1% un Vertucci tipo II. La aparición clínica de incisivos superiores con complejidad anatómica debe ser considerada posible en la práctica endodóntica.

Palabras clave: *tomografía de haz cónico - endodoncia - anatomía - morfología - conducto radicular.*

INTRODUCTION

Tooth anatomy, size and morphology are closely related to the evolutionary processes and diet, playing a pivotal role in human survival. Discrete traits (cusps and accessory ridges, roots and extra canals) are considered as minimal epigenetic variations in the field of dental anthropology. Within this discipline, they constitute an important field of research that can be applied to evaluating biological distances among past populations from a bioarchaeological perspective, as well as to assigning missing persons to a given population during the identification processes in the field of forensic anthropology[1,2]. On the other hand, in endodontic practice, these traits might hinder treatment success. It is widely acknowledged that understanding root canal morphology and its possible variations is of the utmost importance to achieving predictable endodontic outcomes and avoiding potential complications. It is therefore essential that the clinician be acquainted with the available tools to improve treatment planning[3], including radiographic studies, which are crucial to treating teeth with pulpal pathology[4,5].

According to the American Academy of Oral and Maxillofacial Radiology (AAOMR) and the American Associations of Endodontists (AAE), among the imaging studies, periapical radiography should be considered the first choice for assessing a tooth with endodontic pathosis[6]. The number of root canals and the presence and location of associated periapical lesions should be confirmed by radiographic assessment in order to reach the most accurate treatment planning[7,8]. However, it should be considered that traditional periapical radiography presents some drawbacks, such as two-dimensional imaging, sensitivity to distortion because of anatomical structures and the possibility of incorrect acquisition techniques or processing errors[9]. Digital radiology (radiovisiography) has the advantages of overcoming difficulties in image processing and enabling easier documentation of clinical cases, among others[10]. Cone-beam computed tomography (CBCT) is a non-invasive tool capable of overcoming the aforementioned problems which can occur in both traditional and digital periapical radiographs. CBCT is very useful for acquiring anatomic knowledge of the teeth and surrounding structures, as well as for the diagnosis and management of endodontic complication[11], and it has been widely shown to improve the location, description and analysis of unusual dental structures such as *dens invaginatus*[12], C-shaped canal configuration[13] and extra roots[14].

Several authors describe maxillary incisors as teeth with one canal and one root in 100% of the cases [Green (1956)[15], Pineda and Kuttler (1972)[16], and Vertucci (1984)[17]]. The presence of extra canals in this group of teeth is described as extraordinary[18,19]. Nevertheless, another study has reported that it is possible to identify a high diversity of anatomical variations in root canals. Moreover, all teeth – not only a specific group – can present additional canals, which is why canal configuration variations should be considered normal rather than exceptional[20].

The aim of this study was to describe the internal root anatomy of maxillary central and lateral incisors and to quantify its variation in a population of the Autonomous City of Buenos Aires, by assessing CBCT scans taken at the Diagnostic Imaging Department, School of Dentistry of the University of Buenos Aires (FOUBA), Argentina.

MATERIALS AND METHODS

Study design and place

An observational, cross-sectional, descriptive study was designed. The research was conducted by assessing CBCT scans of patients who received care at the FOUBA Diagnostic Imaging Department, which has three tomographs. The device used in this study, as well as the research period, were selected randomly. During 2019, a total 211,146 patients received care at the FOUBA and 10,640 CBCT scans were taken, adding up to a total 298,362 services provided.

Tomographic volumes

Tomographic volumes were acquired with a Planmeca ProMax® 3D Max (Planmeca OY, Helsinki, Finland) tomograph with 88 kV and 9.0 mA, exposure time 12.07 seconds and 150-200 µm voxel size. The CT scans were requested for diagnosis or follow-up of pre-existing pathologies, which were not the reason for the present research. The patients signed the informed consent form by which they understood that their examinations could be used for academic purposes, with their identity being preserved (FOUBA Resolution CD N° 983).

Data collection

This research was conducted through the assessment of 697 CBCT scans of patients who received care at the aforementioned Department from February to March 2019. The CBCT scans were assessed by the direct observation of volumes by two calibrated endodontists who specialized in the detection of unusual internal dental anatomy. Shifts of 1 ½ hour per day per observer were arranged, to avoid visual strain and potential misinterpretation of the images. Data were collected by direct observation of complete DICOM (.dcm) volumes using the scanner's own software (Planmeca Romexis Viewer Launcher version 4.6.0.R. released 02/20/2017, Planmeca OY, Helsinki, Finland). The information was recorded in spreadsheets especially designed for this report.

Selection criteria

Inclusion criteria: Maxillary CBCT scans of patients, regardless of age and sex, with at least one permanent central or lateral incisor with developed apex.

Exclusion criteria: Teeth with previous canal therapy, crown destruction below the cementoenamel junction, or internal or external resorptions.

Elimination criteria: CBCT scans with artifacts or noise interfering with correct image interpretation.

Image assessment

Once the volumes had been selected, biological sex at birth (sex), presence or absence of maxillary central and lateral incisors, and internal root anatomy according to Vertucci[17] for the existing incisors were assigned. To describe internal root anatomy, the following sequence was applied for all volumes: the window "Explorer" in the software was selected, the smallest slice admitted by the volume was chosen, and the axial and coronal plane levels were set for the target tooth. The resulting image was observed in the sagittal plane window and classified according to Vertucci[17]:

Type I: A single canal extends from the pulp chamber to the apex.

Type II: Two separate canals leave the pulp chamber and join short of the apex to form one canal.

Type III: One canal leaves the pulp chamber, divides into two within the root, and then merges to exit as one canal.

Type IV: Two separate and distinct canals extend from the pulp chamber to the apex.

Type V: One canal leaves the pulp chamber and divides short of the apex into two separate and distinct canals with separate apical foramina.

Type VI: Two separate canals leave the pulp chamber, merge in the body of the root, and redivide short of the apex to exit as two distinct canals.

Type VII: One canal leaves the pulp chamber, divides and then re-joins within the body of the root, and finally re-divides into two distinct canals short of the apex.

Type VIII: Three separate and distinct canals extend from the pulp chamber to apex.

Statistical analysis

The data were described by absolute frequencies (AF) and as percentages with 95% confidence interval (CI). The CI was estimated by the Wilson Score method[21]. A Chi-square test (χ^2) was used for comparing frequencies, with a 5% significance level. The following software types were used: Calc (Apache OpenOfficeTM) v. 4.1.3[22], Infostat v. 2018[23] and MedCalc v. 19.0.4[24].

RESULTS

A total 697 CBCT scans were observed, of which 238 met the inclusion criteria, resulting in 761 teeth assessed. Vertucci Type I configuration was found in 760 teeth, which represents 99.9% (CI95: 99.3 to 100.0) (Fig. 1).

Anatomy compatible with Vertucci Type II was found in only one tooth, representing 0.1% (CI95: 0.0 to 0.7). This tooth was associated with *dens in dente* anomaly (Fig. 2).

A hundred and ninety-one absent teeth (20%; CI95: 18% to 23%) and 761 present teeth (80%; CI95: 77% to 82%) were observed, this difference being meaningful (χ^2=341.28; df=1; p<0.05). No significant association was found between the type of tooth and its presence (χ^2=2.27; df=3; p=0.52).

When the Vertucci type configuration was analyzed according to tooth type, in teeth 2.1, 1.1 and 1.2, only Vertucci Type I was found. Among the 185 maxillary left lateral incisors studied (tooth 2.2), 184 corresponded to Vertucci Type I (99.5%; CI95: 97.0% to 99.9%) and only 1 corresponded to Type II, accounting for 0.5% (CI95: 0.1% to 3.0%) (Fig. 3 A).

When the sample was differentiated according to sex, all teeth in all females were Vertucci Type I. In males, Vertucci Type I was apparent in all maxillary central incisors. Among the 151 maxillary lateral incisors, 150 were Vertucci Type I (99.3%; CI95: 96.3% to 99.9%) and 1 was Vertucci Type II, accounting for 0.7% (CI95: 0.1% to 3.7%) (Fig. 3 B).

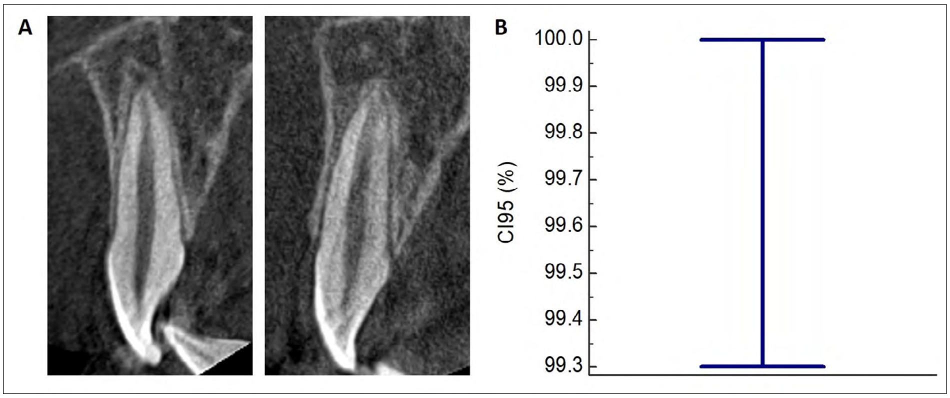

Fig. 1: A. Sagittal plane showing Vertucci Type I. B. A 95% confidence interval. Interval upper and lower limits: 99.3% - 100.0%.

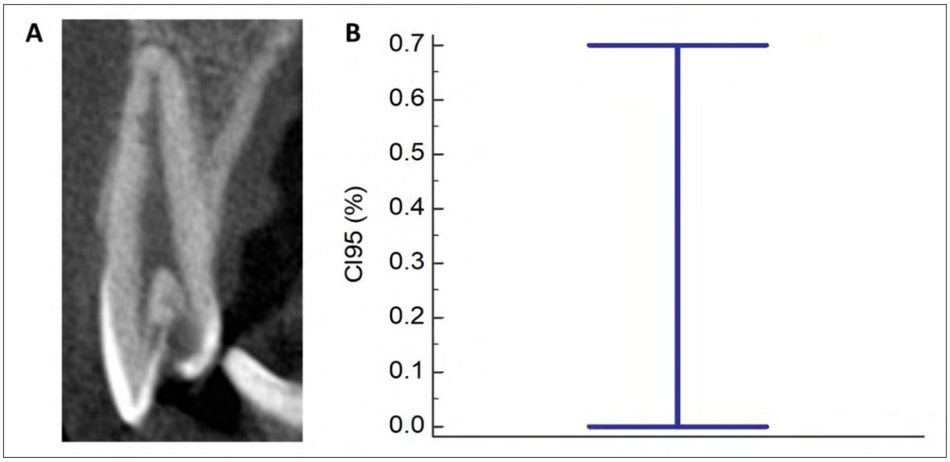

Fig. 2: A. CBCT sagittal plane showing Vertucci Type II. B. A 95% confidence interval. Interval upper and lower limits: 0.0% - 0.7%.

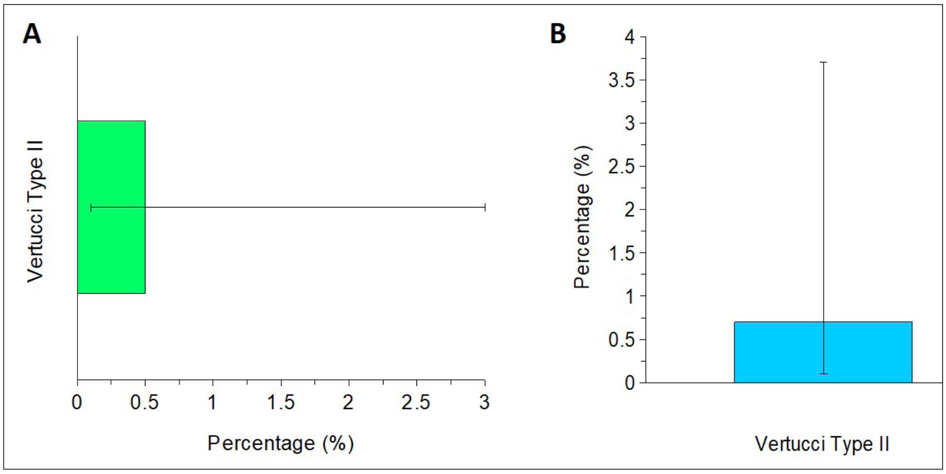

Fig. 3: A. Vertucci Type II configuration in tooth 2.2. B. Vertucci Type II configuration in male maxillary lateral incisors. Bar graph: % (CI95).

DISCUSSION

In the field of anthropology and bioarchaeology, discrete trait variation has been used as an important tool in the study of biological and social change from an evolutionary perspective[25], as well as the characterization and differentiation of ethnic groups, and the evaluation of biodistances, migratory processes and changes in the gene flow, in both current and past populations[26-29]. This is possible given the high heritability of dental traits, which implies that a large part of the observed inter-sample variations can be explained by genetic differences[30,31] Additionally, from the standpoint of dentistry, the thorough understanding of the root canal morphology is essential to achieving predictable endodontic results. In this regard, failure to locate root canals entails a clearly deficient technique, one of the major causes of endodontic failure[32].

Maxillary incisors usually have a single canal[15-17], consistently with the results of the current study, in which Vertucci Type I was identified for the 99.9% of the sample (CI95: 99.3 to 100.0). Incisors with more than one root canal are rarely described in the literature[12,18,19], in agreement with the results obtained in the current research (Vertucci Type II: 0.1%; CI95: 0.0 to 0.7). Vertucci Type II association with the analogy of the *dens in dente* anomaly in a maxillary anterior tooth has been described in a case report by Liji et al.[12], as in the current research.

Sample size, sex and ethnicity are factors that should be addressed regarding the root canal variability. Sert & Bayirly[33] reported that sex and ethnic origin can influence the variability of root canal anatomy. These authors analyzed maxillary lateral incisors in a sample from the Turkish population, identifying very similar percentages of Vertucci Type I according to sex (90% in women, n=100 and 91% in men, n=100). On the other hand, Altunsoy et al.[34] reported that the prevalence of two canals was higher in males than in females in maxillary anterior teeth, regarding sex as an important variable. Their report on a sample of the Turkish population analyzed the differences in CBCT scans according to sex. For maxillary central incisors, males (n=775) had Vertucci Type I: 99.5%, Type III: 0.4%, and Type V: 0.1%, and females (n=768) had Vertucci Type I: 99.7% and Type IV: 0.3%. For maxillary lateral incisors, males (n=759) had Vertucci Type I: 96.7%, Type II: 1.3%, Type III: 0.7% and Type IV: 1.3%, and females (n=745) had Vertucci Type I: 98.3%, Type II: 0.7%, Type IV and V: 0.5%.

Martins et al.[35] compared CBCT scans of maxillary central and lateral incisors of Chinese (n=440) and Portuguese (n=1846) populations, finding Vertucci Type I for 100% of the sample. Pan et al.[36] analyzed the Malasyan population CBCT scans of 347 maxillary central incisors and 362 maxillary lateral incisors, also finding Vertucci Type I in 100% of the sample. Da Silva et al.[37] analyzed CBCT scans of maxillary central incisors (n=200) in the Brazilian population, finding Vertucci Type I anatomy in 98%, and Type II and V in 1%. In maxillary lateral incisors (n=200), Vertucci Type I was 96%, Type II, 3.5% and Type III, 0.5%.

The population Argentina is considered to be heterogeneous in origin, with the immigrant component interacting with the previous native substrate in diverse ways[38,39]. This is why the variability in ethnicity should be considered as a key factor in root canal anatomical diversity. The data in this report were acquired in a single center in Argentina, located in the Autonomous City of Buenos Aires, which constitutes a limitation regarding the impact of the results obtained. Although the FOUBA is considered a national level reference and referral center, the origin of the sample limits its variability and reduces the possibility of extrapolating the research results to other regions of the country. Only one report on the Argentinian population has been found in the literature, which makes exclusive reference to the prevalence of the C-shaped canal anatomy in mandibular second molars evaluated by CBCT scans[40]. The lack of previous reports discussing the dental internal anatomic morphology of maxillary incisors assessed by CBCT scans in Argentina makes this study an important contribution to the knowledge of internal root anatomy in a sample from the Autonomous City of Buenos Aires.

CONCLUSION

Maxillary incisor internal root anatomy prevalence was estimated by CBCT scans for the first time in an Argentine population. The highest prevalence of internal anatomy found and assessed by CBCTs for maxillary incisors was a single canal, corresponding to Vertucci Type I configuration, observed in 99.9% of the sample. The remaining 0.1% was only one tooth with two canals joining in the middle third, with Vertucci Type II configuration. The clinical finding of anatomically complex maxillary incisors should be considered as a possibility in endodontic practice.

ACKNOWLEDGMENTS
The authors acknowledge the FOUBA Diagnostic Imaging Department for providing the volumes assessed in this report.

DECLARATION OF CONFLICTING INTERESTS
The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

FUNDING
None

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