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C-shaped Canal System in Maxillary Molars Evaluated by Cone-Beam Computed Tomography in an Argentine subpopulation

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ABSTRACT

The aim of the present study was to evaluate the presence of maxillary first and second molars with a C-shaped canal system in an Argentine subpopulation, and to classify them. ***Materials and Method:*** *Of the 332 CBCTs initially evaluated, 120 met the selection criteria. Once the presence of a C-shaped canal system had been established, the teeth were classified following Martins et al. Data were expressed as absolute frequencies, percentages with of 95% confidence intervals, according to the score test. Comparisons were analyzed by Chi-square test and Fisher' exact test, with 5% significance level.* ***Results:*** *It was found that 5 out of 120 first molars (4%) and 17 out of 152 second molars (11%) had a C-shaped canal system. Regarding the classification applied, of 5 C-shaped first molars, 2 corresponded to type E2 (40%), 2 corresponded to type C (40%), and 1 corresponded to type B1 (20%). Of 17 C-shaped second molars, 4 resembled a type A (24%), 7 resembled a type B1 (41%), 5 resembled a type B2 (29%), and 1 resembled a type C (6%). UC1 and UC2 configurations were the most common at all levels except apical level.* ***Conclusion:*** *The prevalence of C-shaped canal system pattern in maxillary first and second molars was estimated for the first time in an Argentine subpopulation, in vivo. Knowledge of these data should help clinicians during endodontic treatment.*

Keywords: *maxillary molars - C-shaped root canal - cone-beam computed tomography*

Conductos en C en molares superiores evaluados mediante tomografía cone-beam en una sub-población Argentina

RESUMEN

El objetivo del presente estudio fue evaluar la presencia de conductos en C en primeros y segundos molares superiores, en una subpoblación de Argentina. ***Materiales y Método:*** *Se observaron 332 CBCTs, de las cuales 120 cumplieron los criterios de selección. Una vez determinada la presencia de conducto en C se clasificaron según Martins et al. Los datos fueron descriptos mediante frecuencias absolutas y porcentajes, con intervalos de confianza al 95% (IC95), según método score. Las comparaciones fueron analizadas mediante la prueba de Chi-cuadrado o exacta de Fisher con un nivel de significación del 5%.* ***Resultados:*** *De 120 primeros molares, 5 presentaron conductos en C, es decir un 4% y de 152 segundos molares, 17 presentaron conductos en C, es decir un 11%. Según la clasificación aplicada, de 5 primeros molares en C, 2 correspondieron al tipo E2 (40%), 2 al tipo C (40%) y 1 al tipo B1 (20%). De 17 segundos molares en C, 4 pertenecieron al tipo A (24%), 7 al tipo B1 (41%), 5 al tipo B2 (29%) y 1 al tipo C (6%). Las clasificaciones UC1 y UC2 fueron las más representativas en todos los niveles, excluyendo el tercio apical.* ***Conclusión:*** *La prevalencia de conductos en C en primeros y segundos molares superiores, fue estimada por primera vez en una subpoblación Argentina, in vivo. Los datos obtenidos en el presente estudio, resultan de interés para el abordaje de los tratamientos endodónticos.*

Palabras clave: *molares superiores - forma de C - tomografía de haz cónico*

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INTRODUCTION

An understanding of inner dental anatomy and its variations is essential to ensure successful outcomes in endodontic treatment. This is especially significant for the treatment of C-shaped canal configurations, which generally require modifications of the usual instrumentation, irrigation and obturation techniques[1]. When variations of the tooth morphology remain undetected by the clinician, a therapeutic failure can be expected.

The most commonly reported anatomic configuration in maxillary first molars is the presence of 3 roots (2 buccal and 1 palatal) and 4 canals: 2 in the mesiobuccal root, 1 in the distobuccal root and 1 in the palatal root[2]. A maxillary first molar should be considered a four-canal tooth until proved otherwise; however, a clinician should be aware of the possibility of variations in the number of roots, from 1 to 5[3,4]; the number of root canals, from 1 to 8[4-8], or C-shaped root canal configuration which may or may not be split into two or more canals[9]. The first documented case of a maxillary first molar with a C-shaped root canal was published by Newton & McDonald in 1984[10]. According to De Moor[11], the probability of observing a C-shaped canal in the first maxillary molar is 0.091%, although it would be questionable to use the term prevalence in his work, since only the fusion of the distobuccal and palatal roots were considered. In 2006, Cleghorn et al. observed C-shaped canals in 0.12% of maxillary first molars[2].

Maxillary second molars usually have 3 roots: 1 mesiobuccal, 1 distobuccal and 1 palatal, with one canal in each root[12,13], and these roots may be fused[14]. The presence of an extra canal in the mesiobuccal root (MB2) is not as frequent in maxillary second molars as it is in first molars[15]. Different authors have reported variations in the number of roots and canals, and in presence of C-shaped root canals[6,16-18]. Because maxillary and mandibular molars have different anatomical features and numbers of roots, C-shaped root canals in them are classified differently. Martins et al. developed a classification for maxillary molars in 2016[1], since until that date, the definition of a C-shaped maxillary molar configuration was not clear, and no standardization was available.

Cone-beam computed tomography (CBCT) is sufficiently precise for morphological study of the number of roots and canals for diagnostic purposes. It is a useful diagnostic tool in endodontic practice because of its non-destructive *in vivo* application. Additionally, the radiation dose is lower and the resolution is higher than in conventional computed tomography scans, making it more advantageous for clinical application[19].

The aim of this study was to determine the prevalence and the characteristics of C-shaped root canals in maxillary first and second molars, assessed by the CBCT scans taken at the Department of Diagnostic Imaging, School of Dentistry of the University of Buenos Aires (FOUBA), in the Autonomous City of Buenos Aires, Argentina.

MATERIALS AND METHOD

Sample selection

This was a retrospective, observational, cross-sectional, descriptive study which assessed a total 332 CBCT images obtained between August and September 2020. Informed consent was provided by all patients included in this study. The protocol was approved by the Ethics Committee of the School of Dentistry of the University of Buenos Aires (CETICA/FOUBA 006/2020).

Digitalized CBCT images of maxillary first and second molars were collected from a data bank in Diagnostic Imaging Department. During 2020, a total 80,000 patients received care at the FOUBA during the COVID-19 pandemic, and 4,000 CBCT scans were taken, adding up a total of 220,000 services provided.

Inclusion criteria

Maxillary CBCT scans showing at least one molar other than the third molar and developed apices.

Exclusion criteria

Teeth with crown-root decay involving pulp chamber floor, previous endodontic treatment, root resorption, artifacts preventing appropriate visualization in images, including crown post/core and/or crown, or faulty radiographic technique.

Radiographic technique and image assessment

The assessed images were acquired with a Planmeca ProMax® 3D Max CBCT system (Planmeca OY, Helsinki, Finland), with 88 kV and 9.0 mA, exposure time 12.07 seconds and voxel size 150-200

μm. The images were assessed with the software corresponding to the tomograph in shifts of only two hours a day, to prevent visual strain and any misinterpretation of images. The collected data were entered in ad-hoc data recording sheets.

C-shaped root canal classification

This study was based on the classification proposed by Martins et al.[1], which says that a canal is considered as C-shaped in a maxillary molar when it exhibits root fusion and 3 consecutive axial cross sections with an upper-C (UC) 1 or 2 configuration in the fused root. The UC configuration system for maxillary molars is a modification of the Fan et al.[20] classification for C-shaped mandibular molars, and 5 configurations were observed in axial slices: UC1, continuous large C-shaped canal system; UC2, continuous C-shaped canal with 2 main canal lumens in the extremities connected by a large isthmus; UC3, 2 separate root canals; UC4, a single round or oval root canal; UC5, no canal lumen[1].

In turn, depending on which roots were fused, they were classified into 5 types: Type A: Fusion between the mesiobuccal and palatal roots, forming a semilunar mesiopalatal root canal. Type B: Fusion between the mesiobuccal and distobuccal root canals, forming a semilunar buccal root canal system; the concavity of the semilunar shape may be turned to the palatal (subtype B1) or buccal (subtype B2) root. Type C: Fusion between the distobuccal and palatal roots, forming a large semilunar distopalatal root canal. Type D: Presence of a large palatal root canal, forming a semilunar shape; this type has been previously described as a fusion between 2 palatal roots. Type E: Fusion among the 3 roots; this configuration resembles the mandibular C-shaped anatomy, with a large semilunar mesiopalatal canal merging together with an independent distobuccal canal at a single apical foramen (subtype E1) or with a large semilunar distopalatal canal connecting with a mesiobuccal canal at a single apical foramen (subtype E2)[1].

The classification was developed by observing axial slices at five levels: a) coronal-2 mm apical to the canal orifice openings in the chamber floor; b) apical-2 mm above the anatomic apex; c) middle-middle distance between "coronal" and "apical"; d) one third-middle distance between "coronal" and "middle"; e) two thirds-middle distance between "middle" and "apical".

Statistical analysis

CBCT images were examined by two FOUBA endodontists trained in the observation of tomography slices and updated by means of the continuous critical reading of scientific reports related to the subject matter of this work. Cohen's kappa unweighted coefficient was used to measure interobserver agreement. The kappa coefficient (κ) with a 95% confidence interval (CI95) was obtained. A Z-test was applied to analyze the difference between the coefficient obtained and the zero value, with a significance level of 5%: p-value < 0.05 indicates that the Cohen's kappa coefficient differs significantly from zero. The Cohen's kappa coefficient value was computed according to the criteria proposed by Altman[21]. The assessment was done in software R version 4.0.3[22] using the packages *irr*[23] and *psych*[24].

The age of the patients was described by the following measurements: mean, standard deviation (SD), median, first quartile (Q_1), third quartile (Q_3), minimum and maximum. The remaining data were described by absolute frequencies (AF) and percentages. The score method was used to estimate 95% confidence intervals (CI95) for percentages[25]. The Chi-square test or Fisher's exact test were used to evaluate the association between categorical variables, as required. When all the expected frequencies were higher than or equal to 5, the Chi-square test was utilized. If this condition was not fulfilled, the Fisher's exact test was used. A 5% significance level was set up. The following software was used: Calc, de Apache OpenOfficeTM v. 4.1.6[26] and R v. 4.0.3[22].

RESULTS

The results of Cohen's kappa test for reliability revealed significant agreement for the assessment of C-shaped canal configuration ($\kappa = 0.97$; CI95: 0.91 to 1.00; $Z = 13.7$; $p < 0.05$; $N = 200$).

Out of the 332 CBCTs assessed, 120 (36%; CI95: 31% to 41%) were from patients who met the selection criteria. Out of the 120 patients included in the study, 69 were women (58%; CI95: 49% to 66%) and 51 were men (43%; CI95: 34% to 51%). Age ranged from 19 to 79 years, with mean (SD) 40 years (13) and median (Q_1-Q_3) 38 years (32-48).

A total 272 maxillary molars were assessed; 120 were maxillary first molars (44%; CI95: 38% to 50%) and 152 were maxillary second molars (56%;

CI95: 50% to 62%). A significant association was found between tooth group and presence of C-shaped canal configuration (Chi-square=4.44; df=1; $p<0.05$; Fig. 1). Out of 120 maxillary first molars, 5 had C-shaped canal configurations (4%; CI95: 2% to 9%), whereas 115 did not (96%; CI95: 91% to 98%). Out of 152 maxillary second molars, 17 had C-shaped canal configurations (11%; CI95: 7% to 17%), whereas 135 did not (89%; CI95: 83% to 93%).

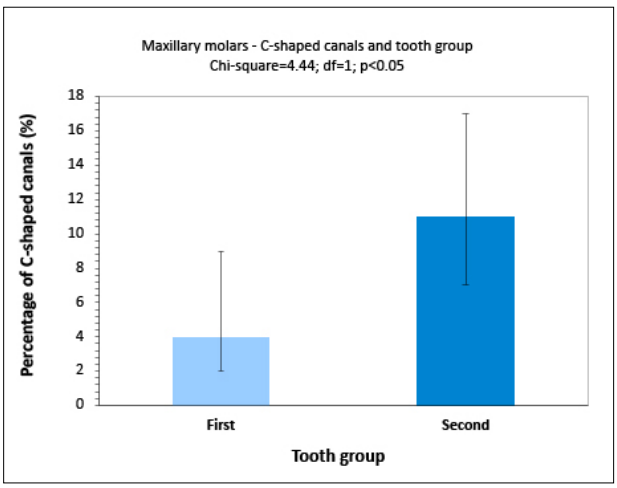

Fig. 1: *Presence of C-shaped canals in maxillary first and second molars (%; CI95).*

The age of patients with C-shaped maxillary first molar canals ranged from 32 to 39 years. The age of patients with C-shaped maxillary second molar canals ranged from 20 to 55 years, with median (Q_1-Q_3) 37 (24-38) and mean (SD) 34 (11) (Fig. 2).

Out of the 5 maxillary first molars with C-shaped canal configuration, 4 belonged to men (80%; CI95: 38% to 96%) and 1 to a woman (20%; CI95: 4% to 62%). Out of the 17 maxillary second molars with C-shaped canal configuration, 7 belonged to men (41%; CI95: 22% to 64%) and 10 to women (59%; CI95: 36% to 78%).

Out of the 22 teeth with C-shaped canals, 11 corresponded to the right side (50%, CI95: 31% to 69%) and 11 to the left side (50%, CI95: 31% to 69%).

In only one of the 2 patients who had both maxillary first molars, a bilateral C-shaped configuration canal was observed, while in the other patient, the C-shaped configuration was seen in tooth 14 (left). In the remaining patients (N=2), the C-shaped configuration was seen unilaterally, 1 in tooth 3 and the other in tooth 14. Regarding the 8 patients who presented both maxillary second molars, 4 had

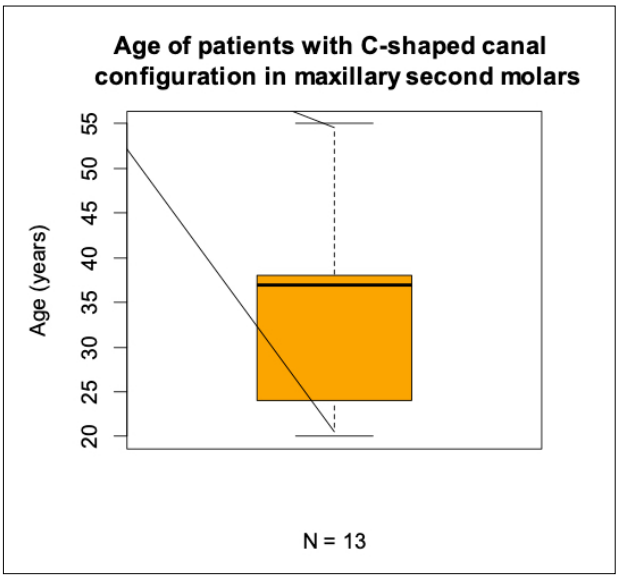

Fig. 2: *Distribution according to age, in patients with C-shaped canal configuration in maxillary second molars. Boxplot: extremes, minimum/ maximum; fences, Q1/Q3; inner line, median.*

bilateral C-shaped configuration canals (N=8 teeth) (50%; CI95: 22% to 78%) (Fig. 3), while the rest did not (50%; CI95: 22% to 78%). In 4 patients out of 9 with unilateral second molars, C-shaped canals were seen in tooth 2 (44%; CI95: 19% to 73%), and in 5 patients, these canals were seen in tooth 15 (56%; CI95: 27% to 81%).

A significant association was found between the C-shaped type according to Martins' classification and the tooth group (Fisher's exact test: $p<0.05$; Fig. 4). Out of 5 C-shaped maxillary first molars, 2 were type E2 (40%; CI95: 12% to 77%), 2 were type C (40%; CI95: 12% to 77%) and 1 was type B1 (20%; CI95: 4% to 62%). In the single case

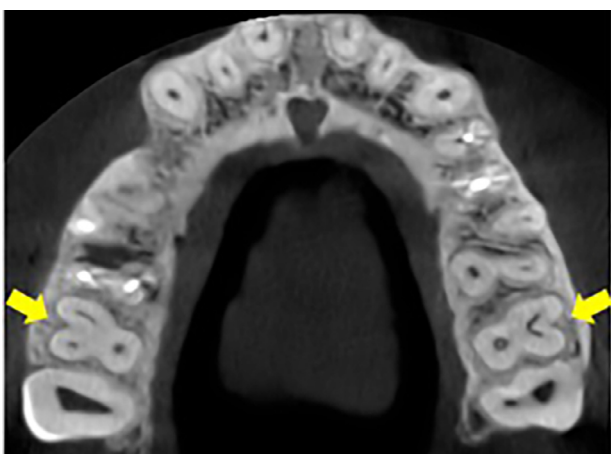

Fig. 3: *Bilateral C-shaped configuration canals in maxillary second molars.*

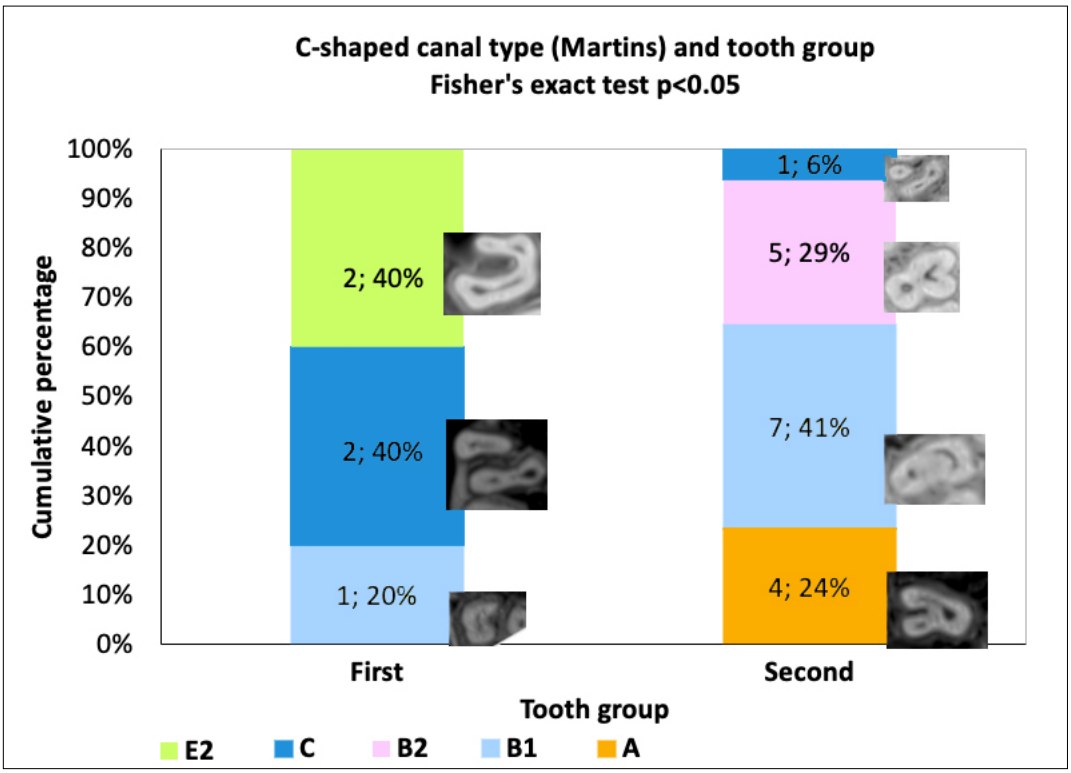

Fig. 4: *Association between the type of C-shaped canal according to the Martins' classification and the tooth group (AF; %).*

of bilateral C, both teeth (3 and 14) had the same configuration. Out of 17 C-shaped maxillary second molars, 4 were type A (24%; CI95: 10% to 47%), 7 were type B1 (41%; CI95: 22% to 64%), 5 were type B2 (29%; CI95: 13% to 53%) and 1 was type C (6%; CI95: 1% to 27%). Out of 4 patients with bilateral C-shaped canals, 2 had the same configuration on both sides, while the other 2 did not.

The UC1 and UC2 categories were the most frequent, except in the apical third, where UC4 was the most frequent. Out of the 5 C-shaped maxillary first molars, 1 was UC1 type (20%; CI95: 4% to 62%) and 4 were UC2 type (80%; CI95: 38% to 96%). Out of 17 C-shaped maxillary second molars, 12 were UC1 type (71%; CI95: 47% to 87%) and 5 were UC2 type (29%; CI95: 13% to 53%). Despite these differences, no statistically significant association was found between the UC configuration and the tooth group (Fisher's exact test: p=0.12). Root fusion was observed in both groups of teeth, but not with the C-shaped configuration.

DISCUSSION

The present study, based on a retrospective assessment of CBCT images, provides a description of the C-shaped anatomy of the first and second maxillary molars, estimated for the first time in an Argentine subpopulation.

The term "C-shaped" in maxillary molars is used to describe root canals with large semilunar canal shape that can represent a whole root canal or a partial fusion of two or more canals[7,10,11,27,28].

In different studies, several methods were used to study root canal morphology, including radiographic technics, clearing technique, spiral computed tomography, sectioning technique and microcomputed tomography, all of which have some limitations. The CBCT scans reveal anatomic details of external and internal anatomy, being an important tool for diagnosis and treatment in endodontic practice[4,7,20].

The prevalence of C-shaped canals in a Portuguese population was 1.1% for first molars and 3.8% for second molars. Martins et al. observed higher prevalence in women[1]. In a Korean population, prevalence was 0.8% in first maxillary molars and 2.7% in second maxillary molars[29]. Mashyakhy et al. reported that the prevalence of C-shaped canals in a Saudi Arabian population was 0.6% in first maxillary molars (only 2 out of 354) and 1.1% in

second maxillary molars (4 out of 372), and the only types found were C and B[18]. A prevalence of 4.9% in second maxillary molars was reported by Yang et al. in a Chinese population after the assessment of 309 extracted teeth by the clearing technique[30]. Ordinola-Zapata et al. evaluated 100 second maxillary molars with fused roots by micro-computed tomography (micro-CT), and found C-shaped configuration in 22 specimens (22%) in a Brazilian population[31]. These differences are likely due to participant ethnicity and age, sample size, study methods and the criteria applied to classify the C-shaped canals.

C-shaped maxillary molars may have low prevalence, but they are of high anatomical complexity because of a large isthmus connecting the root canals that are expected to be separate[1]. Concerning clinical implications, the percentage found in the present study provides heretofore unknown information about the prevalence and characterization of C-shaped canals. This is important since ignoring this morphology might lead to endodontic treatment failure. CBCT scans can enhance the understanding of root canal anatomy, with the potential of improving the outcome of endodontic practice.

Each tooth requiring endodontic treatment should be assessed individually, and the patients should be exposed to the lowest possible amount of radiation to obtain the most useful information for proper diagnoses. When complex, unexpected anatomy is found after access, or when the canals cannot be found, intraoperative CBCT imaging is an excellent tool contributing to correct treatment[32].

A limitation of the current study was that the sample was taken from a single center in the country. FOUBA is a national-level referring center, and although studies about dental anatomy performed by means of CBCT were published[33-35]; further research with a larger number of patients is needed to discuss the outcomes found in this subpopulation.

The percentages found in this study, 4% and 11% of C-shaped canal systems in maxillary first and second molars, respectively, are significant data regarding the prevalence of C-shaped canals in maxillary molars of an Argentine subpopulation.

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DECLARATION OF CONFLICTING INTEREST

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

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