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Frequency of C-shaped Root Canal in Mandibular Second Molars of a Colombian Population: Tomographic Analysis

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ABSTRACT

Introduction: The C-shaped root canal system is a common anatomical variation in mandibular second molars with root fusion, with a prevalence of 2.7% to 44.5%. **Objective:** To estimate the frequency of C-shaped root canals in mandibular second molars by means of computed tomography scans taken from patients who attended radiological centres. **Materials and methods:** A total of 120 mandibular second molars were evaluated. The frequency and type of C-shaped root canal were determined according to the gender and location of the tooth. Invivo5 software was used. For statistical analysis the Chi-squared test (p=0.05) was performed. The C-shape root canal was categorized based on Fan's classification and the presence of notches and grooves based on the classification of Shemesh *et al*. 2017. **Results:** The frequency of C-shaped root canals in the studied population was 25%, with a significant difference in terms of gender. The C-shaped root canal at the level of the cervical and apical root thirds was more frequent for type II and in the middle for type III. It was found that 6.7% of the studied population had type I according to the Shemesh *et al*. classification, the right side occurring more frequently (62.5%); while 3.4% had type III where the left side happened more frequently (75%). **Conclusions:** This is one of the few studies carried out in Colombia related to the frequency of the C-shaped root canals, and it was determined that there is a higher frequency in the female gender (33.3%).

Keywords: computed tomography scan, C-shaped root canals, mandibular second molar, anatomy, Pulp Cavity.

INTRODUCTION

Anatomical variations of the C-shaped root canal system were first reported in the literature in 1979 by Cooke & Cox[1-3]. Its name is due to the transverse morphology of the root and the root canal, which when observed from a transverse angle form a continuous letter "C"[4] or, in ribbon at an angle of 180 degrees, and its configuration can vary along the longitudinal axis of the tooth[5]. The main anatomical feature is the presence of a fin or band that connects the individual root canals, and the roots are generally conical or square in shape[6]. Melton *et al.,* in 1991 classified the C-canal configuration according to its transverse anatomy[6] and this feature was modified by Fan *et al.,*[7] in 2004. Root fusion favours the presence of fine irregularities towards the vestibular or lingual root surface; according to Shemesh *et al.,*[3] in 2017, there may be a notch or a groove in the teeth with root fusion, generating danger zones inside the root canal, increasing the risk of perforation during instrumentation. Ignorance of the anatomical variations that can be found in mandibular second molars can affect the diagnosis, prognosis and success of long-term endodontic treatment.

Cone beam computed tomography (CBCT) has been useful in the diagnosis of C-shaped molars, due to its ability to reconstruct three-dimensional images, facilitating the visualization of root fusion and C-canal configuration along the entire root[8]. Previous studies have reported that this variation can occur bilaterally depending on the population studied. It has been observed in more than 70% of individuals, therefore, if a C-shaped canal is present, it is highly likely that this anatomical configuration is found on the contralateral tooth[9]. This anatomical variation has been reported as one of the most prevalent at the level of the mandibular second

molars at up to 44.5%[9-11]. Most of the published studies have been conducted in the Asian population[11], observing a higher frequency in the Chinese population with 31.5%[6]. In contrast, in the Western Hemisphere there are fewer reports; in Latin American populations there are few publications related to mandibular second molars with C-shaped canal systems, and so far no study had been done in Colombia[12,13]. Therefore, the objective of this study was to estimate the frequency of C-shaped root canals in mandibular second molars by means of CBCT taken from patients who attended radiological centres in Cali, Colombia.

MATERIALS AND METHODS

The present study was observational, descriptive, cross-sectional and retrospective. The study was approved by the Human Ethics Committee of the Faculty of Health of the Universidad del Valle, in accordance with the regulations in force in Colombia (Resolution 8430 of the Ministry of Health, 1993). The study sample belonged to the tomography files of women and men over 14 years of age who attended radiological centres corresponding to dental clinics, as part of the diagnosis and treatment planning between 2012 and 2018-1. A total of 73 tomograms were selected, of which 38 belonged to women and 35 to men.

A total of 120 tomographic images of well-defined mandibular second molars were included, with the presence of one or both mandibular second molars, which had a complete crown-root structure, root integrity, closed apices, without extensive restorations that would make the analysis of the internal root anatomy difficult (inlays, posts, crowns). Teeth with or previously initiated endodontic treatment, with superimposed artifact images that prevented radiographic evaluation and tomography scans of patients with foreign identification cards, were excluded.

The images in DICOM format of the CBCT were exported for analysis to a visualization Invivo5 software (Invivo5 software, Anatomage Inc., Santa Clara, CA, USA), to reconstruct the cross-sectional and sagittal images. Two residents of the postgraduate endodontics program participated in the evaluation, previously trained and with standardized knowledge, and an endodontist as a third evaluator acting as a gold standard, inter- and intra-observer reliability was accepted with a value of Cohen's Kappa coefficient greater than 0.8.

The configuration of the C-shaped canal was categorized into longitudinal view and axial root cuts at three levels: coronal, middle and apical (Figure 1). Coronal (C): 2 mm from the pulp chamber floor, Medium (M): Half the root length from C to A, Apical (A): 2 mm from the apex[14,15].

It was classified according to Fan *et al*.,[7] 2004, Category I (C1): continuous C-shaped canal, Category II (C2): semicolon shape due to an interruption in the "C" outline, however, any angle, a or b, must not be less than 60°, Category III (C3): two or three separate canals and both angles, a and b, must be less than 60°, Category IV (C4): a single round or oval canal, Category V (C5): the lumen of the canal is not observed (this condition is frequently observed at the apical level).

The presence of the notches or grooves was analysed taking into account the classification proposed by Shemesh *et al*.,[3] 2017, Type I: lingual groove, Type II: lingual groove and buccal notch, Type III: buccal groove, Type IV: buccal groove and lingual notch, Type V: none, as well as the presence of bilaterality. Regional differences in frequency distributions were analysed by chi-squared and Fisher's exact tests using IBM® SPSS® Statistics software version 15.0 for Windows, a p-value < 0.05 was considered significant.

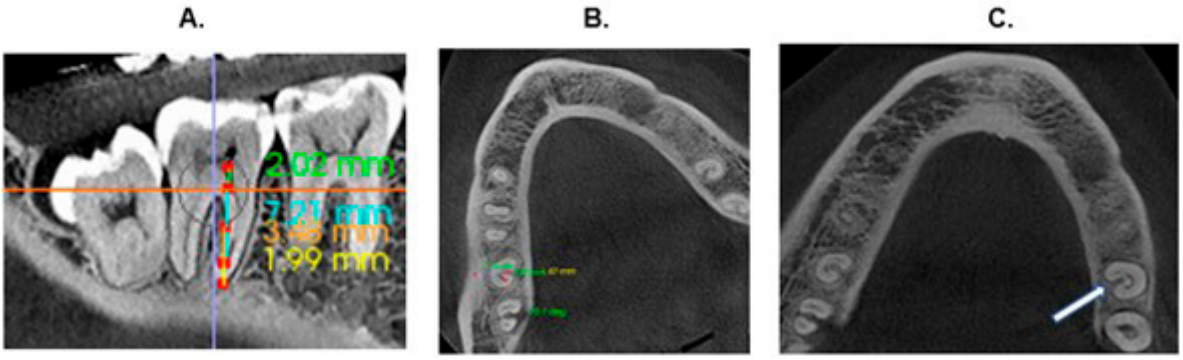

Figure 1. A. Sagittal view of the CBCT exemplifying the three levels at which the evaluation was performed: coronal, middle and apical. **B.** Cross section in the middle third for type II and III classification analysis according to Fan *et al.* 2004. **C.** Cross section in the middle third for analysis of the presence of the groove (arrow).

RESULTS

The study group consisted of 35 men (48%) and 38 women (52%) ranging in age from 14 to 68 years, with a mean age of 41.93 years. The frequency of C-shaped canals in mandibular second molars was 30 (25%) and a statistically significant difference was found by gender, female 21 (33.3%), male 9 (15.8%) (Table 1); there was no statistically significant difference for the side of occurrence (left - right, $p > 0.05$).

During the tomographic analysis, it was evident that three images (teeth) on the left side and four on the right side showed continuity of the C-shaped canal in all the thirds analysed without significant differences versus gender (Table 2). Bilaterality was defined as a symmetrical appearance of C-shaped canal and unilaterality was defined as an asymmetrical C-shaped canal. It was observed that bilaterality was present in only six cases (41.6%).

Table 1.
Frequency of C-shaped canals in mandibular second molars according to gender.

C-shaped canals	Gender		Total
	Female n (%)	Male n (%)	
Absent	42 (66.7)	48 (84.2)	90
Present	21 (33.3) *	9 (15.8)	30
Total	63	57	120

*Chi-squared test (p=0.05); n: sample, %: percentage

Table 2.
C-canal continuity along the root versus gender and side of occurrence.

		CONTINUOUS	DISCONTINUOUS	TOTAL
		***n* (%)**	***n* (%)**	***n* (%)**
Gender	Female	4(6.3)	17(27.0)	21(33.3)
	Male	3(5.3)	6(10.5)	9(15.8)
Occurrence Side	Left	3(5.3)	13(22.8)	16(28.1)
	Right	4(6.3)	10(15.9)	14(22.2)

Chi-squared test (p>0.05); n: sample, %: percentage

The distribution of the type of C-shaped canal in the cervical, middle and apical thirds according to the classification of Fan *et al.*,[7] 2004 at the level of the cervical third, C2 presented a higher frequency (11.7%), while C4 was less frequent (2.5%). In the middle third, C3 was more frequent (11.7%), followed by C2 (10.0%). In the apical third, C2 was found to be more frequent (10.0%), followed by C4 (9.2%), C5 was detected in one (1.8%) corresponding to the left side, while C1 was not evident (Table 3).

Taking the classification of Shemesh *et al.*,[3] 2017 into account, it was found that eight cases (6.7%) presented type I, more frequently on the right side (62.5%). Four (3.4%) had type III, more frequently on the left side (75%). Four of the cases were observed with type IV without significant differences according to the side of occurrence (right or left) (Table 4).

Table 3.
Frequency of C-shaped canal according to the classification of Fan *et al*. 2004: cross-sectional analysis by root thirds.

	Occurrence Side													
	Left (*n*=16) %						Total (%)	Right (*n*=14) %						Total (%)
Root Level	**A**	**C1**	**C2**	**C3**	**C4**	**C5**		**A**	**C1**	**C2**	**C3**	**C4**	**C5**	
Cervical	71.9	3.5	8.8	12.3	3.5	0.0	100	77.8	3.2	14.3	3.2	1.6	0.0	100
Middle	71.9	1.8	10.5	14.0	1.8	0.0	100	77.8	3.2	9.5	9.5	0.0	0.0	100
Apical	71.9	0.0	7.0	3.5	15.8	1.8	100	77.8	0.0	12.7	6.3	3.2	0.0	100

**A: Absent, C1: continuous C-shaped canal, C2: semicolon shape due to an interruption in the "C" contour, however, any angle, a or b, must not be less than 60°, C3: two or three separate canals, and both angles, a and b, must be less than 60°, C4: a single round or oval canal, C5: no canal lumen observed (this condition is frequently observed at the apical level). n: sample, %: percentage.
Cervical: Chi-squared test (p>0.05)
Medium: Chi-squared test (p<0.05)
Apical: Chi-squared test (p>0.05)

Table 4.
Notches/grooves direction versus gender and side of occurrence in teeth that presented C-shaped canal.

Direction	Gender *n* (%)		Occurrence Side *n* (%)		
	F	M	Left	Right	Total (%)
Type I	4 (6.3)	4 (7.0)	3 (5.3)	5 (7.9)	8 (6.7)
Type II	7 (11.1)	1 (1.8)	4 (7.0)	4 (6.3)	8 (6.7)
Type III	4 (6.3)	0 (0.0)	3 (5.3)	1 (1.6)	4 (3.3)
Type IV	4 (6.3)	1 (1.8)	2 (3.2)	3 (4.8)	5 (4.2)
Type V	2 (3.2)	3 (5.3)	4 (7.0)	1 (1.6)	5 (4.2)

Chi-squared test ($p>0.05$), F: female, M: male, n: sample, %: percentage

DISCUSSION

The C-shaped canal configuration is an anatomical variation of the canal system, present more frequently in mandibular second molars and in the Asian population[9]. The CBCT evaluation method allows for non-invasive, three-dimensional visualization of the canal system[9,10], which, compared to other diagnostic imaging techniques, offers greater clarity and objectivity when classifying the C-configuration. Cases of C-shaped canal have been reported in maxillary molars and mandibular premolars[15,16]; however, in the present study permanent mandibular second molars were taken, due to their high incidence in different regions. A worldwide study of C-shaped canal[17] prevalence reported 44% in the Asian population, followed by 14% in the Mexican population and 12% in the Indian population. The present study showed a frequency of C-shaped canals in mandibular second molars comparable with populations such as Mexico 14%[18], Chile 11%[13], and Peru 40.5%[10]. It is important to keep in mind that the configuration of the C-shaped canal can vary along the fused root[9]. In this study, it was found that the most frequent form of C-shaped canals in the middle third was Type III, as reported by Janani *et al.,* 2018[19], in contrast to the study by Kim *et al.,* 2016, where they found that the most frequent root canal pattern was Type I at the orifice level (66%) and Type III at the apical level (56%)[20]. These data show the need to perform a cross-sectional analysis at the 3 levels of each tooth to avoid false negatives regarding the existence of a C-shaped root canal.

Few studies take into account the anatomical presence of a notch and a groove along the root, as a result of root fusion. This anatomical variation is important due to the formation of danger zones, where the dentin is thinner and prone to perforation during instrumentation[7]. Kim *et al.,* 2016, showed that 8 of 770 C-shaped roots had grooves in the buccal direction, and the rest had notches in the lingual direction[20]. Alfawaz *et al.,* in 2019[21], reported that the location of grooves in the mandibular second molar was greater on the lingual surface and more frequent in the female gender. In the present study, the classification proposed by Shemesh *et al.,* 2017[3] was considered and it was found that mandibular second molars with C-shaped canals were most frequently Type I, being similar between both genders. It was observed that only in the female gender did Type III occur more frequently on the left side; while Type II did not present significant differences according to the side of occurrence (right or left) (p=0.5).

Alfawaz *et al*., in 2019, report that 12 of 26 patients showed bilateral C-shaped canal configurations (46.2%), and the remaining 14 patients presented unilateral configuration (53.8%)[21]. In our study, a low bilateral presence was shown in mandibular second molars because many of the tomography scans showed hemiarch cuts that did not allow us to know the anatomy of the contralateral tooth.

A limitation of this study was the sample size, although the selected amount was carefully analysed by the evaluators. In addition, all images were included in a single software, which facilitated visualization with greater objectivity.

CONCLUSIONS

One of every four molars evaluated presented a C-shaped canal. No sexual dimorphism was identified in the morphology of the C-shaped canal, and it was found that this anatomical configuration can vary at different levels of the root.

The presence of notch/groove was found in 30 teeth, with type I and II being more prevalent.

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RECOMMENDATIONS

The data reported by different researchers indicate that "C-shaped canals" are a very common variation with a high prevalence in mandibular second molars. However, reports of the presence of this variation have also been found in mandibular first molars, maxillary molars, even in maxillary lateral incisors. Therefore, it would be important to carry out other studies to establish the prevalence of the "C-shaped canal" in other dental groups in our region, with the aim of contributing to the research already carried out in other regions of the world.

It is recommended to carry out multicentre studies with sample sizes larger than the present one to obtain data on the frequency in Colombia.

Also, to carry out a prospective study to further link the relationship of the C configuration with respect to ethnicity, because this variability of the internal anatomy of the mandibular second molars can be categorized with a great value of its expression as an ethnic discriminator of populations and boost an anthropological search for identity and origin.

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