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Prevalence of C-shaped mandibular second molar canals in the population of central Serbia: a cone-beam computed tomography study

Učestalost kanala C-oblika kod drugih mandibularnih molara u populaciji centralne Srbije: studija sa kompjuterizovanom tomografijom konusnog snopa

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Abstract

Background/Aim. C-shaped canals are a complex morphological variation of the tooth root canal system that, if present, could greatly affect the outcome of endodontic therapy. The prevalence of these canal configurations varies between the populations of different ethnic and geographical origins. Therefore, the goal of this study was to analyze the prevalence and morphology of mandibular second molar C-shaped canals in the population of Central Serbia. **Methods.** The study included a total of 199 mandibular second molars receiving a cone-beam computed tomography (CBCT) examination and determining the presence of C-shaped canal systems, their configuration, minimal wall thickness and its relative position on axial cross-sections at the coronal, middle, and apical level. **Results.** The prevalence of C-shaped mandibular second molars was 5.53%. C1 canal configuration was the most frequent at the coronal cross-section, while C2 configuration was the most frequent at middle and apical cross-sections. Minimal wall thickness decreased going apically, with the mean value of 1.01 mm at the coronal, 0.87 mm at the middle, and 0.67 mm at the apical cross-sections. Minimal wall thickness was mostly directed lingually at all cross-sectional levels. **Conclusion.** C-shaped canals should be expected in mandibular second molars of the population of Central Serbia. CBCT was shown to be the most valuable technique to determine C-shaped canals and facilitate understanding of the C-shaped canal morphology; its implementation could improve the success of endodontic therapy, especially if the complex root canal configuration is present.

Key words:
endodontics; tooth root; tooth anomalies; molar; tomography; serbia.

Apstrakt

Uvod/Cilj. Kanali korenova C-oblika su kompleksne morfološke varijacije kanalnih sistema zuba, čije prisustvo može ozbiljno da utiče na ishod endodontske terapije. Učestalost ovih konfiguracija varira između populacija različitog etničkog i geografskog porekla. Stoga je cilj ove studije bio da analizira učestalost i morfologiju kanala C-oblika drugih mandibularnih molara u populaciji centralne Srbije. **Metode**. Studijom je bilo obuhvaćeno ukupno 199 drugih mandibularnih molara snimljenih kompjuterizovanom tomografijom konusnog snopa, na kojima je analizirano prisustvo kanalnog sistema C-oblika, njegova konfiguracija, najmanja debljina zida i njegova relativna pozicija na aksijalnim presecima na koronarnom, srednjem i apikalnom nivou. **Rezultati**. Učestalost drugih mandibularnih molara sa kanalnim sistemom C-oblika bila je 5,53%. Kanalna konfiguracija C1 bila je najčešća na koronarnom preseku, dok je konfiguracija C2 bila najčešća na srednjim i apikalnim presecima. Vrednosti najmanje debljine zida opadale su prema apeksu, sa srednjim vrednostima od 1,01 mm na koronarnom, 0,87 mm na srednjem i 0,67 mm na apikalnom preseku. Najmanje debljine zida najčešće su bile orijentisane lingvalno na svim presecima. **Zaključak**. Treba očekivati prisustvo kanala C-oblika na drugim mandibularnim molarima u populaciji centralne Srbije. Kompjuterizovana tomografija konusnog snopa pokazala se kao značajna tehnika za pomoć u razumevanju morfologije kanala C-oblika, a njena implementacija može poboljšati uspeh endodontske terapije, posebno ako je prisutna kompleksna konfiguracija kanala korena zuba.

Ključne reči:
endodoncija; zub, korenski kanal; zub, anomalije; molari; tomografija; srbija.

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Introduction

In order to ensure successful endodontic treatment and avoid procedural errors during chemo-mechanical preparation and definitive obturation of the tooth root canal, it is important to know and find out the exact root canal morphology [1, 2]. The internal morphology of the tooth root could be very complex, with differently shaped canals on cross-sections, including round, oval, or irregular. C-shaped canals were first described in 1979 as an anatomic variation of the root canal system in which individual mesial and distal canals are connected by a slit or a network of access canals forming the distinctive shape resembling the letter "C" on the axial cross-section [2–4]. Treatment of these canal systems may be impeded due to the varying canal lumen diameter and the dentine wall thickness, thus making it necessary to properly diagnose the C-shaped canal at the initiation of the treatment [5, 6].

The prevalence of the C-shaped canal is the highest in mandibular second molars, ranging from 2.7% to 44.5%. However, the literature showed that these types of canals could be present in maxillary second premolars and molars or even in the maxillary second incisors [2, 3]. It has been shown that the prevalence of C-shaped canals has a geographical, ethnic, and racial predilection. Asians have the highest prevalence of this canal system compared to the other racial groups. However, there is a difference in prevalence between the populations of East and West Asia [7]. Apart from the lower prevalence in Caucasians, the presence of the C-shaped canal system should not be overlooked [1].

Standard radiographic methods are insufficient to diagnose the C-shaped canals because of a superimposition of the structures on a two-dimensional image; thus, practitioners are encouraged to use cone beam computed tomography (CBCT) for treatment planning and therapy of these canals [8, 9]. Previous studies have shown that CBCT is a precise, non-invasive diagnostic tool that could be used for the visualization of complicated root canal morphology, even though it has not yet been introduced as a routine method in endodontics [2, 4].

The prevalence and configuration of C-shaped canal systems in mandibular second molars have never been examined in the Serbian population. Therefore, the goal of this retrospective study was to analyze the prevalence and morphology of the C-shaped canals in mandibular second molars in the population of Central Serbia. This study is part of major research of the tooth root morphology, conducted at the Faculty of Medical Sciences, University of Kragujevac, Serbia [10–12].

Methods

The study protocol was approved by the Ethics Committee of the Faculty of Medical Sciences, University of Kragujevac, Serbia (No: 01-15942), and it was conducted in accordance with the Helsinki Declaration and Guidelines for Good Clinical Practice.

Sample

This study included CBCT scans of 150 patients of both genders from a pre-existing database. All CBCT images were made in the Radiology Department at the Faculty of Medical Sciences, University of Kragujevac, in the period between October 2014 and October 2018. The scans were obtained using Orthophos XG 3D device (Sirona Dental Systems GmbH, Bensheim, Germany), with three-dimensional settings for recording, VOL1 or VOL1 HD, and a voxel size of 160 μm; the layer thickness was 0.16 mm with a large Field of view (FOV). The reasons for CBCT scanning were different (prosthetic, surgical, orthodontic, and endodontic).

The main image's inclusion criterion was the existence of at least one mandibular second molar. Other inclusion criteria were the following: the tooth is fully visible; has completed root growth; has no radiographically visible periapical lesion; has no radiographically visible external or internal root resorption; is not treated endodontically; has no prosthetic restoration.

C-shaped canal analysis

CBCT images were analyzed using GALAXIS v1.9.4 software (Sirona Dental Systems GmbH, Bensheim, Germany), on the axial cross-sections. Observations were conducted on the 23-inch Philips LED monitor, with a resolution of 1920 × 1080 pixels, in a room with dim lighting. Brightness and contrast were adjusted using the software.

All mandibular second molars' canal systems were analyzed for the presence of the following criteria for C-shaped canals defined by Fan et al. [13]: fused roots; presence of a longitudinal groove on the lingual or buccal surface of the root; at least 1 cross-section of the canal showed a C1, C2, or C3 configuration.

The orientation of the longitudinal groove of a C-shaped canal system was noted as lingual or buccal.

C-shaped canal configuration was analyzed from canal orifice to apical foramen at distinct three cross-sectional levels: C (coronal) – 2 mm from the root canal orifice; M (middle) – at the middle of the root canal length; A (apical) – 2 mm from the apical foramen (Figure 1).

At these cross-sections, C-shaped canal systems were classified in 5 configurations, according to Fan et al. [13] (Figure 2). Differentiation of C2 and C3 configurations was accomplished by measuring angles and shown in Figure 3 — C1: Continuous C-shaped canal; C2: Semicolon shaped because of a discontinuation in the ''C'' outline; however, either angle, α or β, should be no less than 60°; C3: 2 or 3 separate canals, and both angles, α and β, were less than 60°; C4: Single round or oval canal; C5: No canal lumen.

Measurement of the minimum thickness (*t*) between the inner wall of the canal to the outer root surface in the C-shaped canal system was performed at the same three cross-sections by drawing lines at six distinct points: from the most distal canal outline (Dt), from central canal outline (Ct), from

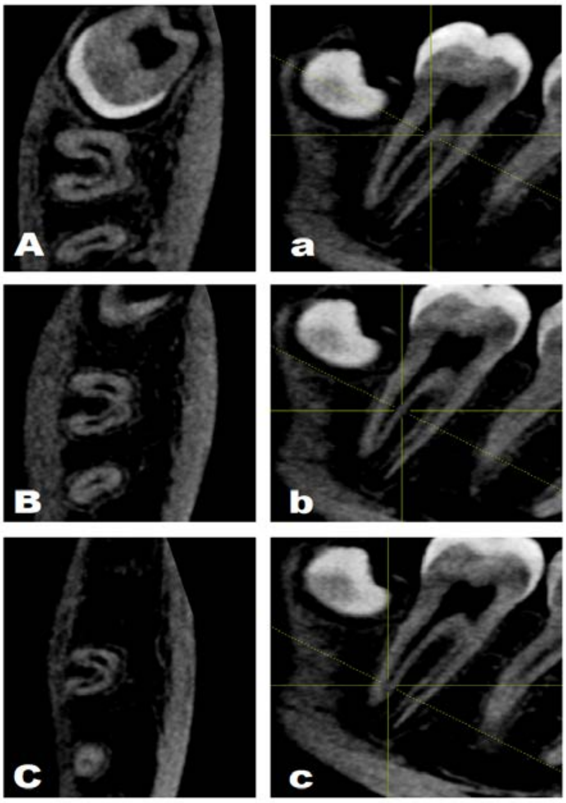

Fig. 1 – Cone-beam computed tomography (CBCT) axial cross-sections of the left mandibular second molar showing different types of C-shaped canal system (A, B, C) with corresponding levels of analysis on sagittal cross-sections (a, b, c).

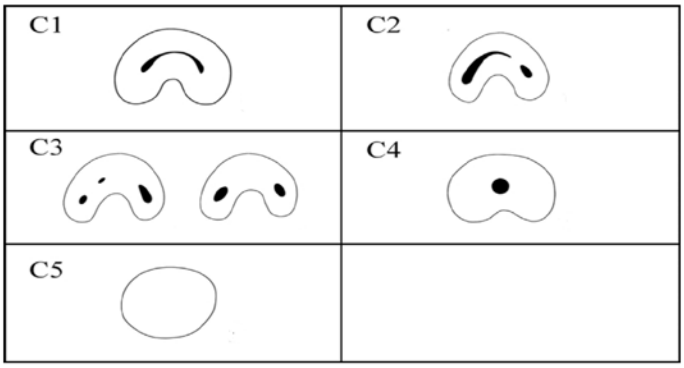

Fig. 2 – Classification of C-shaped canal system configurations.

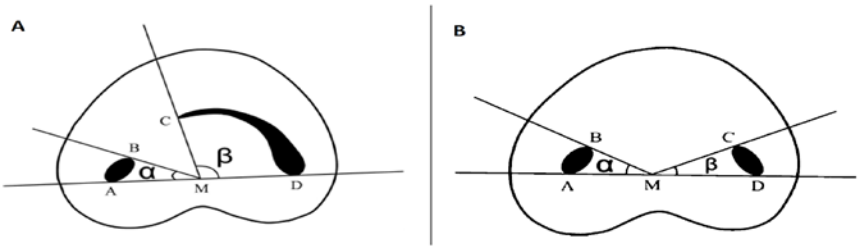

Fig. 3 – Schematic representation of measurement of the angles α and β to differentiate the C2 and C3 canal configurations: (A and B) – Ends of one canal cross-section; (C and D) – Ends of the other canal cross-section.
M – middle point of line AD; α – angle between line AM and line BM;
β – angle between line CM and line DM [2].
(A) C2 canal configuration, angle β > 60º; (B) C3 canal configuration, α < 60º, β < 60º.

the most mesial canal outline (Mt), from the middle between the most distal and central canal outline points (DCt), and from the middle between the most mesial and central canal outline points (MCt). The minimal thickness was noted, as well as its position according to the six directions of the tooth where it was measured (Figure 4).

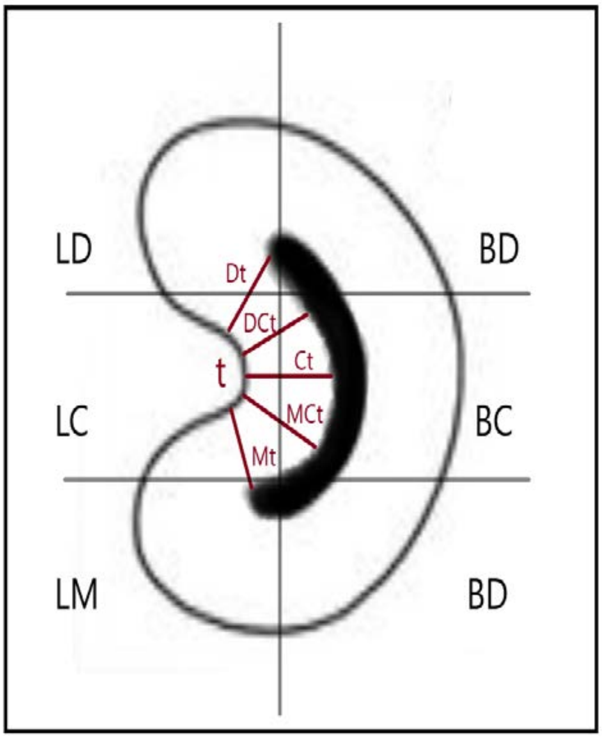

Fig. 4 – Representation of the measurement of the minimal thickness by drawing lines from the five points on the inner canal outline (Dt, DCt, Ct, MCt, Mt) to the closest outline of the root surface (red lines). At every cross-section, axial tooth view was divided into the following sixths: LD – linguo-distal, LC – linguo-central, LM – linguo-mesial, BD – bucco-distal, BC – bucco-central, and BD – bucco-distal. Depending on the sixth where most of the line was located, a minimal thickness value was added to one of the six directions.

In order to analyze the frequencies of different configurations of C-shaped canal systems and the values of minimal thickness and its position, all the collected data were entered into the commercial software for statistical analysis SPSS v20.0 (SPSS Inc., Chicago, IL, USA).

Results

The study sample included CBCT scans from 150 patients, 73 (49%) female, and 77 (51%) male, with a total of 233 mandibular second molars. The average age of the patients was 39 years old (the minimum age being 15, and the maximum 72 years old). Out of the total number of teeth, 199 had reached inclusion criteria, of which 11 teeth (5.53%) had presented C-shaped canal systems. Only one tooth had a buccally oriented longitudinal groove, while the rest had a lingually oriented groove.

Table 1 shows the prevalence of C-shaped canal configurations in mandibular second molars. Most teeth presented a C1 configuration of the C-shaped canal system at the coronal cross-section and C2 configuration at the middle and apical cross-sections.

Table 1

Number of teeth with different configurations of C-shaped canals at the coronal, middle, and apical cross-sections

Type	Number of teeth (%)		
	coronal	middle	apical
C1	8 (72.7)	- (0)	3 (27.3)
C2	1 (9.1)	6 (54.5)	5 (45.4)
C3	2 (18.2)	4 (36.4)	2 (18.2)
C4	- (0)	- (0)	- (0)
C5	- (0)	1 (9.1)	1 (9.1%)
Total		11 (100)	

Minimal *t* values ranged from 0.89 mm to 1.05 mm (mean – 1.01 mm) at the coronal, from 0.54 mm to 1.05 mm (mean – 0.87 mm) at the middle, and from 0.51 mm to 0.83 mm (mean – 0.67 mm) at the apical cross-section (Figure 4). The minimal *t* value was differently oriented at the coronal, middle, and apical levels, but all teeth mostly presented one of the lingual directions at the coronal and middle cross-sections, while in the apical regions, minimal *t* value was presented equally in lingual and buccal directions (Table 2).

Table 2

Number of teeth with different directions of the minimal thickness (t) values at the coronal, middle, and apical cross-sections

Direction	Number (%) of teeth		
	coronal	middle	apical
LM	3 (27.3)	5 (50)	2 (20)
LC	2 (18.2)	- (0)	3 (30)
LD	3 (27.3)	2 (20)	- (0)
Total lingual	8 (72.7)	7 (70)	5 (70)
BM	2 (18.2)	2 (20)	- (0)
BC	1 (9.1)	- (0)	4 (40)
BD	- (0)	1 (10)	1 (10)
Total buccal	3 (27.3)	3 (30)	5 (30)
Total	11 (100)	10* (100)	10* (100)

***One case had presented C5 configuration at the middle and apical cross-section. Thus, the t value and its direction could not be analyzed.**
LD – linguo-distal, LC – linguo-central, LM – linguo-mesial, BD – bucco-distal, BC – bucco-central, and BD – bucco-distal.

Diagrammatic representation of the maximum, mean, and minimum values of the minimal wall thickness for C-shaped canals are presented in Figure 5.

Two cases with complex C-shaped canal systems at coronal, middle and apical cross-section are shown in Figure 6.

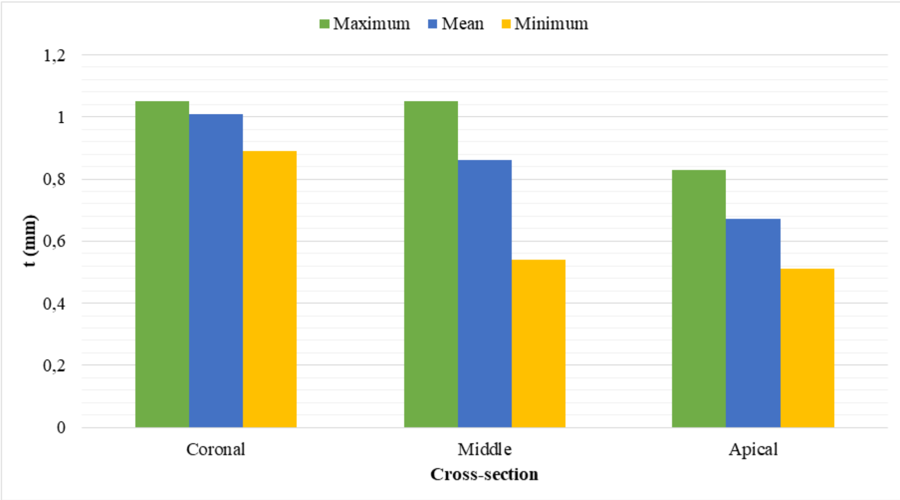

Fig. 5 – Diagrammatic representation of maximum, mean, and minimum values of the minimal wall thickness (t) for C-shaped canals at the coronal, middle, and apical cross-section.

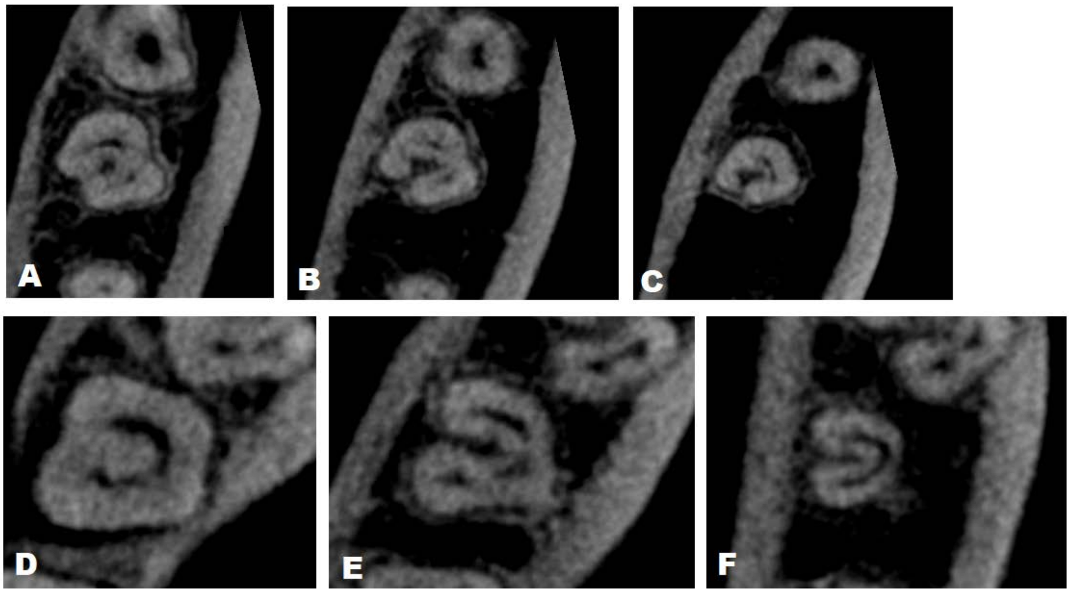

Fig. 6 – Two cases with complex C-shaped canal systems at the coronal, middle, and apical cross-sections. The first case presented C3 configuration at the coronal (A), C2 at the middle (B), and C1 at the apical cross-section (C). The second case is showing a more complex configuration starting with C1 at the coronal (D), dividing to C3 with three canals at the middle (E), and finishing with C1 configuration at the apical cross-section (F).

Discussion

Mandibular second molar has two roots and three canals in most cases, although many variations in the number of roots and the internal canal morphology have been reported [14]. Since anatomical and morphological characteristics of the root canals greatly affect the outcome of the endodontic therapy, practitioners should be familiar with the possible anatomical complexities and variations in the canal system [15]. Different techniques were used in the preoperative analysis of canal morphology, with varying outcomes. The ideal technique should be non-invasive, non-destructive, feasible, and precise in the *in vivo* conditions [5].

Digital dental radiography is an important diagnostic method in endodontics, but it is not sufficient in assessing the teeth with complicated morphology [2]. The European Society of Endodontology has proposed that CBCT should be considered if complicated root canal morphology was suspected [9].

In order to consider a possible presence of a C-shaped canal system, a longitudinal groove should exist on the root surface, buccally or lingually. The most widely accepted theory for the formation of C-shaped canals is the failure of Hertwig's epithelial root sheath to fuse either at the buccal or at the lingual root surface, thus forming the groove on the side contrary to the fuse failure [1, 16]. The orientation of this groove determines the direction of instruments during chemo-mechanical root canal preparation in order to avoid the possibility of canal perforation and other procedural errors [6, 17]. Most teeth have a lingually oriented longitudinal groove, as shown in a study in China, where no buccally oriented groove was found [7]. Nevertheless, a buccally oriented groove could be present in a smaller percentage, as shown in two cases in a study in the Turkish population [2] and one case in our study. A higher occurrence was found in the Portuguese population in 22% of the examined teeth [18]. These variations could be attributed to the population's race and ethnicity, or the study sample size and methodology of root canal analysis [2, 7, 19].

The prevalence of C-shaped mandibular second molars' canals is quite diverse between the populations from different geographical origins. Regardless of the canal morphology analysis method, the highest prevalence of C-shaped canals was reported in East Asia, up to 44.5% in China and Korea [7, 20]. Going west, the prevalence reduces, as shown in Sri Lanka and India, 6% and 7.5% [21, 22]. A relatively high prevalence of C-shaped canals was also reported in the Middle East region, ranging from 7.2% to 10.6% in Iran, Israel, and Saudi Arabia [14, 16, 23]. In Brazil, the prevalence of C-shaped canals was shown to range from 3.5% to 15% depending on the used methods [5]. The presence of C-shaped canals was also reported in the European population, with differences between countries; for example, in Portugal, the prevalence of C-shaped canals was found to be 8.5%, similarly to Turkey, where the prevalence was 8.9% [2, 18, 19]. A lower prevalence of C-shaped canals, similar to our results, was found in a Greek study, 4.6% [24]. These results, as well as ours, coincide within the range (2.7%–8.1%) shown in studies in the Caucasian race [3, 22–24], which suggests that these differences could be racial or ethnic.

Because of their complexity, C-shaped canal systems could complicate the endodontic treatment, which may be even more complicated when they present configurations with a variable number of canals at different axial cross-sections [6, 17], such as a C-shaped canal presented in Figure 6; for example, that canal presented the C1 configuration at the coronal cross-section, then the C3 in the medial cross-section with three separate canals, merging again to the C1 configuration at the apical cross-section [25–27] (Figure 6, E, F, G). Frequencies of different configurations on cross-sectional levels have also been shown to differ by population. Our results showed that at the coronal and apical cross-sections, most canals have the C1 configuration, which was similar to the Israeli population [16], but contrary to our results, they found the highest prevalence of the C3 configuration at the middle cross-section. The highest frequency of the C2 configuration at all cross-sectional levels was found in the studies of Yang et al. [28], Jayasinghe and Li [29], and Seo and Park [30], while a study in Portugal showed that the most common was the C3 canal configuration [18]. Fernandes et al. [1] claimed that these differences could be racially or ethnically determined, but they could also be caused by differences in study sample sizes or used methodology.

Seo et al. [4] stated that the thickness of the canal wall and the related position of the thinnest wall should be thoroughly analyzed in order to avoid procedural errors during canal instrumentation. Therefore, we have examined the minimal thickness of the inner wall at the coronal, middle, and apical cross-sections. Our results indicate that the minimal wall thickness decreases going apically, similarly to the results of Seo et al. [4]. In addition, we analyzed the direction of the thinnest wall on axial cross-sections. Even though most canals showed lingual directions, we found a high frequency of the thinnest wall in buccal directions at all cross-sectional levels, contrary to the previous findings [4]. These results could help practitioners in endodontic treatment of C-shaped canals, where they could reduce the incidence of root wall perforations during a chemo-mechanical preparation by directing instrumentation opposite to the less thin wall [1, 2, 6, 17].

Conclusion

Our results showed that C-shaped canals should be expected in mandibular second molars of the population of Central Serbia with a prevalence of 5.53%. Configuration of C-shaped canals varied in morphology and the number of canals on different axial cross-sections. Knowing and recognizing the root canal morphology facilitates preoperative and operative canal identification, prevents the unnecessary removal of a healthy tooth structure, reduces the incidence of procedural errors, and thus increases the overall success of endodontic therapy.

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