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C-shaped canals in Serbian Population
Abstract

**Background/Aim.** C-shaped canals are complex morphological variation of tooth root canal system that if present could greatly affect the outcome of endodontic therapy. Prevalence of these canal configurations varies between populations of different ethnic and geographical origine. Therefore, the goal of this study was to analyse the prevalence and morphology of second mandibular molar C-shaped canals in the population of Central Serbia. **Methods.** The study included a total of 199 second mandibular molars receiving 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 coronal, middle and apical level. **Results.** Prevalence of C-shaped second mandibular molars was 5.53%. C1 canal configuration was the most frequent at 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. **Conclusions.** C-shaped canals should be expected in second mandibular molars of the population of Central Serbia. CBCT is 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:** cone-beam computed tomography; second mandibular molars; root canal morphology; c-shaped canals.

Apstrakt

**Uvod/Cilj.** Kanali korenova Ce-oblika kompleksne su 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 Ce-oblika drugih mandibularnih molara u populaciji centralne Srbije. **Metode.** Studijom je obuhvaćeno ukupno 199 drugih mandibularnih molara snimljenih kompjuterizovanom tomografijom konusnog snopa, na kojima je analizirano prisustvo kanalnog sistema Ce-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 Ce-oblika bila je 5,53%. Kanalna konfiguracija S1 bila je najčešća na koronarnom preseku, dok je konfiguracija S2 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 lingualno na svim presecima. **Zaključak.** Treba očekivati prisustvo kanala Ce-oblika na drugim mandibularnim molarama u populaciji centralne Srbije. Kompjuterizovana tomografija konusnog snopa pokazala se kao značajna tehnika za pomoć u razumevanju
morfologije kanala Ce-oblika, a njena implementacija može poboljšati uspeh endodontske terapije, posebno ako je prisutna kompleksa konfiguracija kanala korena zuba.

Ključne reči: kompjuterizovana tomografija konusnog zraka, drugi mandibularni molari, morfologija kanala korena, kanali ce-oblika.

Introduction

In order to ensure successful endodontic treatment and to avoid procedural errors during chemo-mechanical preparation and definitive obturation of 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 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 diagnose properly the C-shaped canal at the initiation of the treatment (5,6).

The prevalence of the C-shaped canal is the highest in second mandibular molars, ranging from 2.7% to 44.5%. However, literature showed that these types of canals could be present in second maxillary premolars and molars, or even in the second maxillary 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 populations of East and West Asia (7). Apart from lower prevalence in Caucasians, presence of C-shaped canal system should not be overlooked (1).

Standard radiographic methods are insufficient to diagnose 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, although it has not been yet introduced as a routine method in endodontics (2,4).

Prevalence and configuration of C-shaped canal systems in second mandibular molars have never been examined in Serbian population. Therefore, the goal of this retrospective study was to analyse the prevalence and morphology of the C-shaped canals in second mandibular molars in the population of Central Serbia. This study is part of a major research of the tooth root morphology, which was 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.
This study included CBCT scans of 150 patients of both genders from a pre-existing database. All CBCT images were made in Radiology Department, Faculty of Medical Sciences, University of Kragujevac, between October 2014 and October 2018. The scans were obtained using Orthophos XG 3D device (Sirona Dental Systems GmbH, Bensheim, Germany), with a three-dimensional settings for recording, VOL1 or VOL1 HD, and a voxel size of 160μm; the layer thickness was 0.16mm with 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 following: 1) tooth is fully visible; 2) has completed root growth; 3) has no radiographically visible periapical lesion; 4) has no radiographically visible external or internal root resorption; 5) is not treated endodontically; and 6) has no prosthetic restoration.

C-Shaped Canal Analysis

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

All second mandibular molars’ canal systems were analyzed for the presence of following criteria for C-shaped canals defined by Fan et al. (13):

1. Fused roots
2. Presence of a longitudinal groove on lingual or buccal surface of the root
3. At least 1 cross-section of the canal showed a C1, C2, or C3 configuration

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 as proposed by Fan et al. (13) 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 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 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).

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

Results

Study sample included CBCT scans from 150 patients, 73 (49%) female and 77 (51%) male, with the total of 233 second mandibular molars. Average age of the patients was 39 years old (minimal age was 15 years old; maximal age was 72 years old). Out of 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 buccal oriented longitudinal groove while the rest had the groove oriented lingually.

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

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 was presented equally in lingual and buccal directions (Table 2).

Discussion

Second mandibular 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 endodontic therapy, practitioners should be familiar with the possible anatomical complexities and variations in the canal system (15). Different techniques were used in preoperative analysis of canal morphology, with varying outcomes. The ideal technique should be non-invasive, non-destructive, feasible and precise in in vivo conditions (5). Digital dental radiography is an important diagnostic method in endodontics, but it is not sufficient in assessment of 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 possibly 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 direction of instruments during chemo-mechanical root canal preparation in order to avoid a possibility of canal perforation and other procedural errors (6,17). Most teeth have lingually oriented longitudinal groove, as shown in a study in China, where no buccally oriented groove was found (7). Nevertheless, buccally oriented groove could be present in smaller percentage,
as shown on two cases in a study in Turkish population (2), and in one case in our study. Higher occurrence was found in Portuguese population in 22% of the examined teeth (18). These variations could be attributed to population’s race and ethnicity, or to the study sample size and methodology of root canal analysis (2,7,19).

Prevalence of C-shaped second mandibular molars’ canals diverse greatly between populations from different geographical origine. Regardless the method of canal morphology analysis, 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 region of Middle East, 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). 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). Lower prevalence of C-shaped canals, and similar to our results was found in a study from Greece, 4.6% (24). These results, as well as ours, coincide within the range (2.7% - 8.1%) shown in studies in Caucasian race (3,22-24) which suggests that these difference could be racial or ethnical.

Because of their complexity, C-shaped canal systems could really complicate endodontic treatment, which may be even more complicated when they present configurations with variable number of canals at different axial cross-sections, such as a C-shaped canal presented in figure 6 (6,17); for example, that canal presented C1 configuration at the coronal cross-section, than C3 in the medial cross-section with three separate canals, merging again to C1 configuration at the apical cross-section (Figure 6, E,F,G)). Frequencies of different configurations on cross-sectional levels have been also shown to differ by population. Our results showed that at the coronal and apical cross-sections most canals have C1 configuration, which was similar to 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 C2 configuration at all cross-sectional levels was found in the studies of Yang et al. (28), Jayasinghe (29), and Seo & Park (30), while a study in Portugal showed that the most common was 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 analysed in order to avoid procedural errors during canal instrumentation. Therefore, we have examined 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 analysed the direction of the thinnest wall on axial cross-sections. Even though the most canals showed lingual directions, we found high frequency of the thinnest wall in buccal directions at all cross-sectional levels, contrary to previous findings (4). These results could help practitioners in endodontic treatment of C-shaped canals, where they could reduce incidence of root wall perforations during a chemo-mechanical preparation by directing instrumentation opposite to the less thinner wall (1,2,6,17).

**Conclusion**
Our results show that C-shaped canals should be expected in second mandibular molars of the population of Central Serbia with the prevalence of 5.53%. Configuration of C-shaped canals varied in morphology and in 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.

REFERENCES

FIGURE LEGENDS

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

Figure 2. Classification of C-shaped canal system configurations

Figure 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

Figure 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 the most of the line was located, minimal thickness value was added to one of the six directions

Figure 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

Figure 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 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)
FIGURES
<table>
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(2)

(3)

A

![Image](image6.png)

B

![Image](image7.png)
### Table 1.

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of teeth (%)</th>
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<tr>
<td></td>
<td>Coronal</td>
</tr>
<tr>
<td>C1</td>
<td>8 (72.7%)</td>
</tr>
<tr>
<td>C2</td>
<td>1 (9.1%)</td>
</tr>
<tr>
<td>C3</td>
<td>2 (18.2%)</td>
</tr>
<tr>
<td>C4</td>
<td>- (0.0%)</td>
</tr>
<tr>
<td>C5</td>
<td>- (0.0%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>11 (100.0%)</td>
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</table>
Table 2.

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

<table>
<thead>
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<th>Direction</th>
<th>Number of teeth (%)</th>
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<tbody>
<tr>
<td></td>
<td>Coronal ( % )</td>
<td>Middle ( % )</td>
<td>Apical ( % )</td>
</tr>
<tr>
<td>LM</td>
<td>3 (27.3%)</td>
<td>5 (50.0%)</td>
<td>2 (20.0%)</td>
</tr>
<tr>
<td>LC</td>
<td>2 (18.2%)</td>
<td>- (0.0%)</td>
<td>3 (30.0%)</td>
</tr>
<tr>
<td>LD</td>
<td>3 (27.3%)</td>
<td>2 (20.0%)</td>
<td>- (0.0%)</td>
</tr>
<tr>
<td>Total lingual</td>
<td>8 (72.7%)</td>
<td>7 (70.0%)</td>
<td>5 (70.0%)</td>
</tr>
<tr>
<td>BM</td>
<td>2 (18.2%)</td>
<td>2 (20.0%)</td>
<td>- (0.0%)</td>
</tr>
<tr>
<td>BC</td>
<td>1 (9.1%)</td>
<td>- (0.0%)</td>
<td>4 (40.0%)</td>
</tr>
<tr>
<td>BD</td>
<td>- (0.0%)</td>
<td>1 (10.0%)</td>
<td>1 (10.0%)</td>
</tr>
<tr>
<td>Total buccal</td>
<td>3 (27.3%)</td>
<td>3 (30.0%)</td>
<td>5 (30.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>11 (100.0%)</td>
<td>10* (100.0%)</td>
<td>10* (100.0%)</td>
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</table>

* One case had presented C5 configuration at the middle and apical cross-section. Thus, the t value and its direction could not be analysed.