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Evaluation of the Prevalence of C-Shaped Canal Configuration in Mandibular First and Second Molar Teeth with Cone Beam Computed Tomography in the Turkish Subpopulation: A Retrospective Study

Türk Subpopülasyonunda Mandibular Birinci ve İkinci Molar Dişlerde C-Şekilli Kanal Konfigürasyon Prevalansının Konik Işınlı Bilgisayarlı Tomografi ile Değerlendirilmesi: Retrospektif Çalışma

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ABSTRACT Objective: The aim of this study was to evaluate the prevalence, symmetry, configuration, and radicular groove type of C-shaped canals in mandibular first and second molars in a group of Turkish populations using cone-beam computed tomography (CBCT) images. **Material and Methods:** CBCT images of 442 (202 males and 240 females) patients, mandibular first and second molars were examined. The roots of the teeth were analyzed using axial sections in three different regions as coronal, middle and apical. The presence and classification of C-shaped canal configuration was evaluated in four categories according to the criteria of Fan et al. Also, the presence and classification of the radicular groove was assessed in three categories: buccal, lingual and buccal-lingual. Data analyzed by chi-square test. **Results:** While C-shaped canal configuration wasn't observed in first molars in the Turkish subpopulation, the frequency of "C" shape in lower second molars was determined as 6.94%. The presence of C-shaped canals was found to be higher in women than in men ($p<0.05$). In mandibular second molars, C-shaped canals were seen more frequently on the left side (65.96%). The prevalence of C1 canal configuration in the coronal (44.68%) and C4 configuration in the apical third (51.06%) was found to be significantly higher ($p<0.05$). The most common radicular groove type was determined to be the lingual groove with a prevalence of 74.47%. **Conclusion:** Gender and side factors seem to be effective in the variation of the C-shaped canal. Therefore, 3-dimensional evaluation of tooth morphology with CBCT is very important in terms of treatment planning and prognosis prediction.

Keywords: Cone-beam computed tomography; tooth root; mandibular molar; C-shaped canal configuration

ÖZET Amaç: Bu çalışmanın amacı, bir grup Türk popülasyonunda mandibular birinci ve ikinci molar dişlerdeki "C" şeklindeki kanalların prevalansını, simetrisini, konfigürasyonunu ve radiküler oluk tipini konik ışınlı bilgisayarlı tomografi (KIBT) görüntüleri kullanarak değerlendirmektir. **Gereç ve Yöntemler:** Çalışmada 442 (202 erkek ve 240 kadın) hastada, mandibular birinci ve ikinci molar dişlerin KIBT görüntüleri incelendi. Dişlerin kökleri koronal, orta ve apikal olmak üzere üç farklı bölgede aksiyal kesitler kullanılarak analiz edildi. "C" şeklindeki kanal konfigürasyonunun varlığı ve sınıflandırılması, Fan ve ark.nın kriterlerine göre dört kategoride değerlendirildi. Ayrıca radiküler oluğun varlığı ve sınıflandırılması bukkal, lingual ve bukkal-lingual olmak üzere üç kategoride değerlendirildi. Veriler ki-kare testi ile analiz edildi. **Bulgular:** Türk subpopülasyonunda birinci molar dişlerde "C" şeklinde kanal konfigürasyonu bulunmazken mandibular ikinci molar dişlerde "C "şeklinin görülme sıklığı %6,94 olarak belirlendi. "C "şekilli kanal varlığı kadınlarda erkeklerden daha yüksek bulundu ($p<0,05$). Mandibular ikinci molar dişlerde "C" şekilli kanal sol tarafta daha sık görüldü (%65,96). Koronalde C1 kanal konfigürasyonunun (%44,68) ve apikal üçlüde C4 konfigürasyonunun (%51,06) prevalansı anlamlı olarak yüksek bulundu ($p<0,05$). En sık görülen radiküler oluk tipi %74,47 prevalans ile lingual oluk olarak tespit edildi. **Sonuç:** C şeklindeki kanalın varyasyonunda cinsiyet ve simetri faktörlerin etkili olduğu görülmektedir. Bu nedenle KIBT ile diş morfolojisinin 3 boyutlu değerlendirilmesi, tedavi planlaması ve prognoz tahmini açısından çok önemlidir.

Anahtar Kelimeler: Konik ışınlı bilgisayarlı tomografi; diş kökü; mandibular molar dişler; C şekilli kanal konfigürasyonu

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Root canal structures may have various variations that affect the prognosis of endodontic treatments.[1] Knowing the variations in dental anatomy and the characteristic features of the root canal structures in various racial groups may be useful for locating the canals and management of treatments. One of the most significant variation seen in root canals is C-shaped root canal structures.[2] The main cause of C-shaped roots is the failure of Hertwig's epithelial root sheath to fuse at the lingual or buccal root surface.[3] In addition, the fusion formed by the accumulation of cementum with time can also lead to this formation.[4] In the literature, it is reported that C-shaped canal systems are mostly seen in the mandibular second molars (MSM), but may also occur in the other tooth groups.[5] It has been reported that races are effective in the incidence of C-shaped configurations. Therefore, variations in the root canal systems are thought to be related to ethnic origin and genetic structure.[6] It is reported that the prevalence of the C shape canal, which is more common in Asian communities compared to other regions, varies between 2.7% and 52.0% according to the population evaluated.[1,5]

The description of C-shaped root canal structure in the endodontic literature was made for the first time by Cooke and Cox in 1979.[7,8] The existence of fin- or web-shaped apertures that connect distinct root canals is its primary anatomical feature. Moreover, there may be variability in configuration along the root length.[4,9] The pulp chambers in these teeth often have a greater apico-occlusal width and the bifurcation area is at a lower level. There may be fusion formation in the mesial and distal roots of molar teeth that have this canal shape, both on the buccal and lingual surfaces. Due to this, occluso-apical groove representing this fusion line can be seen on the buccal or lingual surface of the root surface.[8] Melton et al. recommended a classification of C-shaped root canal systems based on cross-section views to describe these variations.[10] In Fan et al.'s classification, the root canal systems were re-evaluated in different axial sections along the canal and different configurations were distinguished.[4]

These morphological complexities create difficulties in terms of disinfection, debridement, canal filling procedures in the root canal structure. The success and appropriate of endodontic therapy may ultimately be impacted by these anatomical characteristics.[9] In periapical and panoramic radiographs, which are frequently used for diagnosis in clinics, anatomical clues of the C shape canal such as a large pulp chamber, roots with fusion or very close to each other can be seen.[8] However, conventional methods with limited aspects such as evaluation in two dimensions, superimposition and geometric distortion are insufficient in defining the characteristics of anatomical variations.[11-13] The most important advantage of the cone beam computed tomography (CBCT) as compared to conventional radiographs is its three-dimensional geometric accuracy.[13] Three-dimensional imaging provides higher sensitivity in the evaluation of real structures and helps to detect extra canals and anatomical variations in endodontics.[14]

The aim of this research was to evaluate the prevalence, symmetry and configuration of C-shaped canals in mandibular first molars (MFM) and MSMs in a group of Turkish population using CBCT images. In addition, it is aimed to investigate the presence of grooves in teeth with C-shaped root canal configuration and to reveal the root canal structure features of these teeth.

MATERIAL AND METHODS

The present study was conducted in accordance with the relevant guidelines of the principles of the Declaration of Helsinki and with the approval of protocol number 2022/27 (date: May 30, 2022) from the Ethics Committee of the Faculty of Dentistry of Selçuk University. In this retrospective study, the CBCT archive of Selçuk University Faculty of Dentistry was analyzed and images of 442 patients were included in the study. No additional CBCT images were taken for the study; instead, images from patients with indications for CBCT for reasons such as implant planning, impacted tooth evaluation, and pathological lesions were included. All CBCT images were selected from Central Anatolia region of Turkish population. Images of at least one MFM or MSM on both sides of which had completely formed roots were included for the study. However, images of teeth with root canal treatment, post-crown restora-

tion, periapical lesions and root resorption, as well as images with dental anomalies and low quality were not included in the investigation.

CBCT images are selected from images taken using the Instrumentarium Dental device (Palo DEx Group Oy, Nahkelantie, Tuusula, Finland). Slice thickness was used at 0.5 mm, and the acquisition parameters were 89 kVp and 4-12 mA. The software's image processing tool was used to optimize visualization by adjusting the images' contrast and brightness in accordance with the manufacturer's recommendations. The observers then performed analyses in sagittal, axial, and coronal planes using the same criteria and variants.

In CBCT images of 442 patients, MFMs and MSMs were examined separately and independently by two oral and maxillofacial radiologists (at least 4 years of experience). The roots of the teeth were evaluated using axial sections in three different regions, namely the coronal (below the pulpal floor by 2 mm), middle (full length of the root between the coronal and the apical region), apical (2 mm coronal of the radiographic apex) of the root. The presence of a C-shaped root canal system was determined according to three factors determined by Fan et al: having fused roots; the presence of a longitudinal groove on the lingual or buccal face of the root; showing a C1, C2 or C3 configuration in at least one of the axial sections. Configuration evaluation was made according to criteria modified by Fan et al.:[4]

Category 1 (C1): No division or separation of the continuous C-shaped canal,

Category 2 (C2): A semicolon-like image caused by the discontinuation of the C line, but the angle between alpha and beta should not be less than 60 degrees,

Category 3 (C3): Two or three separate canals with angles that were both under 60 degrees,

Category 4 (C4): Only one canal (circular or oval),

Category 5 (C5): No canal lumen (usually only seen near the apex). (C5 is not included because the apical 2 mm of the root cannot be clearly evaluated with CBCT) (Figure 1).[4]

At the same time, the presence and location of a radicular groove in the C-shaped roots was evaluated. In this evaluation, the location of the longitudinal groove was classified as buccal, lingual, or buccal and lingual.

Firstly, the existence and configuration of the C shape; the longitudinal groove was evaluated, then the results were analyzed. In addition, the presence of unilateral/bilateral C-shaped anatomy was also detected. Inter-observer agreement was evaluated in

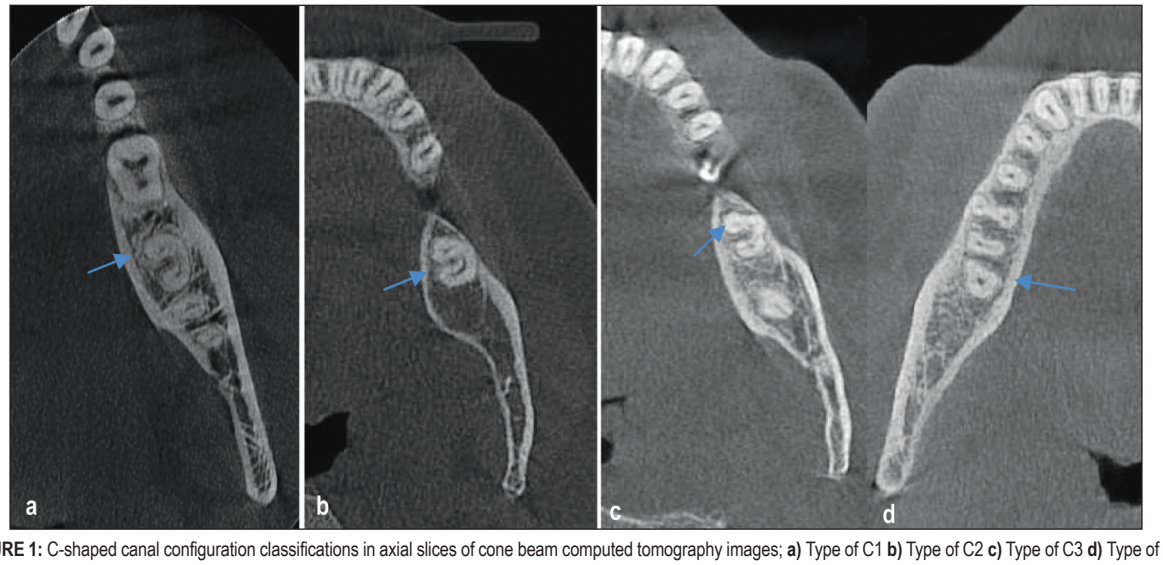

FIGURE 1: C-shaped canal configuration classifications in axial slices of cone beam computed tomography images; **a)** Type of C1 **b)** Type of C2 **c)** Type of C3 **d)** Type of C4.

20% of the sample size using Cohen's kappa coefficient. Consensus was made in different results and then data analysis using statistics was performed. The detected C-shaped canals were analyzed using the one sample chi-square test according to their configuration. At the same time, the association between C-shaped canal systems and gender, and whether the C-shaped canal was on one side or on both sides were evaluated with using chi-square test. SPSS version 22 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The level of $p<0.05$ was accepted as statistically significant.

RESULTS

Interobserver reliability was high in the evaluation of C-shaped canals (kappa value: 0.950).

In this study, CBCT images of 442 patients (202 males and 240 females) were analyzed. A total of 1,261 teeth, including 584 MFMs and 677 MSMs were evaluated.

C shape variation was detected in 35 patients. (7.92%) No C-shaped canal configuration was detected in the MFMs. The presence of C shape was determined in 47 MSM teeth. (6.94%) Among 35 patients, C-shape presence was detected bilaterally (both right and left) in 12 patients. (34.29%) In 23 patients, unilateral C shape was determined. (65.71%)

Table 1 shows the distribution of C shape canal configuration by gender and side. The prevalence of C shape was determined as 3.22% (10 individuals) among men and 10.11% (37 individuals) among women. It was found that female individuals showed a significantly higher c shape incidence than male individuals ($p<0.05$). Of the C-shaped canal morphology in MSMs, 65.96% were on the left side and 34.04% were on the right side. The prevalence of MSM tooth with C-shaped canal configuration was statistically significantly higher in the left mandible ($p<0.05$) (Table 1).

In 47 MSMs, the prevalence of C1 canal configuration (44.68%) in the coronal and C4 configuration (51.06%) in the apical third was determined to be statistically significantly higher ($p<0.05$). Although the prevalence of C2 (31.91%) in the middle third was higher than in other configurations, there was no statistically significant difference ($p>0.05$) (Table 2).

The most common lingual groove was seen in C-shaped MSMs with a prevalence of 74.47%. Buccal groove was detected in only one tooth (2.13%) ($p<0.05$) (Table 3).

TABLE 1: Prevalence of C-shaped morphology in second molar according to gender and side.

	Present n (%)	Absent n (%)	Total n (%)	p values
Gender				
Female	37 (10.11)	329 (89.89)	366 (100)	0.000*
Male	10 (3.22)	301 (96.78)	311 (100)	
Total	47 (6.94)	630 (93.06)	677 (100)	
Side				
Right	16 (4.91)	310 (95.09)	326 (100)	0.045*
Left	31 (8.83)	320 (91.17)	351 (100)	
Total	47 (6.94)	630 (93.06)	677 (100)	

Chi-square test, *$p<0.05$.

TABLE 2: Distribution of C-shaped canal configurations in different axial sections.

Root level	C1	C2	C3	C4	p values
Coronal	21 (44.68%)	8 (17.02%)	14 (29.79%)	4 (8.51%)	0.003*
Middle	13 (27.66%)	15 (31.91%)	11 (23.40%)	8 (17.02%)	0.517
Apical	10 (21.28%)	6 (12.77%)	7 (14.90%)	24 (51.06%)	0.000*

One sample chi-square test, *$p<0.05$.

TABLE 3: Prevalence of Groove type in C-shaped second molar.

Groove location	Buccal	Lingual	Buccal and lingual	Total	p values
Mandibular second molar n (%)	1 (2.13)	35 (74.47)	11 (23.40)	48	0.000*

One sample chi-square test, *p<0.05.

DISCUSSION

Irregular and retaining areas affect the root canal treatment success in teeth with C-shaped root-canal morphology.[15] It is very crucial to detect these morphologies radiologically in order to increase the chance of success of treatment using advanced technological methods.[16] C-shaped canal morphology may not be determined by two-dimensional imaging. CBCT is a non-invasive imaging method that enables the examination of tooth anatomy in three axes: axial, coronal and sagittal. Variations are detected by three-dimensional evaluation.[6,17] In this study, the frequency and configuration of C-shaped canal variation in MFMs and MSMs in a group of Turkish Populations were examined with CBCT images.

The ethnic factor is effective in the C-shaped canal configuration. It is known that the incidence is high in East Asians and less common in Europeans and Americans.[8,18] In the literature, studies with the highest incidence of C-shaped morphology in MSMs were conducted in Korean (36.8%, 39.8%) and Chinese populations (34.6%, 38.6%).[19-22] The prevalence of C-shaped canal variation varies between 4.6% and 14.32% in different populations such as Brazil, Portugal and Nepal except East Asian countries.[1,3,6,9,23,24] In the Turkish subpopulation, the prevalence of MSM teeth with C-shaped canal variation was reported as 10.7% by Sönmez Kaplan et al., 7.7% by Kaya Büyükbayram et al., 8.9% by Helvacioglu-Yigit and Sinanoglu and 4.1% by Duman et al.[15,16,25,26] In our study, the prevalence of C-shaped canal configuration in MSMs was determined as 6.94%. This result is similar to the average of the prevalence values found in previous studies in Turkish society.

Although C-shaped canal variation is most common in MSMs, it can also be observed in MFMs, mandibular first premolars, maxillary molars and maxillary lateral incisors.[2,8] It has been reported that C-shaped variation is rare in MFMs.[3] In studies conducted in different populations, the incidence of C-shaped canal variation in MFMs was found to be between 0.16% and 2.39%.[1,5,9,11,17] In the Turkish population, Kaya Büyükbayram et al. and Duman et al. reported similar results with a prevalence of 0.41% and 0.15%, respectively.[15,25] In this study, 584 MFM teeth were evaluated and no C-shaped canal variation was found. This result is compatible with the low prevalence values in the Turkish population and other populations.

Zheng et al., Helvacioglu-Yigit and Sinanoglu, Shemesh et al. stated that there was no relationship between gender and the prevalence of C-shaped canal variation in MSMs.[9,21,26] However, in many studies conducted in different ethnic communities, the prevalence of MSMs with C-shaped canal variation was found to be higher in women.[1,5,11,15,16,19] In current study, women had a higher prevalence (10.11%) than men (3.21%), which is consistent with the results of most studies in the literature. In the light of these results, it is thought that ethnic factor is not effective in the correlation of possible C-shaped canal anatomy and gender, but sample size and the difference in the evaluated subpopulations may be effective.

The prevalence of bilateral C-shaped canal variation was determined to be 81.3% by Zheng et al. in the Chinese population and 75.3% by Yang et al. in the Korean population. Contrary to these results, Sönmez Kaplan et al. and Ulfat et al. stated that the prevalence of unilateral and bilateral C-shaped canal variation was equal (50%).[6,16,20,21] The findings of this study revealed that the C-shaped canal configuration was more frequently seen unilaterally (65.71%), consistent with Alfawaz et al. (53.8%) and Ladeira et al. (68.3%).[11,17] Although studies have found different results for the bilateral incidence of C-shaped canal morphology, it is encountered at a substantial rate in every population evaluated. Therefore, dentists

should take into account that similar anatomical variation can be observed contralaterally when the C-shaped canal morphology of the MSM teeth is encountered on one side. Besides, our findings show that this variation is more common on the left side unlike some researchers who reported that there was no significant relationship between the anatomy of the C-shaped canal and the sides of the mandible.[15,19,26-28]

Different classifications have been made for C-shaped canals according to their anatomical and radiological features.[9,10,29] Fan et al. made the current classification of C-shaped canal configurations with micro CT and defined five groups.[29] In this study, C-shaped canal morphology was evaluated on CBCT images in three cross sections (coronal, middle, apical third) based on the classification technique developed by Fan et al.[29] Since the apical 2 mm of the root could not be evaluated clearly with CBCT, C5 was not included and four groups were used for classification.

In this study, C1 was the most common configuration in the coronal third of the root, consistent with the findings of previous researchers.[9,16,23,27,28] Besides, Amoroso-Silva et al. evaluated MSMs with a C-shaped canal using micro-CT and found that the most common configurations in the cervical third of the root were C1 and C2.[30]

In the middle third of the root, Shemesh et al. C2 and C3 configuration, Joshi et al. and Nejaim et al. C1 configuration, Sönmez Kaplan et al. reported that the C2 configuration was the most prevalent.[1,9,16,23] We observed the most common configuration as C2 in the same region, but there was no statistically significant difference.

Shemesh et al. reported that the C1 configuration is common in the apical third of the root, while Joshi et al. and Sönmez Kaplan et al. stated that C2 and C4, C4 configurations are observed frequently, respectively.[9,16,23] In addition, in the Micro-ct study it was determined that the C4 configuration was most frequently encountered in the apical third.[30] Consistent with these findings, the prevalence of C4 configuration (51.06%) was found to be high in the apical third region in the present study.

In our study in a group of Turkish population, the most common configurations in the coronal, middle, and apical sections, respectively, were C1, C2, and C4. These findings were similar to the results of a study conducted in another subpopulation in the same society.[16] This suggests that the ethnic factor may have an effect not only on the prevalence of the C-shaped variation, but also on the configuration types. In order to support this hypothesis, different studies need to be done in the same populations using the same methodologies and large sample size.

Knowing the longitudinal groove's location and its relationship to the root canals prevents possible strip perforation when inserting the instrument during endodontic treatment.[11,15] Consistent with most studies in different populations in the literature, the prevalence of lingual grooves (74.47%) in C-shaped canals was also found to be high in this study.[6,9,11,15] Contrary to these results, where the buccal groove is rarely seen, Ladeira et al. reported that the prevalence of the buccal groove in C-shaped canals was 69.4%.[17] In the same study, it was stated that it is associated with more buccal grooves in C-shaped teeth with more than one canal. Therefore, detailed studies are needed to evaluate the relationship between groove localization and canal number.

A limitation of this study is that the relationship between the age factor and the C-shaped canal was not evaluated. Another restriction is that only mandibular molars were included in the study.

CONCLUSION

In this study;

- No C-shaped canal variation was detected in MFMs in the Turkish subpopulation.
- The prevalence of C-shaped canals in MSMs was 6.94%; C-shaped canal was observed more frequently in women.
- The C-shaped canal anatomy was mostly seen unilaterally and on the mandible's left side. The most common configurations in the coronal, middle, and apical sections, respectively, were C1, C2, and C4. This population's most prevalent groove type was lingual.

■ It is seen that gender and symmetry factors are effective in C-shaped canal variation. Although its prevalence is not high in our society, it is important to evaluate the morphology of these teeth in 3D with CBCT in terms of treatment planning and prognosis prediction.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Zeynep Betül Arslan, Fatma Büşra Doğan;* ***Design:*** *Zeynep Betül Arslan, Fatma Büşra Doğan;* ***Control/Supervision:*** *Derya İçöz;* ***Data Collection and/or Processing:*** *Zeynep Betül Arslan, Fatma Büşra Doğan, Derya İçöz;* ***Analysis and/or Interpretation:*** *Zeynep Betül Arslan, Fatma Büşra Doğan;* ***Literature Review:*** *Zeynep Betül Arslan, Fatma Büşra Doğan, Derya İçöz;* ***Writing the Article:*** *Zeynep Betül Arslan, Fatma Büşra Doğan;* ***Critical Review:*** *Zeynep Betül Arslan, Fatma Büşra Doğan, Derya İçöz.*

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