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Original Article

# Cone-beam computed tomography evaluation of C-shape canals and longitudinal grooves of mandibular first and second molar teeth

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## Abstract

**Aim:** This study aims to evaluate the anatomical features and prevalence of C-shaped roots and longitudinal grooves in mandibular first and second permanent teeth using cone-beam computed tomography (CBCT).

**Material and Methods:** CBCT records of first and second mandibular teeth from 839 patients who applied to the Department of Oral and Maxillofacial Radiology between 2011 and 2018 were used. The CBCT examination was performed at five different axial levels and the mandibular molars were classified as types of longitudinal groove and C-shape according to the Fan criteria. Differences between genders, age groups, left and right side and type of tooth were determined.

**Result:** A total of 2903 teeth (1321 first molars and 1582 second molar) from 839 patients were included in the study. C-shaped canals were found in mandibular first molar teeth with a prevalence of 0.15%, while 4.1% in mandibular second molar teeth. Only two mandibular first molars exhibited C-shaped canal. Female patients had a higher prevalence than males. Longitudinal grooves were most commonly found lingual surface.

**Conclusions:** The occurence of C-shaped canals in mandibular first and second molars among Turkish population was generally less than in other populations. CBCT is a valuable tool to evaluate the C-shaped root canal configuration in vivo.

**Keywords:** Cone-beam computed tomography; C-shaped canal; mandibular molar

## INTRODUCTION

The determination of anatomical and morphological differences by examining the root canal systems has an important place in the success and prognosis of root canal treatment (1). C-shaped root canal systems that are present in root canals is one of the anatomical variations in which the root canals of teeth are combined with a connection. The reason that this anatomical variation is expressed in "C" is that the shape resulting from the connection of the roots that are expected to be separated resembles the shape of "C" in cross-section (2). Firstly, in 1911, Keith and Knowles pictured a C-shaped canal found in the human mandibular second molar teeth root (3). However, the first C-shaped canal term was defined by Cox and Cooke in 1979 (4).

Radiographic examination is one of the important steps in the diagnosis and treatment planning of endodontic diseases (5). In very thin situations of C-shaped root systems, the diagnosis of dentin between the roots is very difficult with panoramic radiographs and intraoral radiographs that give two-dimensional (2-D) images (4,6). On the other hand, clinically it is hard to predict whether the C-canal morphology detected in the canal entry will continue to be C-shaped throughout the root, and they may exhibit variable morphological features towards apical regions (2,7). Cone-Beam Computed Tomography (CBCT) or Dental Volumetric Tomography (DVT) is an extraoral image scanner that can create a three-dimensional (3D) image of jaw and facial tissues (8). The use of CBCT in the evaluation of C-shaped root canal systems has been

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reported to be more advantageous than other radiographs in terms of obtaining 3D images, dividing the image into sections and creating a higher quality image with low dose radiation (9). Segmental examination of the root structure in the axial plane helps to determine the morphological features of C canal.

C-shaped root systems are found mostly in the mandibular second molar teeth (2,7,10-14). It was also reported to be seen in the maxillary molar (13), and mandibular premolar (15) and mandibular third molar teeth (16). C-shaped canals are rare anatomical variations, but its incidence in the Asian communities is more than in other regions (9,14,17). C-shaped root systems have been reported to be bilateral generally (3,9) and in this respect, symmetrical teeth in jaw should be evaluated in terms of this variation (18).

The purpose of this study is the evaluation of anatomical properties and prevalence of the C-shaped roots and longitudinal groove in mandibular first and second permanent teeth by using CBCT.

## MATERIAL and METHODS

In this study, CBCT (Newtom 5G, QR, VERONA, ITALY) records of first and second mandibular teeth from 839 patients who applied to the Department of Oral and Maxillofacial Radiology of Inonu University Faculty of Dentistry between 2011 and 2018 were used. All CBCT images were se¬lected from a Turkish population from the Eastern Anatolia region of Turkey. Researchers collected the data according to the cross-sectional research method. Extra CBCT data was not taken from any patient for this study, the existing data in our clinic were used. The permission and consent documents required for the use of the data of the patients were obtained from the Inonu University Scientific Research and publication Ethics Committee before the study. (Approved number: 2018/23-16)

Patients with at least one mandibular first molar or second molar teeth were included in the study. Patients who had healthy mandibular first and second molars which were completely impacted and which had completely developed their root development were included in the assessment. Patients with non-clear and distorted CBCT images, teeth with pathological problems such as crowns or post, periapical abscess, root canal treatment history, and root resorption were excluded from the study. CBCT sections of 0.15mm were formed. Experienced at least five years in the field four dentomaxillofacial radiolog and a

paedodontist evaluated concurrently all the images to reach a consensus in the interpretation of the radiographic findings. The contrast and brightness of the images were adjusted according to the manufacturer's instructions to ensure standardization. The reliability values were detected using Cohen's kappa test (0.86).

The modified classification method of Fan et al.(2) was used in the evaluation of canal configurations of C root canal systems for 2903 scanned teeth;

Category 1 (C1): Continuous C-shaped canal without any separation or division,

Category 2 (C2): A semicolon-like image resulting from the discontinuation of the C line, but either alpha angle or beta angle must be less than 60 degrees,

Category 3 (C3): 2 or 3 separate canals, and both alpha and beta angles must be less than 60,

Category 4 (C4): Only one round or oval canal in the section,

Category 5 (C5): The canal lumen is not visible or is only seen near the apex.

Types of longitudinal groove of teeth with C root canal system are as follows;

Tip 1: Only a Lingual groove,

Tip 2: A deep groove on the lingual wall and a shallow groove on the buccal wall,

Tip 3: Only a buccal groove,

Tip 4: A deep groove on the buccal wall and a shallow groove on the lingual wall.

Each tooth was examined in axial, coronal and sagittal sections, and three different levels were identified as coronal (2 mm below the Pulpa floor), medium (full length of the root from pulpal floor to apex separation point) and apical (2mm coronal of radiographic apex) for the axial section. The presence of the types of canal configurations root were evaluated using toolbar by carefully rolling downward through the images from coronal to the apex. In the study, the relationship of the patient's gender and age with C canal systems, the localization of longitudinal groove in the teeth, whether the C-shaped canals are single sided or bilateral, and its category were evaluated. These correlations were determined by the chi-square test. Data were analyzed with significance level set at 5% ($p<0.05$) with using SPSS software (IBM SPSS Statistics for Windows, Version 22.0, Armonk, NY, USA) (Figure 1-2).

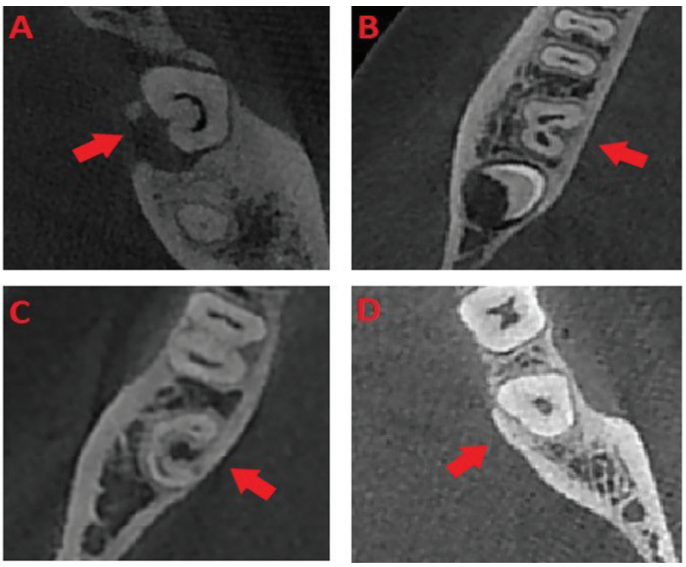


**Figure 1.** C-shaped canal types on the axial slices of CBCT images. A. Type-1 B. Type-2 C. Type-3 D. Type-4

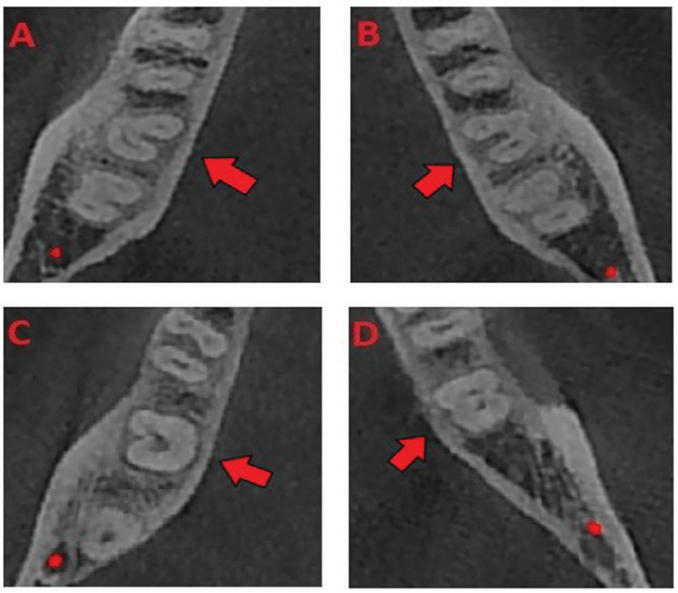


**Figure 2.** Longitidunal groove types on the axial slices of CBCT images. A. Type-1 B. Type-2 C. Type-3 D. Type-4

## RESULTS

A total of 2903 teeth (1321 first molars and 1582 second molar) from 839 patients (469 female and 370 male) were included in the study. The ages of patients are between 15 and 73 years old, and the mean age is 28.4 (female=27.6, male=29.5). In the study, 30 females and 13 males, in total 43 patients (5.1%) had the C-shaped canal system. C-shaped canal were found more in the female patients than the male patients (P<0.05) (Table 1). Regarding the type of tooth ; two C-shaped canals (n=1321) were determined at first mandibular molars and 65 C-shaped canals (n=1582) were identified at second mandibular molars. The difference between teeth was considered statistically significant at p<0.05.

The prevalence of C-shaped canals were found 0.15% (n=2) in mandibular first molar teeth (n=1321) .Only two mandibular first molars exhibited C-shaped canal and CBCT image sections, C2 root canal configurations and only lingual groove were observed.

Prevalence of C-shaped canals were found 4.1% (n=65) in mandibular second molar teeth (n=1582). C canal systems were mostly encountered in 21-30 years old (52.3%), and the number of teeth with C-shaped root decreased with advanced age(Table 2). There were no significant differences in the distribution of C-shaped canals between unilateral and bilateral regions. Similar results were obtained between the right (47.7%) and left (52.3%) regions when the position of the teeth with C-shaped canals on the jaws was evaluated (p>0.05) (Table 3). In the CBCT image sections, C2 (58.4%) root canal configurations were observed mostly, followed by C1 (20%) and C3 (16.9%) canal configurations. C4 canal configuration was seen at only three teeth. There was no C5 canal configuration at all. When looking at groove localizations of teeth with C-shaped grooves, the most common was found the lingual groove (61.5%) (Table 2-3).

**Table 1. Prevalence of the number of patients with C-shaped canals and teeth according to the total number of patients and teeth number**

| | General Population | | C-shaped canals | |
|---|---|---|---|---|
| | Patients n (%) | Teeth n (%) | Patients n (%) | Teeth n (%) |
| Female* | 469 (55.9) | 1641 (56.5) | 30 (3.57) | 44 (2.6) |
| Male | 370 (44.1) | 1262 (43.5) | 13 (1.54) | 23 (1.8) |
| Total | 839 (100) | 2903 (100) | 43 (5.1) | 67 (2.3) |

Chi square, * p<0.05, % = Frequency, n: Number

**Table 2. Canal configurations and distribution of groove types of C-shaped mandibular second molar teeth according to the age of patients**

| | Canal configurations | | | | | Groove Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C1 n (%) | C2 n (%) | C3 n (%) | C4 n (%) | Total n (%) | Tip1 n (%) | Tip2 n (%) | Tip3 n (%) | Tip4 n (%) | Total n (%) |
| 15-20 | 3 (4.6) | 8 (12.3) | 3 (4.6) | | 14 (21.6) | 9 (13.9) | 5 (7.7) | | | 14 (21.6) |
| 21-30 | 9 (13.9) | 17 (26.1) | 5 (7.7) | 3 (4.6) | 34 (52.3) | 22 (33.8) | 11 (16.9) | 1 (1.5) | | 34 (52.3) |
| 31-40 | 1 (1.5) | 8 (12.3) | 1 (1.5) | | 10 (15.3) | 8 (12.3) | 1 (1.5) | | 1 (1.5) | 10 (15.3) |
| >41 | | 5 (7.7) | 2 (3.1) | | 7 (10.8) | 1 (1.5) | 5 (7.7) | 1 (1.5) | | 7 (10.8) |
| Total | 13 (20) | 38 (58.4) | 11 (16.9) | 3 (4.6) | 65(100) | 40 (61.5) | 22 (33.8) | 2 (3.0) | 1 (1.5) | 65 (100) |

C1: Continuous C-shaped canal without any separation or division, C2: A semicolon-like image resulting from the discontinuation of the C line, but either alpha angle or beta angle must be less than 60 degrees, C3: 2 or 3 separate canals, and both alpha and beta angles must be less than 60, C4: Only one round or oval canal in the section, C5: The canal lumen is not visible or is only seen near the apex Type 1: Lingual groove, Type 2: A deep groove on the lingual wall and a shallow groove on the buccal wall, Type 3: Buccal groove, Type 4: A deep groove on the buccal wall and a shallow groove on the lingual wall, % = Frequency, n: Number of teeth

**Table 3. Canal configurations and distribution of groove types of C-shaped mandibular second molar teeth according to sides**

| | Canal configurations | | | | | Groove Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C1 n (%) | C2 n (%) | C3 n (%) | C4 n (%) | Total n (%) | Tip1 n (%) | Tip2 n (%) | Tip3 n (%) | Tip4 n (%) | Total n (%) |
| Left | 8 (12.3) | 20 (30.7) | 5 (7.7) | 1 (1.5) | 34 (52.3) | 19(29.2) | 13 (20) | 1 (1.5) | 1(1.5) | 34(52.3) |
| Right | 5 (7.7) | 18 (27.7) | 6 (9.2) | 2 (3.1) | 31 (47.7) | 21(32.3) | 9 (13.9) | 1 (1.5) | | 31(47.7) |
| Total | 13 (20) | 38 (58.4) | 11(16.9) | 3 (4.6) | 65 (100) | 40(61.5) | 22 (33.9) | 2(3.1) | 1(1.5) | 65 (100) |

Chi-square analysis, *p>0.05, %= Frequency, n: Number of teeth. C1: Continuous C-shaped canal without any separation or division, C2: A semicolon-like image resulting from the discontinuation of the C line, but either alpha angle or beta angle must be less than 60 degrees, C3: 2 or 3 separate canals, and both alpha and beta angles must be less than 60, C4: Only one round or oval canal in the section, C5: The canal lumen is not visible or is only seen near the apex Type 1: Lingual groove, Type 2: A deep groove on the lingual wall and a shallow groove on the buccal wall, Type 3: Buccal groove, Type 4: A deep groove on the buccal wall and a shallow groove on the lingual wall

## DISCUSSION

In addition to the traditional radiographs, many techniques are used in the examination of root canal systems (11,19). However, the CBCTs, developed in parallel to technological advances, are becoming increasingly widespread in assessing the anatomical structures and configurations of root and canal systems. The main endodontic applications of CBCT include the diagnosis of root pathologies, evaluation of root canal morphology, diagnosis of periapical lesions and follow-up of prognosis, and evaluation of environmental tissues before surgery (5). In addition, the causes of widespread use of this device are that it allows the examination of the images on different planes by three-dimensional image acquisition, also reduces the possibility of superposition and clearly reveals the desired area (19). CBCT is mostly used in morphology studies in endodontics. Especially, the studies on root canal morphology in different societies is noteworthy. In our study, the patient population in eastern Anatolia region of Turkey was investigated using CBCT for the evaluation of C canal systems. The study is the most comprehensive study in this respect in terms of the number of investigated teeth.

There are several examples of invasive studies made using extracted teeth (11,14,20). However, in the evaluation of the root canals, standard and correct results may not be achieved since extracted teeth are usually pathological problematic teeth, and calcification can be observed.

The root canal configurations need to be well known for the proper shaping of canals and the success of endodontic treatment. C-shaped canal systems affect the success of canal treatment and access to canals due to their complex structures. These anatomical differences are most common in mandibular second molar teeth (2,3,10,13). In the studies, in which root canal morphologies were examined, conducted in different societies, this anatomical variation were observed to reach high prevalence in the Asian countries (9,17). The prevalence rates of 39% and 44.5% in the studies performed in China (9) and Korea (17), respectively, support this data. According to the studies performed in different societies, the prevalence of C-shaped canal in mandibular second molar teeth is 10% in Thailand (14), 7.2% in Iran (11), 15.3% in Brazil (21), 14% in Russia (22), 4.58% in Greece (6), 8.5% in Portugal (23), 9.1% in Saudi Arabia (12). These studies are evidence that C canal prevalence may vary depending on ethnicity differences. Zuben (24) revealed the prevalence of C-shaped canals as 13.9% on average for different populations. In Turkey, Helvacıoğlu (7) determined the prevalence of mandibular second molar teeth with C-shaped canal as 8.9%. In the present study, the prevalence was also determined as 4.1%. In the Asian population, the prevalence of C-canals was bilaterally quite high (9,17,22). Contrary to that, Ladeira (21) and Alfawaz (12) stated that C-shaped canals were usually seen as unilateral. Although the prevalence of bilateral canals is higher in our study, there was no significant difference between the single-sided or double-sided cases. However, it should be kept in mind that when a C canal is detected on a tooth on the right side of the jaw, it may also seen on the left side. In addition, this difference may be due to the differences in ethnic origin, and the fact that there are few studies on this subject and the lack of detailed research.

C canal systems are most commonly seen in the lower second molar teeth, but these configurations are less found in the lower first molar teeth(12,23) and the lower second premolar (15) teeth. Alfawaz et al. (12) reported the prevalence of the C canal in the lower first molar teeth as 0.19%, similarly, Martins et al. (23) reported as 0.6%. We found it as 0.15% in the present study. Zhen (9), Jin (17), Helvacıoğlu (7), and Laderira (21) did not find a significant difference between the C canal prevalence in terms of age and gender, whereas, in the studies of Alfawaz (12), Zuben (24), Martins (23), as well as in the present study, the C canal had more prevalence in females than in males. In most of the studies (7,9,24) that have evaluated the C canal morphology, there is no significant difference between the teeth in the right and left parts of the jaws, which is similar

to the findings in our study.

The most common type of C canal configuration at the coronal study level is C1, however, when the canals move from the coronal to the apical region, they form two or more branches and this finding is similar to that of Zheng et al. (9) in the Asian population.

Since C-shaped canal morphology has a complicated structure, it creates irregular and retentive areas that are difficult to clean within the canal during treatment. Inadequate cleaning, shaping, and filling of these areas have a negative effect on the success of root canal treatment (25). Knowing the localization of longitudinal groove during endodontic instrumentation in C canal configured teeth is very important to avoid strip perforation. It can also be associated with longitudinal groove root canals (2). Therefore, in addition to normal treatment procedures, some applications, and modified techniques are used to eliminate these negative symptoms (25,26). In the present study, longitudinal groove was found mostly as lingual groove (61.5%). Although this finding is similar to Martins (23) and Helvacioglu (7); Ladeira (21) found that the buccal groove had the most common prevalence with 69.4%.

In the Turkish population, C-shaped canals were previously investigated by Cimili (20) and Helvacıoğlu (7). However, the present study were not conducted with invasive techniques and allowed the evaluation of a high number of teeth using CBCT, so it differs from the study of Cimili (20). Similarly, our study differs from the study of Helvacıoğlu (7) because of the large number of teeth examined and involvement of mandibular first molar teeth. These differences make the present study more comprehensive than other research conducted in the Turkish population.

## CONCLUSION

In conclusion, our finding demonstrate that occurence of C-shaped canals in mandibular first and second molars among Turkish population was generally less than in other populations. CBCT is a effective diagnostic modality and useful tool for endodontic treatment.

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