Evaluating root canal configuration of mandibular incisors with cone-beam computed tomography in a Turkish population

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KEYWORDS
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Abstract
Background/purpose: The aim of this retrospective study was to analyze the morphology of root canal systems of mandibular incisors using cone-beam computed tomographic (CBCT) images.

Materials and methods: A total of 374 mandibular incisors’ images obtained from CBCT of 101 patients were included in the study. The following information was recorded: (1) the age and sex of the patient, (2) the tooth type, (3) the number of roots, (4) the root canal configuration, and (5) the bilateral/unilateral diversity in root number and the configuration of the root canals. The configuration of the root canals was categorized using Vertucci’s classification as the main reference. Statistical analysis was carried out using Chi-square and Spearman’s rank correlation tests (P = 0.05).

Results: Overall, 52.4% (n = 196) of the teeth had one root canal (Type I), and 47.6% (n = 178) had two root canals with different root canal configurations. The rate of complex root canal configurations was higher in males than in females (P < 0.001).

Conclusion: Almost one of two mandibular incisors had complex root canal systems. The CBCT may be recommended as an effective diagnostic device for identifying complex root canal configurations. The prevalence of complex root canal configuration was higher in males than in females.

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Introduction

Successful management of endodontic cases stems from a detailed understanding of the morphology of the root canal system. Adequate chemomechanical preparation and effective filling of the root canal system are based on knowledge of normal root canal morphology and variations from the norm obtained from studies of root and canal morphology. It is well established that the failure to treat all the canals effectively leads to poor endodontic outcomes.

The morphology of the root canal systems of mandibular incisor teeth may be different depending on the population. Previous studies have shown that a high percentage of mandibular incisor teeth have more than one root canal. The incidence of mandibular incisor teeth with more than one canal has been reported to range from 11.5% to 50%. A case report also recorded more than one root in these teeth. The variations in mandibular incisor teeth may result in missing root canals, nonsurgical endodontic treatment failure, and a need for surgical procedures.

Clearing techniques, cross sections, and radiographic evaluations have been used in studies that evaluated the root canal morphology of mandibular incisor teeth. In recent times, cone-beam computed tomography (CBCT) has been used to evaluate the morphology of root canals. The CBCT provides a practical tool for noninvasive and three-dimensional reconstruction imaging by clinicians in endodontic applications and morphological analyses.

Kartal and Yanikoglu, and Sert and Bayirli used clearing technique and evaluated the mandibular incisors using a microscope. Bellizzi and Hartwell conducted a clinical in vivo study and evaluated the root canal systems on mandibular incisors using radiographs. In the study by Karagoz-Kucukay, the frequency of root canal ramifications in mandibular incisors was evaluated at 30× magnification after a low-temperature injection of thermoplasticized gutta-percha (Table 1). The CBCT can depict a more detailed feature of root canal configuration of mandibular incisors. However, this imaging method has not been used to detect the root canal configuration of mandibular incisors. Thus, the purposes of this study were to investigate the morphology of the root canal systems of mandibular incisor teeth in a Turkish population using CBCT and to correlate the findings with the patient’s age and gender.

Materials and methods

We selected 217 previously obtained CBCT images from the archive of the Department of Oral and Maxillofacial Radiology of Izmir Kâtip Çelebi University, Izmir, Turkey. All the images were obtained with a NewTom 5G CBCT machine (QR Srl, Verona, Italy) from patients with different dento-maxillofacial problems between October 2012 and April 2013. The voxel size was 0.15 mm and the slice thickness was 1.0 mm. The acquisition process was performed by an experienced radiologist according to the manufacturer’s recommended protocol, with the minimum exposure time necessary for adequate image quality.

Inclusion criteria were the presence of (1) high-quality CBCT images and (2) CBCT images of mandibular incisors with fully formed apices. Exclusion criteria were the presence of (1) coronal restoration, (2) root canal fillings and posts, and (3) internal/external resorption or periapical lesions in mandibular incisors. The CBCT images of 374 mandibular incisors from 101 patients who met the inclusion/exclusion criteria were analyzed with NNT software using a Dell Precision T5400 workstation (Dell, Round Rock, TX, USA). Eighty-eight patients had bilateral mandibular central incisors, and 89 patients had bilateral mandibular lateral incisors. These data were used to analyze the distribution and the occurrence of the unilateral and bilateral root canal configurations.

Two independent endodontists assessed the axial, sagittal, and coronal sections to reach a consensus on the interpretation of the radiographic findings. In cases where a consensus was not reached, a third professional oral radiologist was asked to perform a decisive evaluation. Forty of the images were selected and assessed by the same examiners 6 weeks after the first evaluation.

The following information was recorded: (1) the age and gender of the patient, (2) the tooth type (central or lateral), (3) the numbers of roots, (4) the root canal configuration, and (5) the bilateral/unilateral diversity in root number and root canal configuration. The root canal configuration was categorized using Vertucci’s classification as the main reference (Fig. 1).

- Type I: In this type, single root canal leaves the pulp chamber and ends as single foramen.

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Year</th>
<th>Model</th>
<th>Total number of mandibular incisors</th>
<th>Number of teeth with more than one single canal</th>
<th>Percentage of total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kartal and Yanikoglu</td>
<td>1992</td>
<td>Clearing technique; microscope</td>
<td>100</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Sert and Bayirli</td>
<td>2004</td>
<td>Clearing technique; microscope</td>
<td>400</td>
<td>271</td>
<td>67.75</td>
</tr>
<tr>
<td>Bellizzi and Hartwell</td>
<td>1983</td>
<td>In vivo; radiographs</td>
<td>417</td>
<td>76</td>
<td>18.2</td>
</tr>
<tr>
<td>Karagoz-Kucukay</td>
<td>1994</td>
<td>Thermoplasticized gutta-percha; microscope</td>
<td>40</td>
<td>15</td>
<td>37.5</td>
</tr>
</tbody>
</table>

a Other tooth groups except mandibular incisor were evaluated. The numbers are only for mandibular incisors.
b Root canal ramifications were evaluated.
Type II: Two root canals leave the pulp chamber and end as single foramen.

Type III: In this type, single root canal leaves the pulp chamber, separates into two separate root canals, and ends as single foramen.

Type IV: Two root canals leave the pulp chamber and end as two foramina.

Type V: In this type, single root canal leaves the pulp chamber and ends as two foramina.

Type VI: Two root canals leave the pulp chamber, join again as single root canal, and end as two foramina.

Type VII: In this type, single root canal leaves the pulp chamber, separates into two separate root canals. These root canals join again as a single root canal, and end as two foramina.

Type VIII: Three root canals leave the pulp chamber, and end as three foramina.

Additional type (introduced by Ng et al19): Two root canals leave the pulp chamber, join again as single root canal, which separates into two branches and end as two foramina.

Additional forms of root canals were also evaluated using additional types reported by Kartal and Yanikoglu, Gulabivala et al,16 Ng et al,19 and Sert and Bayirli. The different sections of CBCT scanning were evaluated together to ascertain the root canal configuration (Fig. 2).

Statistical analysis

To avoid confusing definitions of root canal complexity, two distinct categories were used, namely, noncomplex and complex. Vertucci Type I was defined as noncomplex, and the others were defined as complex root canals. The frequency of intercanal communication was also analyzed. Chi-square and Spearman’s rank correlation tests were performed for the variables of root canal complexity, gender, age, and tooth type (P = 0.05). All statistical analyses were performed using the SPSS 16.0 software (SPSS Inc., Chicago, IL, USA).

Results

In this study, 54 patients were females, and 47 were males. They were aged between 10 years and 70 years (mean age: 36.10 years). The CBCT images of 374 mandibular incisors were evaluated by the examiners, including 95 mandibular left lateral, 90 mandibular left central, 94 mandibular right central, and 95 mandibular right lateral incisor teeth. Eighty-eight patients had bilateral mandibular central incisors, and 89 had bilateral lateral incisors. Of a total of 177 bilateral mandibular incisors, 138 had similar root canal configurations (77.9%), and 39 had different root canal configurations (22.1%).

All the mandibular incisors examined in this study had one root. The number of root canals is summarized in Table 2. The analysis of the number of root canals of the mandibular incisors, irrespective of the type and the localization of the teeth, revealed one canal (noncomplex) in 52.4% (n = 196) of cases and complex root canals in 47.6% (n = 178) of cases. The most common root canal configuration was Vertucci Type I (52.4%; n = 196), followed by Type III (42%; n = 157), Type II (3.5%; n = 13), additional type introduced by Ng et al19 (1.1%; n = 4), and Type V (1.1%; n = 4). A selection of the root canal configuration types identified in this study is shown in Fig. 3.

The frequency of complex root canal configurations in males (63%; n = 108) was higher than in females (35%; n = 70, Chi-square, P < 0.001; Table 3). There was no statistically significant difference between the complexity of root canal systems classified by Vertucci and the additional type used.

Figure 1 Systematic representation of types of root canal systems classified by Vertucci and the additional type used.

Figure 2 (A and B) Cone-beam computed tomographic scanning images with different planes display different root canal configurations (“lines” denote views of root canal configurations at different planes in the same patient).
and the tooth type (P > 0.05). The Spearman’s rank correlation test revealed that there was no correlation between the complexity and the patient’s age (P > 0.05). Intracanal communication was present in 3.7% of the teeth (n = 17; Fig. 4).

### Discussion

Conventional and modified canal staining and clearing techniques are considered the gold standard method of studying root canal morphology. The CBCT has been also used as a tool to examine root canal morphology in different populations. Neelakantan et al demonstrated that CBCT is as accurate as the canal staining and clearing technique in identifying root canal morphology. It provides a noninvasive and clinically applicable examination of root canal morphology. It is also well established that because of the two-dimensional nature of conventional periapical radiographic films, inevitable geometric distortion, and anatomical noise mean it is not possible to examine the morphology of the root canal accurately. Thus, in this study, we used CBCT to examine the root canal morphology of mandibular incisors.

Another advantage of CBCT is that it can examine both unilateral and bilateral root canal configurations in the same patient. In this study, there was a higher rate of bilateral than unilateral root canal configurations (77.9%)

| Table 2 Root canal configuration according to Vertucci’s classification, and the additional type introduced by Ng et al. |
|---|---|---|---|---|---|
| | Type I | Type II | Type III | Type V | Additional type |
| | 1-1 | 2-1 | 1-2-1 | 1-2 | 2-1-2-1 |
| Central incisor | 96 (51.9) | 8 (4.3) | 77 (41.6) | 1 (0.5) | 3 (1.6) |
| Lateral incisor | 100 (52.9) | 5 (2.6) | 80 (42.3) | 3 (1.6) | 1 (0.5) |
| Total | 196 (52.4) | 13 (3.5) | 157 (42.0) | 4 (1.1) | 4 (1.1) |

Data are presented as n (%).

Figure 3 Cone-beam computed tomographic scanning in the coronal, middle, and apical thirds of the roots shows the variation in the root canal configuration (“arrows” denote the root canal configuration). (A–C) Type I; (D–F) Type II; (G–I) Type III; (J–L) Type V; (M–P) the additional type described by Ng et al (Vertucci’s classification was used as the main reference).
among the mandibular incisors. There are no data in the current literature on the bilateral occurrence of root canal configurations among mandibular incisors. Further studies using CBCT in different racial groups should be performed to reassess the results of this study.

Although CBCT scanning has advantages for root canal anatomy investigations, according to current recommendations, the use of CBCT scanning depends on outweighing the benefits with the risks. The use of CBCT results in exposing the patient to ionizing radiation that may pose elevated risks to some patients (e.g., cases of pregnancy, previous treatment with ionizing radiation, and younger patients). Nevertheless, CBCT should be reserved for selected cases when conventional imaging fails to provide defined information about complex endodontic conditions. In this study, we used CBCT images that were previously taken for different dentomaxillofacial problems.

The main focus of this retrospective study was to evaluate the complex canal anatomy of mandibular incisors using CBCT. One of the most important findings was that the rate of complexity in mandibular incisors was higher in males than in females. Although statistical analysis was not performed, the study by Sert and Bayirli of the root canal configurations in a Turkish population revealed comparable results. In their study, a lower incidence of the presence of a second canal was detected in male central incisors (65%) than in female central incisors (70%). This finding was inharmonious with our results. The differences among the studies may due to the fact that examined teeth in Sert and Bayirli’s study were extracted teeth, whereas in this study they were living teeth. In previous studies, however, the gender and age were not recorded; therefore, the complexity of root canals in mandibular incisors was not correlated with age or gender. Because limited data are available in the literature about this issue, the findings of this study can only be compared with the results of the study in which the root canal configuration of different tooth groups were evaluated. Sert and Bayirli reported that the incidence of single canal in the second premolars was 57% and 85% for males and females, respectively. This finding was harmonious with our results. Most other studies have disregarded the effect of gender on root canal complexity. Therefore, further studies should be conducted to confirm our results.

This study showed that the incidence of mandibular incisors with complex root canals (n = 178, 47.6%) was in accordance with that reported by Kartal and Yanikoglu (45%), who also examined a Turkish population. However, it was lower than that reported by Sert and Bayirli (65.25%) and higher than that reported by Bellizzi and Hartwell (13.7%), Mauger et al (3%), and Miyashita et al (12.7%). The differences among the studies may due to several possible reasons. The racial group in this study was the same as that in the study by Kartal and Yanikoglu and Sert and Bayirli, but was different from that in the other studies. Another possible reason might be that although the examined teeth in the other studies were extracted teeth, in this study they were living teeth. These differences may result in different frequencies of mandibular incisors with complex root canal configurations.

If the complex root canal configurations are not detected and all of the root canals are not treated, they can result in the failure of root canal treatment. Root canal treatments of teeth with complex root canal configurations are more difficult. The complete debridement and obturation of all root canals can be achieved by detecting complex root canal configurations. Herein, CBCT was used for the assessment of root canal configurations. Panoramic evaluation of root canal configurations can be misleading because of its two-dimensional nature. It has been reported that three-dimensional images identified a greater number of morphologic variations than panoramic radiographs. Thus, CBCT can be beneficial clinically for detecting complex root canal configurations.

Limited data are available in the literature on the morphology of the root canal systems of mandibular incisor teeth using CBCT. The prevalence of complex root canal configurations based on sex according to Vertucci’s classification, and the additional type introduced by Ng et al.

<table>
<thead>
<tr>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type V</th>
<th>Additional type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>2-1</td>
<td>1-2-1</td>
<td>1-2</td>
<td>2-1-2-1</td>
</tr>
<tr>
<td>Male</td>
<td>64 (37.2)</td>
<td>9 (5.2)</td>
<td>95 (55.2)</td>
<td>3 (1.7)</td>
</tr>
<tr>
<td>Female</td>
<td>132 (65.3)</td>
<td>4 (2.0)</td>
<td>62 (30.7)</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Total</td>
<td>196 (52.4)</td>
<td>13 (3.5)</td>
<td>157 (42.0)</td>
<td>4 (1.1)</td>
</tr>
</tbody>
</table>

Data are presented as n (%).

Figure 4 (A and B) Cone-beam computed tomographic scanning images display intercanal communications (“arrows” denote the intercanal communications).
configurations was higher in males than in females. This study shows that the bilateral occurrence of root canal configurations was 77.9%. Therefore, clinicians should be aware that root canal configurations can be bilateral in the same patient. The CBCT scanning can be helpful for the mapping of root canal configurations. This study provides supplemental information about mandibular incisors in a Turkish population.

Conflict of interest

The authors deny any financial affiliations related to this study or its sponsors.

References