Research Article

ISSN 2639-9490

Oral Health & Dental Science

An Evaluation of the Root Canal Anatomy of Mandibular Incisors in Turkish Population with Cone-Beam Computed Tomography (CBCT)

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Received: 02 December 2020; **Accepted:** 27 December 2020

Citation: Erkan E, Olcay K, Eyüboğlu TF, et al. An Evaluation of the Root Canal Anatomy of Mandibular Incisors in Turkish Population with Cone-Beam Computed Tomography (CBCT). Oral Health Dental Sci. 2020; 4(3); 1-7.

ABSTRACT

Objectives: *Mandibular incisors and canines usually have a single root and canal formation but missed root canals and extraordinary root canal anatomy may cause endodontic failure. The aim was to investigate the prevalence of two root canals or root numbers and root canal shapes by gender in a selected Turkish population.*

Materials and Methods: *A total of 2823 teeth in 477 patients were evaluated. 939 central mandibular incisors, 947 lateral mandibular incisors, 937 mandibular canine teeth were examined on 578 CBCT scans. The root canal morphologies and cross-sectional shapes of the samples were analyzed.*

Results: *According to findings, Type I root canal morphology was observed most in all tooth groups (72.58%). The second most common root canal type in the incisors was Type III. Type VII and type VIII were not seen in any group. The incidence of two roots in canines was higher than the incisors. When the cross-sectional designs of the mandibular incisors were evaluated, there was no difference between all the groups (P > .05). Therefore, the most common cross-sectional design at the apical third was round in all groups (99%).*

Conclusion *The incidence of two root canal formation 26.6% and Type III formation was the most common canal type among the two root canal formations. Two root percentage of two root number in canines was more than incisors. The cross-sectional shape of the incisors was almost completely round at apical third.*

Keywords

Mandibular incisors, Mandibular canines, Cone-beam CT, Root canal morphology.

Introduction

Chemo-mechanical cleaning and 3-dimensional obturation of the root canals is the main goal of the current endodontic therapy. All root canals must be detected clearly and obturated hermetically for a successful endodontic treatment. Untouched areas within the root canal system due to missing root canals may cause endodontic failure which might especially be inevitable in infected teeth [1]. Therefore, the detection of root canal anatomy and variations successfully by the clinician is important for the long term prognosis of root canal treatment [1,2].

Previously, 8 types of root canal system models to define the anatomical features of the teeth were adopted [2]. The single canal-single apical formation was found in 70% of mandibular central teeth and in 75% of mandibular lateral teeth. Observation of 1085 mandibular incisors revealed the rate of the single canal to be 87.6% [3]. Shemesh et al. [4] also found that the occurrence of the more than 1 root canal in mandibular incisors in the Israeli population was 40%. The second canal formation was reported to be 31,2% [5], 65,3% [6], and 45% [7] among different Turkish population.

Another characteristic of the mandibular anterior teeth affecting the success of root canal therapy is the cross-sectional design. A 3-type design was described before as round, oval, and long oval [8].Flattened or irregular types were then added to this description [9]. These different types may complicate root canal treatment and therefore, requires extensive observation [8,9].

Since the last century, several studies have been carried out on root canal anatomy. Some procedures have been developed, such as conventional and modified radiographic evaluation techniques, to demonstrate complex anatomical relationships by staining and coloring the root canals [2-6]. However, these complicated techniques can only be applied to extracted teeth. On the other hand, noninvasive *in vivo* cone-beam computed tomography (CBCT) analysis in determining root canal anatomy may allow a larger study sample size. Using CBCT imaging in endodontic applications provides the ability to assess an area of interest in 3 dimensions and eliminates the superimposition that is inherent in conventional radiographic imaging. Its improved accuracy, higher resolution, lower scan time, and radiation doses as compared with the medical CT make this form of imaging modality particularly suitable for determining root canal anatomy [10-14].

Even though numerous studies have evaluated the root canal morphology of mandibular incisors [5-7], sparse information was provided on the root canal system of the mandibular incisors among Turkish individuals via CBCT [11]. This retrospective cohort study aimed to investigate the root canal morphology of mandibular incisors in a selected Turkish population by gender and age using CBCT.

Materials and Methods

The study was approved by the Ethics Committee of Istanbul Medipol University (Approval Number: 10840098-604.01.01-E.856). A total of 477 CBCT images of mandibular incisors and canines collected between 2000 and 2017 were evaluated retrospectively. CBCT examination of the patients was a natural part of their routine dental treatment such as preoperative planning of dental implants, complex surgical operations, or orthognathic surgical treatments. Personal details of the patients were recorded such as age and sex. The inclusion criteria of the study were the presence of at least one tooth mandibular incisor or canine with complete root formation and absence of root canal treatment, coronal restoration, and periapical lesion. Also, the teeth, which could not be monitored due to the imaging errors, were excluded from the study.

The CBCT images were taken using ani-CAT17–19 Imaging System (Imaging Sciences Int., Inc.) with a standardized scanning protocol according to the manufacturer's recommended protocol with a voxel size of 0, 25 mm. Besides, all volumes were acquired at 120 kVp and 20.27 mAs using a 16 cm × 11 cm field of view. Root canal morphology was evaluated by one radiologist and two endodontists with at least 10 years of experience. In-case the researchers had different opinions; it was ensured that a consensus was reached by re-evaluating. Tooth number, root canal number, cross-sectional root canal shape, and root canal configuration, were then recorded and analyzed.

To determine the root canal configuration, a series of cross-sectioned images were examined from the cemento-enamel junction to the root apex, and classified according to the Vertucci Classification:

a. Type I: A single canal extends from the pulp chamber to the apex.
b. Type II. Two separate canals leave the pulp chamber and join short of the apex to form one canal.
c. Type III. One canal leaves the pulp chamber, divides into two within the root, and then merges to exit as one canal.
d. Type IV. Two separate and distinct canals extend from the pulp chamber to the apex.
e. Type V. One canal leaves the pulp chamber and divides short of the apex into two separate and distinct canals with separate apical foramina.
f. Type VI. Two separate canals leave the pulp chamber, merge in the body of the root, and re-divide short of the apex to exit the root apex as two distinct canals.
g. Type VII. One canal leaves the pulp chamber, divides and then rejoins within the body of the root, and finally re-divides into two distinct canals short of the apex.
h. Type VIII. Three separate and distinct canals extend from the pulp chamber to the apex.

Statistical Analysis

IBM SPSS Statistics 22 software (IBM SPSS, Türkiye) was used for statistical evaluation. In the comparison of qualitative data, the Chi-square test (to detect the difference between gender distributions), Fisher's Exact Chi-Square test, Continuity (Yates) correction, and Fisher Freeman Halton Test were used. The correlations between the prevalence of root canal number and tooth number were evaluated by the Fisher exact test. Differences

between the parameters were considered statistically significant when *P* value less than .05.

Results

The study was performed on 2823 teeth of patients, aged between 13 and 79, 202 males (42.3%), 275 females (57.7%). The ratio of females was significantly higher than males in gender distribution.

The distribution of the mandibular anterior teeth according to the Vertucci classification can be seen in Table 1. Accordingly, Type I root canal morphology was observed most in all teeth. The second root canal type in the incisors was Type III. The incidence of Type II, IV, V, and VI was less than Type I respectively. Type VI could not be detected in canine teeth. Types VII and VIII could not be detected in any group. While the frequency of the occurrence of Type I in canine teeth is higher, there was no difference between the other groups (Figure 1).

Gender presented no difference in Vertucci classification between the right and left canines in by, but the other groups were varied. The incidence of Type III at left central teeth was higher in females (35.8%) than males (26.5%). In the left lateral teeth group; the prevalence of Type III in females (35.1%) was higher than males (26.9%). In the right central teeth group; the incidence of Type III formation in females (35.4%) is higher than males (26.3%). In the right lateral incisors; the prevalence of Type III in females (36.7%) is more than males (26.5%).

There was a difference between the distributions of the root canal morphology of the mandibular anterior teeth by the number of roots. The incidence of two roots in the left canine teeth (2.3%) was higher than the left central incisors, left lateral incisors, right central incisors, and right lateral incisors respectively. The occurrence rate of two roots (1.1%) in the right canine was significantly higher than the left central incisors, right central incisors, and right lateral incisors. There was no difference between the other groups in terms of root number distributions (Table 2).

The incidence of root canal numbers of mandibular incisors was different at all groups. Two canal incidences (8.9%) in left canine teeth were less than left central incisors, left lateral incisors, right central incisors, and right lateral incisors. The occurrence of two canal formation in the right canine (8.1%) was less than the left central incisors, left lateral incisors, right central incisors, and right lateral incisors. There is no statistically significant difference between the other groups in terms of root canal number (Table 2).

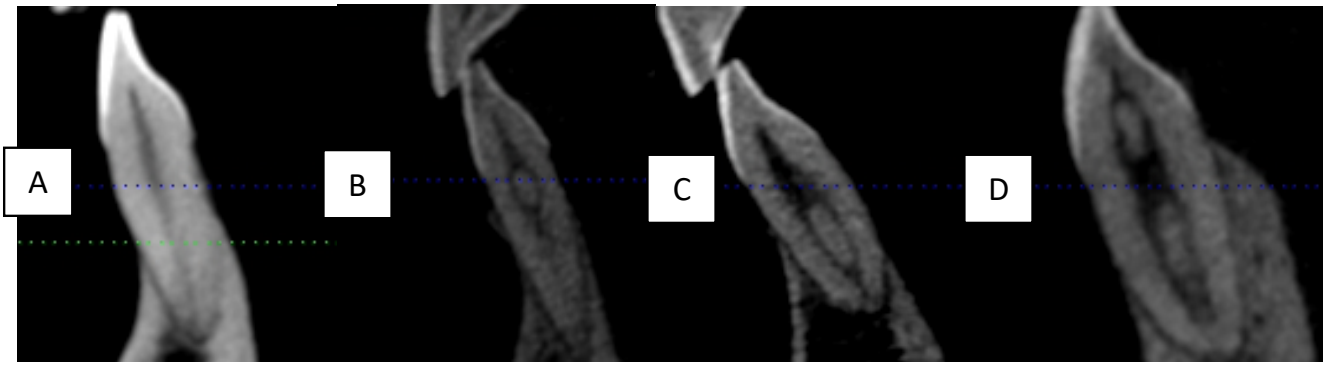

Figure 1: CBCT Images of Mandibular incisors: *(A)* type 1; *(B)* type 2; *(C)* type 3; *(D)* type 6.

Gender	Vertucci Classification	Left Central n (%)	Left Lateral n (%)	Left Canine n (%)	Right Central n (%)	Right Lateral n (%)	Right Canine n (%)	*Total n (%)*
Male	I	133 (67,9%)	134 (66,7%)	188 (93,1%)	135 (68,2%)	132 (66%)	183 (93,4%)	905 (75,9%)
	II	4 (2%)	9 (4,5%)	2 (1%)	4 (2%)	11 (5,5%)	1 (0,5%)	31 (2,6%)
	III	52 (26,5%)	54 (%26,9%)	7 (3,5%)	52 (26,3%)	53 (26,5%)	9 (4,6%)	227 (19%)
	IV	5 (2,6%)	4 (2%)	3 (1,5%)	5 (2,5%)	3 (1,5%)	1 (0,5%)	21 (1,8%)
	V	1 (0,5%)	0 (0%)	2 (1%)	1 (0,5%)	1 (0,5%)	2 (1%)	7 (0,6%)
	VI	1 (0,5%)	0 (0%)	0 (0%)	1 (0,5%)	0 (0)	0 (0)	2 (0,2%)
	Total	196	201	202	198	200	196	1193
Female	I	166 (61,3%)	166 (61,3%)	243 (90, %7)	169 (61,7%)	163 (59,3%)	237 (87,5%)	1144 (70,2%)
	II	3 (1,1%)	6 (2,2%)	2 (0,7%)	4 (1,5%)	6 (2,2%)	3 (1,1%)	24 (1,5%)
	III	97 (35,8%)	95 (35,1%)	21 (7,8%)	97 (35,4%)	101 (36,7%)	24 (8, 9%)	435 (26,7%)
	IV	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0,4%)	1 (0,1%)
	V	3 (1,1%)	2 (0,7%)	2 (0,7%)	2 (0,7%)	3 (1,1%)	6 (2,2%)	18 (1,1%)
	VI	2 (0,7%)	2 (0,7%)	0 (0)	2 (0,7%)	2 (0,7%)	0 (0)	8 (0,5%)
	Total	271	271	268	274	275	271	1630

Table 1: Root Canal Classification of Mandibular Incisors and Canines.

Root Number	Left Central (n=467) n (%)	Left Lateral (n=472) n (%)	Left Canine (n=470) n (%)	Right Central (n=472) n (%)	Right Lateral (n=475) n (%)	Right Canine (n=467) n (%)	*Total (n=2823) n (%)*
One	467 (%100)	471 (%99,8)	459 (%97,7)	472 (%100)	475 (%100)	462 (%98,9)	2806 (%99,4)
Two	0 (%0)	1 (%0,2)	11 (%2,3)	0 (%0)	0 (%0)	5 (%1,1)	17 (%0,6)
Root Canal Number	**(n=467) n (%)**	**(n=467) n (%)**	**(n=467) n (%)**	**(n=467) n (%)**	**(n=467) n (%)**	**(n=467) n (%)**	**(n=467) n (%)**
One	330 (%70,7)	329 (%69,7)	428 (%91,1)	332 (%70,3)	328 (%69,1)	429 (%91,9)	2176 (%77,1)
Two	137 (%29,3)	143 (%30,3)	42 (%8,9)	140 (%29,7)	147 (%30,9)	38 (%8,1)	647 (%22,9)
p	*0,000**	*Ki-square test*		**p<0.05*			

Table 2: The Root Number and Root Canal Number of the Mandibular Incisors and Canines.

Tooth	Canal BFC Level	Male n (%)	Female n (%)	*Total n (%)*	*p*
Left Central	**Absent**	133 (67,9%)	171 (63,1%)	304 (65,1%)	0,701
	Apical	1 (0,5%)	2 (0,7%)	3 (0,6%)	
	Middle	59 (30,1%)	95 (35,1%)	154 (33%)	
	Cervical	3 (1,5%)	3 (1,1%)	6 (1,3%)	
Left Lateral	**Absent**	132 (65,7%)	166 (61,3%)	298 (63,1%)	0,098
	Apical	1 (0,5%)	2 (0,7%)	3 (0,6%)	
	Middle	57 (28,4%)	97 (35,8%)	154 (32,6%)	
	Cervical	11 (5,5%)	6 (2,2%)	17 (3,6%)	
Left Canine	**Absent**	188 (93,1%)	236 (88,1%)	424 (90,2%)	0,042*
	Apical	1 (0,5%)	5 (1,9%)	6 (1,3%)	
	Middle	11 (5,4%)	27 (10,1%)	38 (8,1%)	
	Cervical	2 (1%)	0 (0)	2 (0,4%)	
Right Central	**Absent**	134 (67,7%)	166 (60,6%)	300 (63,6%)	0,442
	Apical	1 (0,5%)	3 (1,1%)	4 (0,8%)	
	Middle	61 (30,8%)	102 (37,2%)	163 (34,5%)	
	Cervical	2 (1%)	3 (1,1%)	5 (1,1%)	
Right Lateral	**Absent**	132 (66%)	160 (58,2%)	292 (61,5%)	0,009*
	Apical	2 (1%)	2 (0,7%)	4 (0,8%)	
	Middle	54 (27%)	107 (38,9%)	161 (33,9%)	
	Cervical	12 (6%)	6 (2,2%)	18 (3,8%)	
Right Canine	**Absent**	182 (92,9%)	233 (86%)	415 (88,9%)	0,030*
	Apical	3 (1,5%)	7 (2,6%)	10 (2,1%)	
	Middle	10 (5,1%)	31 (11,4%)	41 (8,8%)	
	Cervical	1 (0,5%)	0 (0)	1 (0,2%)	

Table 3: Root Canal Bifurcation Level (BFC) of the Mandibular Incisors and Canines by Gender.

Fisher Freeman Halton Test
**p<0.05*

The root canal bifurcation levels of the mandibular incisors were different between all groups. The frequency of bifurcation in the left canine teeth (9.8%) was less than the left central incisors, left lateral incisors, right central incisors, and right lateral incisors. The frequency of bifurcation in the right canine teeth (11.1%) was significantly less than the left central incisors, left lateral incisors, right central incisors, and right lateral incisors. There was no difference between the other groups in terms of root canal bifurcation level distributions (Table 3).

When evaluated by gender, our findings of right and left canine and right lateral incisor were statistically different from other groups (Table 4). The occurrence of the middle third at right mandibular canines in females (11.4%) was higher than males (5.1%). The occurrence of the middle third at right mandibular lateral in females (38.9%) was higher than males (27%). Finally, the occurrence at left canines in females (10.1%) was higher than in males (5.4%) (Table 3).

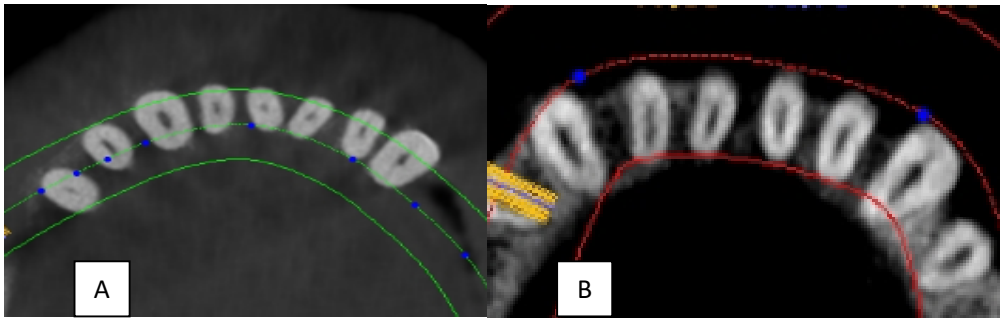

Figure 2: CBCT Images of Mandibular incisors: *(A)* round type; *(B)* oval type.

Cross-Sectional Shape	Left Central (n=467) n (%)	Left Lateral (n=472) n (%)	Left Canine (n=470) n (%)	Right Central (n=472) n (%)	Right Lateral (n=475) n (%)	Right Canine (n=467) n (%)	*Total (n=2823) n (%)*
Oval	2 (0,4%)	3 (0,6%)	6 (1,3%)	4 (0,8%)	5 (1,1%)	8 (1,7%)	28 (1%)
Round	465 (99,6%)	469 (99,4%)	464 (98,7%)	468 (99,2%)	470 (98,9%)	459 (98,3%)	2795 (99%)
p	*0,404*						

Table 4: The Cross-Sectional Shape of the Mandibular Incisors and Canines at Apical Zone.

When the root canal morphologies of the mandibular incisors were evaluated in terms of their cross-sectional designs (Figure 2), there was no difference between all the groups ($P > .05$). According to our findings, the most common cross-sectional design at the apical third was round in all groups (Table 4).

Discussion

In the present study the root canal morphology of mandibular anterior teeth in Turkish society was evaluated using CBCT. 2823 teeth from 202 males (42.3%) and 275 females (57.7%), aging between 13-79, were analyzed. 578 CBCT scans including 939 central incisors, 947 lateral incisors and 937 canine teeth were examined.

In our study, it was found that mandibular incisors were mostly single root and the single canal (Vertucci Type I) (72.6%). Compared to other studies, the findings were higher than a previous study (58.6%) [10]. In contrast, it was less than Miyashita et al. (87.6%) [3] and Lin et al. (81.8%) [11] presented in their studies. However, when the mandibular central and lateral incisors were evaluated separately, our findings were less than Han et al. [12] reported for central incisors (84.29%) and lateral incisors (72.4%) and less than Shemesh et al. [4] presented for the central incisors (59.5%) and for the lateral incisors (60.93%). On the other hand, it was similar to Al-Qudah and Awawdeh's values[13].

Type III formation was observed more (23.5%) among the double root canal formation than other types. Type II, V, IV, and VI follow these two groups respectively. In our study, Type VII and VIII were not detected in the mandibular anterior teeth. The percentage of second root canal incidence in our study was 26.6% and it was similar to the data of Vertucci (27.5%) [2] and Al-Qudah and Awawdeh (26.2%) [13]. In contrast, our findings were higher than Han 21.55% [12], Madeira and Hatem 11.6% [14], Miyashita et al. 12.4% [3] and Liu et al. 13.2% [15] presented but less than the findings of Rahimi 36.62% [16], Benjamin and Dowson 41.4% [10]. Our data had similar percentages in mandibular central and lateral incisors, similar to the data revealed in the studies mentioned.

In the present study, the incidence of two root canals in the mandibular canine teeth was 7.89%, and it was higher than the mandibular incisors. Although, our values were close to the findings of Han et al. (6,27%) [12] and Rahimi (8,4%) [16], and it was less than Vertucci (22%) [2]. The mandibular canines had a single root and canal formation (Type I) in general. The main reason for the general differences in rates might be explained by the fact that the methods used in the studies are different as well as the racial differences. However, geographical features are also effective in these results. In the images examined in the study, we can state that the high number of female patients affects the results.

The single root and canal formation at mandibular incisors were detected 72,58% (Type I) in the present study when the findings were compared to other studies in Turkish society and it was higher than Calıskan et al. (68,63%) [5], Geduk et al. (64,4%) [17], Kartal and Yanıkoglu (55%) [7], and Sert et al. (48,5%) [18] reported in their studies respectively. On the other hand, Type II formation was 1,94% in our study and it was less than the findings of Calıskan et al. (13,73%) [5], Kartal and Yanıkoglu (%16) [7], Geduk et al. (15,2%) [17], and Sert et al. (23%) [18]. Type III formation was 23,45% in the present study and it was higher than the findings of Kartal and Yanıkoglu (20%) [7], Sert et al. (19,5%) [18], Geduk et al. (19,4%) [17], and Calıskan et al. (15,49%) [5] respectively. We assume that the differences between the values in the studies due to the different case numbers and observation techniques such as staining and clearing or radiography and CBCT.

Few researchers have examined the cross-sectional design of root canals. Wu et al. [8] has defined the long-oval section where the long size of the section diameter is more than twice the short size, and the incidence of a long-oval canal section in the areas of 2 to 5 mm from the apical of the mandibular incisors may increase up to 50%. This ratio decreases to 10% in apical 1 mm. Shemesh et al. [4] reported that among the examined root cross-sections, round formation of root canal were observed in 66.28% in the cervical third and 96.2% of the apical third of the cross-sections. In the present study, we obtained that 99% of the teeth examined in apical 1 mm have a round cross-sectional design. For this reason, especially in the cervical and middle third, the cross-sectional root canal design is considered to be oval, and warm gutta-percha techniques [19], and sonic or ultrasonic irrigation activation [20] are strongly recommended during the root canal treatment.

It is mandatory to acknowledge the root canal anatomy for successful root canal treatment [2]. Different methods were used in examining the anatomical structures of the mandibular incisors and canines. Staining and clearing methods and micro CT [2,3,5-7,13,14,16] imaging techniques have been used to examine root canal morphology in the past studies. However, these methods mandate extraction of the teeth. Considering the clinical conditions, the use of CBCT can be applied with intra or extra-oral radiography techniques. On the other hand, CBCT imaging is a non-invasive and safe method compared to the staining technique [21]. However, it should be remembered that CBCT uses ionizing radiation and is not indicated as a standard method for demonstration of root canal anatomy [21]. It must be preferred as a diagnostic tool in cases where conventional intraoral radiographs provide information on root canal anatomy which is inadequate for planning treatment [12].

Conclusion

According to the limitations of the present study, the incidence of two canal formation in 939 central incisors examined was 35.03%, in 947 lateral incisors was 36.7%, and in 937 canines was 7.89%. The incidence of the second canal formation was 22.9% at all 2823 mandibular incisors. Although cross-sectional designs can be oval in the cervical and middle third, they are 99% round in apical third. We think that the results obtained in the present study will contribute to the selection of the right technique and methods in clinical irrigation and obturation protocols.

References

1. Nair PN, Sjögren U, Krey G, et al. Intraradicular bacteria and fungi in root-filled, asymptomatic human teeth with therapy-resistant periapical lesions: a long-term light and electron microscopic follow-up study. J Endod. 1990; 16: 580-588.
2. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surgery, Oral Medicine, Oral Pathology. 1984; 58: 589-599.
3. Miyashita M, Kasahara E, Yasuda E, et al. Root canal system of the mandibular incisor. J Endod. 1997; 23: 479-484.
4. Shemesh A, Kavalerchik E, Levin A, et al. Root Canal Morphology Evaluation of Central and Lateral Mandibular Incisors Using Cone-beam Computed Tomography in an Israeli Population. J Endod. 2018; 44: 51-55.
5. Calişkan MK, Pehlivan Y, Sepetçioğlu F, et al. Root canal morphology of human permanent teeth in a Turkish population. J Endod. 1995; 21: 200-204.
6. Sert S, Bayirli GS. Evaluation of the root canal configurations of the mandibular and maxillary permanent teeth by gender in the Turkish population. J Endod. 2004; 30: 391-398.
7. Kartal N, Yanikoğlu F. The incidence of mandibular premolars with more than one root canal in a Turkish population. J Marmara Univ Dent Fac. 1992; 1: 203-210.
8. Wu MK, R'oris A, Barkis D, et al. Prevalence and extent of long oval canals in the apical third. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000; 89: 739-743.
9. Jou Y-T, Karabucak B, Levin J, et al. Endodontic working width: current concepts and techniques. Dent Clin North Am. 2004; 48: 323-335.
10. Benjamin KA, Dowson J. Incidence of two root canals in human mandibular incisor teeth. Oral Surg Oral Med Oral Pathol. 1974; 38: 122-126.
11. Lin Z, Hu Q, Wang T, et al. Use of CBCT to investigate the root canal morphology of mandibular incisors. Surg Radiol Anat. 2014; 36: 877-882.
12. Han T, Ma Y, Yang L, et al. A study of the root canal morphology of mandibular anterior teeth using cone-beam computed tomography in a Chinese subpopulation. J Endod. 2014; 40: 1309-1314.
13. Al-Qudah AA, Awawdeh LA. Root canal morphology of mandibular incisors in a Jordanian population. Int Endod J. 2006; 39: 873-877.
14. Madeira MC, Hetem S. Incidence of bifurcations in mandibular incisors. Oral Surg Oral Med Oral Pathol. 1973; 36: 589-591.
15. Liu J, Luo J, Dou L, et al. CBCT study of root and canal morphology of permanent mandibular incisors in a Chinese population. Acta Odontologica Scandinavica. 2014; 72: 26-30.
16. Rahimi S, Milani AS, Shahi S, et al. Prevalence of two root canals in human mandibular anterior teeth in an Iranian population. Indian J Dent Res. 2013; 24: 234-236.
17. Geduk. Cone-beam computed tomography study of root canal morphology of permanent mandibular incisors in a Turkish sub-population. Journal of Oral and Maxillofacial Radiology. 2015; 3: 7-10.
18. Sert S, Aslanalp V, Tanalp J. Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. Int Endod J. 2004; 37: 494-499.
19. Tomson RME, Polycarpou N, Tomson PL. Contemporary obturation of the root canal system. Br Dent J. 2014; 216: 315-322.

20. Tomson PL, Simon SR. Contemporary Cleaning and Shaping of the Root Canal System. Prim Dent J. 2016; 5: 46-53.

21. Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium-enhanced digital radiography in studying root canal morphology. J Endod. 2010; 36: 1547-1551.