

## Root Morphology Of Mandibular Anterior Teeth In Mecca City Population

Research Article

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### Abstract

**Background:** Root canal morphology is of utmost importance to the success of endodontic treatment

**Objectives:** The present study aim is to determine the variation in root canal morphology of the lower anterior permanent teeth using cone-beam computed tomography (CBCT) in a Saudi population especially Mecca city population.

**Material and Methods:** Cross-sectional study using CBCT images of 388 patients included according to specific criteria to evaluate the number of canals and their configuration according to Vertucci's classification.

**Results:** The prevalence of the second canal of mandibular canine was 11% (11.3 in male and 10.7 in female), for mandibular lateral incisor was 22.3% (28.5 for male and 16.7 for female) and mandibular central incisor represented 21% (22% for male 20.1% for female), these differences were not significant for canine ( $p=0.454$ ) and central incisor ( $p=0.277$ ) but significant for lateral incisor ( $p=0.028$ ). Regarding position, there were no significant differences between right and left side ( $p=0.517$ ,  $p=0.627$  and  $p=0.507$  for canine, lateral and central incisors respectively). According to Vertucci's classes; type I was the most prevalent followed by type III, II and V for lateral and central incisors and type III, V and II for canine. There were statistically significant differences between male and female for lateral and central incisors morphology ( $p=0.003$  and  $p=0.013$ ) while the difference was non significant for canine ( $p=0.303$ ). There were no significant differences between right and left side ( $p=0.476$ ,  $p=0.707$  and  $p=0.362$  for canine, lateral and central respectively).

**Conclusion:** Type I Vertucci's configuration was the most common type in all lower anterior teeth. The presence of second canal is more prevalent in mandibular lateral and central incisors and the morphology of their root canals is significantly different between males and females.

**Keywords:** Cone-Beam Computed Tomography CBCT; Mandibular Anterior Teeth; Root Canal Morphology.

### Introduction

One of the most common causes of endodontic treatment failure is intraradicular infection due to untreated canal anatomy [1]. Since unfilled canals are thought to be a potential reason for contamination and can promote periapical disease after treatment, their exact recognition would be fundamental [2]. The knowledge about root canal morphology is of utmost importance to the success of endodontic treatment [3]. It was previously assumed that mandibular anterior teeth had only one root canal [4].

Root canal morphology of permanent mandibular anterior teeth may be compromised by the involvement of the second canal, lat-

eral canal, and apical deltas [2]. For permanent mandibular anterior teeth, one of the most prevalent canal morphology is a single root having a single canal [4]. However, there is a difference between the numbers of canals among the different populations [5]. Iranian people had a prevalence of two root canals in 27.3% of mandibular central, 29.4% of mandibular lateral, and 28.2% of mandibular canine [6]. The Chinese population shows the prevalence of the second canal in central incisors 9.8%, Lateral incisors 21.5%, canines 9.2% [7]. Indian population study showed that, 18.63% had two root canals in canine and 28.43% had two root canals in central and lateral incisor [8].

Cone-beam computed tomography (CBCT) provides a three-dimensional image in three different planes. Detection of the

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configuration and root canal convergence and divergence can be viewed [9]. Mecca city have diverse population with expected variation in root canal morphology of mandibular anterior teeth, thus the current study was designed to determine the root canal morphology of the permanent lower anterior teeth using cone-beam computed tomography in Mecca city population.

## Material And Methods

### The study design and ethical approval

The current study was a cross-sectional study using Electronic Health Records (EHR) at Umm Al-Qura University, Faculty of Dentistry, Mecca, Saudi Arabia. Ethical approval (Ref #161-19) was obtained from the Research Ethical Committee at the Faculty of Dentistry, Umm Qura University. The confidentiality of the participants was maintained.

### Sample size determination

The sample size (S) was calculated by the following equation ( $s=N/(1+Ne^2)$ ) [10].

N= number of population e= level of precision, calculated with 5% margin error acceptance and 95% confidence level. The required sample was 388 participants.

### Sample selection

The sample was selected after applying the inclusion/exclusion criteria to 966 EHR. The focus group was Saudi population in Mecca city included according to the following inclusion criteria: Unrestored lower anterior teeth, complete root formation with closed apex, Saudi people. Patients with deep caries, crown or bridge, periapical lesion and root resorption, posts and root canal fillings, missing anterior teeth were excluded from the study.

### Root canal evaluation

CBCT dental imaging system (iCATvisionQ, Imaging Sciences International, Hatfield, PA, USA) operates at 120 kVp and 3-7 mA. was used to evaluate the root canal morphology of lower anterior teeth. The study was conducted on 388 CBCT images of lower anterior teeth to estimate the number of root canals and their types. CBCT images evaluated 1552 permanent mandibular incisors, 776 permanent mandibular canines. Configuration of the canal categorized according to the method of Vertucci's [3]. (Figure 1)

Type I: A single canal extends from the pulp chamber to the canal terminus.

Type II: two separate canals depart the pulp chamber and connect each other to create one canal at the canal terminus.

Type III: one canal departs the pulp chamber, split into two canals then merging each other to create one canal at the apex.

Type IV: Two separate canals present from the pulp chamber to the canal terminus.

Type V: One canal depart the pulp chamber, split into two separate canals with two apical foramina.

Type VI: Two separate canals depart the pulp chamber, connect each other in the body of the root, and separate short of the apex to exit as two distinct canals.

Type VII: One canal depart the pulp chamber, divides and then reconnect in the body of the root, and at the end separates into two distinct canals short of the apex.

Type VIII: Three separate and well defined canals extend from the pulp chamber to the apex.

The number of canals and root canal configuration of permanent lower anterior teeth were examined in three dimensions by three researchers after training and measurement of intra and inter examiner consistency. Kapa test results was 86% for intra examiner and 91 % for inter examiner stability.

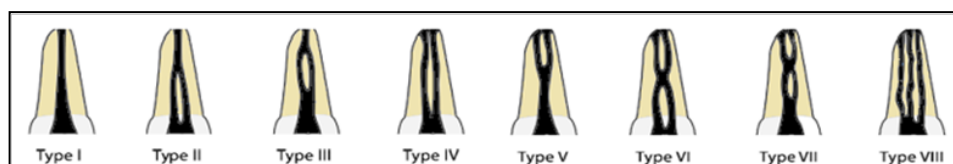
## Result

The prevalence of two canals was 11% for canine, 22.3% for lateral and 21% for central incisor. According to position, the differences between right and left side were not significant for #3 ( $p=0.517$ ), #2 ( $p=0.657$ ) and #1 ( $p=0.507$ ). On comparison between male and female, there were no significant differences between them for #3 ( $p=0.454$ ) and #1 ( $p=0.277$ ) while there was significant difference for #2 ( $p=0.028^*$ ). (Table 1, Figure 1 and 2) The differences between right and left side were not significant for both male and female participants, for male [#3 ( $p=0.751$ ), #2( $p=0.311$ ), #1 ( $p=0.500$ ) and total of #2 + #1 ( $p=0.369$ )] and for female [#3 ( $p=0.611$ ), #2 ( $p=0.378$ ), #1 ( $p=0.638$ ) and total of #2 + #1 ( $p=0.591$ )]. (Table 2)

According to Vertucci's classes, the difference between male and female was not significant for #3 ( $p=0.303$ ) while the differences between them were statistically significant for #2 ( $p=0.003^*$ ) and #1 ( $p=0.013^*$ ). The differences between right and left side were not significant for #3 ( $p=0.476$ ), #2 ( $p=0.707$ ) and #1 ( $p=0.362$ ). (Table 3)

The differences between right and left side root canal types were not significant for both male and female. For male participants [#3 ( $p=0.667$ ), #2 ( $p=0.857$ ) and #1 ( $p=0.844$ )] and female participants [#3 ( $p=0.641$ ), #2 ( $p=0.772$ ) and #1 ( $p=0.221$ )]. (Table 4)

Figure 1. Eight types of Vertucci's classification of mandibular anterior teeth.



## Discussion

Many reasons are leading to endodontic treatment failure, one of the most common causes is missed canal due to improper diagnosis, other causes include ledges, transportations, perforations, separated instruments. Any of these influences the result of root canal therapy. These operational errors are not specifically responsible for endodontic failure. These mistakes negatively affect the proper cleaning, shaping, and obturation of the root canal, which in turn inhibits the prevention of endodontic infection [11-13].

CBCT used in different branches of dentistry, in endodontic treatment like surgical apexification, root hemisection, and root morphology. The key benefit of CBCT imaging is non-harmful for the patient and allowing to clarify the image from sagittal, axial, and coronal dimensions and provide imaging for anatomical structures inside and outside the tooth and underlying bone structures [14-16]. The most important advantages of CBCT are lower radiation dose, accurate measurement, and lower cost relative to traditional CT [17, 18].

The results of the current study indicated that, all the lower per-

manent incisors have one root, the prevalence of the second canal in permanent lower incisors was 21.6% (22.3% for lateral and 21% for central). The prevalence of two canals in lower incisors of Mecca city populations was within the range recorded by previous literature review where it was from 11.6% to 65.3%[12]. The present results were higher than the prevalence obtained by Madeira and Hetemet al. (11.6%)[19], Miyashita et al. (12.4%) [20], and Liu et al. (13.2%)[21]. The current prevalence was agreed with that reported by Green (20%)[22] and Han et al. (21.55%) [12]. On the other hand the reported prevalence in the present study was less than that reported by Benjamin and Dowson (41.4) [23], Vertucci (27.5%)[24], Kartal et al. (45%)[25], Caliskan et al. (31.37%)[26], Al-Qudah and Awawdeh (26.2%)[27], Aminsobani et al. (29%)[6], Rahimi et al. (36.62%)[4] and Kamtane et al. (36%) [8].

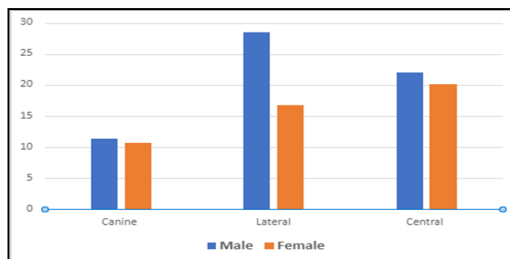
The prevalence of the second canal in permanent mandibular canine teeth of Mecca city population was (11%) which was higher than the prevalence reported by Zhao et al. (3%)[7], Zhengyan et al. (4.2%) [28], Rahimi et al. (8.4%) [4], Han et al. (6.7%) [11] and Haghanifar et al. (9.4%)[29]. On the other hand, the prevalence was less than that obtained by Vertucci (22%) [24] and Sert et al. (24%)[30].

**Table 1. Comparison between root canal number of mandibular anterior teeth in relation to gender and position.**

Tooth	Number of canals	Gender		P	Position		P	Total No (%)
		Male	Female		Right	Left		
		No (%)	No (%)		No (%)	No (%)		
#3	1	323 (88.7)	368 (89.3)	0.454	348 (89.7)	343 (88.4)	0.517	691 (89.0)
	2	41 (11.3)	44 (10.7)		40 (10.3)	45 (11.6)		85 (11.0)
	Total	364 (100)	412 (100)		388 (100)	388 (100)		776 (100)
#2	1	260 (71.5)	343 (83.3)	0.028*	305(78.6)	298 (76.4)	0.657	603 (77.7)
	2	104 (28.5)	69 (16.7)		83 (21.4)	90 (23.2)		173 (22.3)
	Total	364 (100)	412 (100)		388 (100)	388 (100)		776 (100)
#1	1	284 (78.0)	329 (79.9)	0.277	306 (78.8)	307 (79.2)	0.507	613 (79.0)
	2	80 (22.0)	83 (20.1)		82 (21.2)	81 (20.8)		163 (21.0)
	Total	364 (100)	412 (100)		388 (100)	388 (100)		776 (100)

No (%) = Number and percentage. #3, #2 and #1 = lower canine, lateral incisor and central incisor respectively. p = p value calculated by Chi square test comparing between root canal number of mandibular anterior teeth of right and left side as well as between male and female.

**Figure 2. The percentage of two canals in mandibular anterior teeth in relation to gender.**



**Figure 3. The percentage of two canals in mandibular anterior teeth in relation to position.**

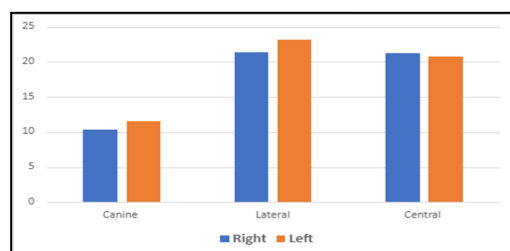


Table 2. Comparison between root canal number of mandibular anterior teeth in relation to position for male and female.

Tooth	Number of canals	Male		p	Female		p
		Right	Left		Right	Left	
		No (%)	No (%)		No (%)	No (%)	
#3	1	162 (89.0)	161 (88.4)	0.751	186 (90.2)	182 (88.4)	0.611
	2	20 (11.0)	21 (11.6)		20 (9.8)	24 (11.6)	
	Total	182 (100)	182 (100)		206 (100)	206 (100)	
#2	1	132 (72.6)	128 (70.4)	0.311	173 (84.0)	170 (82.6)	0.378
	2	50 (27.4)	54 (29.6)		33 (16.0)	36 (17.4)	
	Total	182 (100)	182 (100)		206 (100)	206 (100)	
#1	1	142 (78.0)	142 (78.0)	0.5	164 (79.6)	165 (80.2)	0.638
	2	40 (22.0)	40 (22.0)		42 (20.4)	41 (19.8)	
	Total	182 (100)	182 (100)		206 (100)	206 (100)	
Total	1	274 (75.2)	270 (74.2)	0.369	337 (81.8)	335 (81.4)	0.591
#2+#1	2	90 (24.8)	94 (25.8)		75 (18.2)	77 (18.6)	
Total		364 (100)	364 (100)		412 (100)	412 (100)	

No (%) = Number and percentage. #3, #2 and #1 = lower canine, lateral incisor and central incisor respectively. p = p value calculated by Chi square test comparing between right and left side root canal number of mandibular anterior teeth for male and female separately.

Table 3. Comparison between root canal types of mandibular anterior teeth in relation to gender and position.

Tooth	Canal types	Gender		p	Position		p	Total No (%)
		Male	Female		Right	Left		
		No (%)	No (%)		No (%)	No (%)		
#3	I	329 (90.4)	368 (89.3)	0.303	354 (91.2)	343 (88.4)	0.476	697 (89.8)
	II	3 (0.8)	0 (0)		1 (0.3)	2 (0.6)		3 (0.4)
	III	23 (6.3)	28 (6.8)		22 (5.6)	29 (7.4)		51 (6.6)
	IV	0 (0)	0 (0)		0 (0)	0 (0)		0 (0.0)
	V	8 (2.2)	15 (3.6)		11 (2.8)	12 (3.0)		23 (3.0)
	VI	1 (0.3)	1 (0.2)		0 (0)	2 (0.6)		2 (0.3)
	VII	0 (0)	0 (0)		0 (0)	0 (0)		0 (0.0)
	Total	364 (100)	412 (100)		388 (100)	388 (100)		776 (100)
#2	I	260 (71.4)	343 (83.2)	0.003*	305 (78.6)	298 (76.8)	0.707	603 (77.7)
	II	13 (3.6)	8 (1.9)		12 (3.0)	9 (2.2)		21 (2.7)
	III	86 (23.6)	58 (14.1)		68 (17.6)	76 (19.5)		144 (18.6)
	IV	0 (0)	1 (0.2)		0	1 (0.4)		1 (0.1)
	V	4 (1.1)	2 (0.5)		3 (0.8)	3 (0.8)		6 (0.8)
	VI	0 (0)	0 (0)		0 (0)	0 (0)		0 (0.0)
	VII	1 (0.3)	0 (0)		0 (0)	1 (0.3)		1 (0.1)
	Total	364 (100)	412 (100)		388 (100)	388 (100)		776 (100)
#1	I	281 (77.2)	353 (85.7)	0.013*	319 (41.1)	315 (40.6)	0.362	634 (81.7)
	II	7 (1.9)	2 (0.5)		4 (0.5)	5 (0.6)		9 (1.2)
	III	70 (19.2)	53 (12.9)		57 (7.3)	66 (8.5)		123 (15.9)
	IV	0 (0)	1 (0.2)		1 (0.2)	0 (0)		1 (0.1)
	V	3 (0.9)	1 (0.2)		4 (0.5)	2 (0.3)		6 (0.8)
	VI	0 (0)	0 (0)		0 (0)	0 (0)		0 (0.0)
	VII	3 (0.8)	2 (0.5)		3 (0.4)	0 (0)		3 (0.4)
	Total	364 (100)	412 (100)		388 (100)	388 (100)		776 (100)

No (%) = Number and percentage. #3, #2 and #1 = lower canine, lateral incisor and central incisor respectively. p = p value calculated by Chi square test comparing between root canal types of mandibular anterior teeth of right and left side as well as between male and female. \*p value = statistically significant value.

Table 4. Comparison between right and left root canal types of mandibular anterior teeth for male and female.

Tooth	Canal types	Male			Female			Grand total No (%)
		Right	Left	P	Right	Left	P	
		No (%)	No (%)		No (%)	No (%)		
#3	I	168 (46.2)	161 (44.2)	0.667	186 (45.1)	182 (44.2)	0.641	697 (89.8)
	II	1 (0.3)	2 (0.6)		0 (0)	0 (0)		3 (0.4)
	III	10 (2.7)	13 (3.6)		12 (2.9)	16 (3.9)		51 (6.6)
	IV	0 (0)	0 (0)		0 (0)	0 (0)		0 (0)
	V	3 (0.8)	5 (1.4)		8 (2.0)	7 (1.7)		23 (2.9)
	VI	0 (0)	1 (0.3)		0 (0)	1 (0.2)		2 (0.3)
	VII	0 (0)	0 (0)		0 (0)	0 (0)		0 (0)
	Total	182 (50)	182 (50)		206 (50)	206 (50)		776 (100)
#2	I	132 (36.3)	128 (35.2)	0.857	173 (42.0)	170 (41.2)	0.772	603 (77.7)
	II	7 (1.9)	6 (1.6)		5 (1.2)	3 (0.7)		21 (2.7)
	III	41 (11.3)	45 (12.4)		27 (6.6)	31 (7.5)		144 (18.6)
	IV	0 (0)	0 (0)		0 (0)	1 (0.2)		1 (0.1)
	V	2 (0.5)	2 (0.5)		1 (0.2)	1 (0.2)		6 (0.8)
	VI	0 (0)	0 (0)		0 (0)	0 (0)		0 (0.0)
	VII	0 (0)	1 (0.3)		0 (0)	0 (0)		1 (0.1)
	Total	182 (50.0)	182 (50.0)		206 (50.0)	206 (50.0)		776 (100)
#1	I	140 (38.5)	141(38.7)	0.844	179 (43.4)	174 (42.2)	0.221	634 (81.7)
	II	4 (1.1)	3 (0.8)		0 (0)	2 (0.5)		9 (1.2)
	III	34 (9.3)	36 (9.9)		23 (5.6)	30 (7.3)		123 (15.9)
	IV	0 (0)	0 (0)		1 (0.2)	0 (0)		1 (0.1)
	V	2 (0.6)	1 (0.3)		1 (0.2)	0 (0)		4 (0.5)
	VI	0 (0)	0 (0)		0 (0)	0 (0)		0 (0.0)
	VII	2 (0.6)	1 (0.3)		2 (0.5)	0 (0)		5 (0.6)
	Total	182 (50.0)	182 (50.0)		206 (50.0)	206 (50.0)		776 (100)

No (%) = Number and percentage. #3, #2 and #1 = lower canine, lateral incisor and central incisor respectively.p = p value calculated by Chi square test comparing between right and left side root canal types of mandibular anterior teeth formale and female separately.

In the current study,the prevalence of the second canal in lower permanent incisorsin male was 25.3% (right side is 24.8% and 25.8% in left side) and the difference was non significant (p=0.369). For female, the prevalence was 18.4% (right side is 18.2% and 18.6% in left side)and the difference was non significant (p=0.591), these findings weer higher than that reported by-Green [22].

The prevalence of the second canal in permanent mandibular caninein male was 11.3% (right side is 11% and 11.6% in left side) and the difference was non significant (p=0.751). For female, the prevalence was 10.7% ( right side is 9.8% and 11.6% in left side) and the difference was non significant (p=0.611), these results were closed tothe results reported by Rahimi et al.[4].

Totally there were no differences between right and left side regarding lower permanent teeth (Table 1 and 2). The intermediate prevalence of two root canals in Mecca population may be due to diversity of its population and may be due to special characteristics of Mecca population that different races had inter-married and stayed there due to the holy nature of Makkah to all Muslim population.

The findings of the present study showed that, Virtucci's Type I is the most prevalent type (89.8% for canine, 77.7% for lateral and 81.7 for central incisor) followed by type III (6.6% for #3, 18.6% for #2 and 15.9% for #1), type II (0.4% for #3, 2.7% for

#2 and 1.2% for #1) and type V (2.9% for #3, 0.8% for #2 and 0.5% for #1).These findings were agreed with the results obtained by numerous researches showed that Vertucci's type I is the most prevalent type [31-33].

It has shown that, among double root canals, Vertucci's type III was the most prevalentfor mandibular anterior teeth and this support the results obtained byLin et al.[13]. The highest prevalence of the various types of canals associated with Vertucci's classification were types I, III, II and V which differe than that obtained byAminsobhani et al.[6] who reported that, the prevalence was types I, II, IV, III, and V respectively. The present findings showed that, Vertucci's type III has the highest prevalence as a two canaled mandibular incisors and this not agreed with resultsreported by Altunsoy et al. [32] where they found Vertucci's type V had the highest prevalence in double root canals.Another study showed that the highest prevalence was the type's I, II, III, and IV, respectively [4]. The prevalence of Vertucci's types were I, III, V, respectively reported by da Silva et al.[34]. These differences may be due to different ethnicity of the participants.

The present results indicated that, the endodontists should take care during treatment of lateral and/or central incisors as there were significant differences between male and female (p=0.003 and p=0.013). Also, the results indicated that, there were no specific precautions during treating right or left side either for male or male as there were no significant differences among them (Ta-

ble 4)

## Conclusion

Type I Vertucci's classification was the most common type in all mandibular anterior teeth. Type IV and VII Vertucci's canal configuration were the least prevalent type in canine. Type IV, VI and VII were the least prevalent in lateral incisor. Type IV, V and VII were the least prevalent in mandibular central incisors.

The presence of the second canal and Type III Vertucci's classification was relatively high in mandibular lateral and central incisors so more attention should be given for these teeth during endodontic treatment.

The Prevalence of the second canal in mandibular right and left canines was the lowest, and mandibular right and left lateral incisors was the highest.

The configuration of double rooted lateral and central incisors is significantly differ in males than females.

## Limitations

CBCT has limitations like image artifact and, it is sensitive to technique errors so it needs special training for interpretation. Moreover, CBCT is not a substitution for periapical, bitewing, and panoramic x-rays it is used only for a particular diagnosis. There is a restricted usage of CBCT in endodontics for the evaluation of complex root canal morphology, root resorption, and related conditions [18].

## References

- [1]. Siqueira JF Jr. Aetiology of root canal treatment failure: why well-treated teeth can fail. *IntEndod J.* 2001 Jan;34(1):1-10. PubMed PMID: 11307374.
- [2]. Saati S, Shokri A, Foroozandeh M, Poorolajal J, Mosleh N. Root Morphology and Number of Canals in Mandibular Central and Lateral Incisors Using Cone Beam Computed Tomography. *Braz Dent J.* 2018 May-Jun;29(3):239-244. PubMed PMID: 29972448.
- [3]. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endod. Top.* 2005; 10: 3–29.
- [4]. Rahimi S, Milani AS, Shahi S, Sergiz Y, Nezafti S, Lotfi M. Prevalence of two root canals in human mandibular anterior teeth in an Iranian population. *Indian J Dent Res.* 2013 Mar-Apr;24(2):234-6. PubMed PMID: 23965453.
- [5]. Pan JYY, Parolia A, Chuah SR, Bhatia S, Mutalik S, Pau A. Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. *BMC Oral Health.* 2019 Jan 14;19(1):14. PubMed PMID: 30642318.
- [6]. Aminsobhani M, Sadegh M, Meraji N, Razmi H, Kharazifard MJ. Evaluation of the root and canal morphology of mandibular permanent anterior teeth in an Iranian population by cone-beam computed tomography. *J Dent (Tehran).* 2013 May;10(4):358-66. PubMed PMID: 24396355.
- [7]. Zhao Y, Dong YT, Wang XY, Wang ZH, Li G, Liu MQ, Fu KY. [Cone-beam computed tomography analysis of root canal configuration of 4 674 mandibular anterior teeth]. *Beijing Da XueXueBao Yi Xue Ban.* 2014 Feb 18;46(1):95-9. PubMed PMID: 24535357.
- [8]. Kamtane S, Ghodke M. Morphology of Mandibular Incisors: A Study on CBCT. *Pol J Radiol.* 2016 Jan 13;81:15-6. PubMed PMID: 26834865.
- [9]. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. *J Endod.* 2007 Sep;33(9):1121-32. doi: 10.1016/j.joen.2007.06.011. Epub 2007 Jul 19. PMID: 17931947.
- [10]. Ryan TP. Sample Size Determination and Power, Sample Size Determination and Power. 2013.
- [11]. Eleftheriadis GI, Lambrianidis TP. Technical quality of root canal treatment

- and detection of iatrogenic errors in an undergraduate dental clinic. *IntEndod J.* 2005 Oct;38(10):725-34. PubMed PMID: 16164687.
- [12]. Han T, Ma Y, Yang L, Chen X, Zhang X, Wang Y. A study of the root canal morphology of mandibular anterior teeth using cone-beam computed tomography in a Chinese subpopulation. *J Endod.* 2014 Sep;40(9):1309-14. PubMed PMID: 25043332.
- [13]. Lin Z, Hu Q, Wang T, Ge J, Liu S, Zhu M, Wen S. Use of CBCT to investigate the root canal morphology of mandibular incisors. *SurgRadiol Anat.* 2014 Nov;36(9):877-82. doi: 10.1007/s00276-014-1267-9. Epub 2014 Feb 11. PMID: 24515289.
- [14]. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *EurRadiol.* 1998;8(9):1558-64. PubMed PMID: 9866761.
- [15]. Bornstein MM, Wölner-Hanssen AB, Sendi P, Von Arx T. Comparison of intraoral radiography and limited cone beam computed tomography for the assessment of root-fractured permanent teeth. *Dent Traumatol.* 2009 Dec;25(6):571-577. PubMed PMID: 19843131.
- [16]. Patel S, Horner K. The use of cone beam computed tomography in endodontics. *Int J Endod.* 2009; 42: 755–756.
- [17]. Cohenca N, Simon JH, Roges R, Morag Y, Malfaz JM. Clinical indications for digital imaging in dento-alveolar trauma. Part 1: traumatic injuries. *Dent Traumatol.* 2007 Apr;23(2):95-104. PubMed PMID: 17367457.
- [18]. Mallya S, Lam E. White and Pharoah's Oral Radiology. 2018;1608.
- [19]. Madeira MC, Hetem S. Incidence of bifurcations in mandibular incisors. *Oral Surg Oral Med Oral Pathol.* 1973 Oct;36(4):589-91. PubMed PMID: 4517109.
- [20]. Miyashita M, Kasahara E, Yasuda E, Yamamoto A, Sekizawa T. Root canal system of the mandibular incisor. *J Endod.* 1997 Aug;23(8):479-84. PubMed PMID: 9587315.
- [21]. Liu J, Luo J, Dou L, Yang D. CBCT study of root and canal morphology of permanent mandibular incisors in a Chinese population. *Acta Odontol Scand.* 2014 Jan;72(1):26-30. PubMed PMID: 24255962.
- [22]. GREEN D. A stereomicroscopic study of the root apices of 400 maxillary and mandibular anterior teeth. *Oral Surg Oral Med Oral Pathol.* 1956 Nov;9(11):1224-32. PubMed PMID: 13370115.
- [23]. Benjamin KA, Dowson J. Incidence of two root canals in human mandibular incisor teeth. *Oral Surg Oral Med Oral Pathol.* 1974 Jul;38(1):122-6. PubMed PMID: 4525678.
- [24]. Vertucci FJ. Root canal anatomy of the mandibular anterior teeth. *J Am Dent Assoc.* 1974 Aug;89(2):369-71. PubMed PMID: 4527223.
- [25]. Kartal N, Yanikoğlu FÇ. Root canal morphology of mandibular incisors. *J Endod.* 1992;18:562–564.
- [26]. Calişkan MK, Pehlivan Y, Sepetçioğlu F, Türkün M, Tuncer SS. Root canal morphology of human permanent teeth in a Turkish population. *J Endod.* 1995 Apr;21(4):200-4. PubMed PMID: 7673821.
- [27]. Al-Qudah AA, Awawdeh LA. Root canal morphology of mandibular incisors in a Jordanian population. *IntEndod J.* 2006 Nov;39(11):873-7. PubMed PMID: 17014525.
- [28]. Zhengyan Y, Keke L, Fei W, Yueheng L, Zhi Z. Cone-beam computed tomography study of the root and canal morphology of mandibular permanent anterior teeth in a Chongqing population. *TherClin Risk Manag.* 2015 Dec 23;12:19-25. PubMed PMID: 26730198.
- [29]. Haghaniyar S, Moudi E, Bijani A, Ghanbarabadi MK. Morphologic assessment of mandibular anterior teeth root canal using CBCT. *Acta Med Acad.* 2017 Nov;46(2):85-93. PubMed PMID: 29338272.
- [30]. Sert S, Aslanalp V, Tanalp J. Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. *IntEndod J.* 2004 Jul;37(7):494-9. PubMed PMID: 15189440.
- [31]. Altunsoy M, Ok E, Nur BG, Aglarci OS, Gungor E, Colak M. A cone-beam computed tomography study of the root canal morphology of anterior teeth in a Turkish population. *Eur J Dent.* 2014 Jul;8(3):302-306. PubMed PMID: 25202207.
- [32]. Kayaoglu G, Peker I, Gumusok M, Sarikir C, Kayadugun A, Ucok O. Root and canal symmetry in the mandibular anterior teeth of patients attending a dental clinic: CBCT study. *Braz Oral Res.* 2015;29:S1806-83242015000100283. PubMed PMID: 26154376.
- [33]. Verma GR, Bhadare C, Bhoosreddy AR, Vedpathak PR, Mehrotra GP, Nerkar AC, Bhandari A, Chaubey S. Cone Beam Computed Tomography Study of Root Canal Morphology of Permanent Mandibular Incisors in Indian Subpopulation. *Pol J Radiol.* 2017 Jul 7;82:371-375. PubMed PMID: 28794810.
- [34]. da Silva EJ, de Castro RW, Nejaime Y, Silva AI, Haiter-Neto F, Silberman A, Cohenca N. Evaluation of root canal configuration of maxillary and mandibular anterior teeth using cone beam computed tomography: An in-vivo study. *Quintessence Int.* 2016 Jan;47(1):19-24. PubMed PMID: 26417615.