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Original Article

Volumetric pulp chambers measurements in mandibular and maxillary permanent first molar using cone-beam computed tomography by age and gender

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Abstract

Aim: The aim of this study was to demonstrate the anatomical structure of pulp chamber, measure the volume of the total pulp chambers in mm3 and evaluate the pulp chamber volume changes by age and gender statistically in mandibular and maxillary first molars by means of CBCT.

Methodology: In our study, CBCT examinations of patients between the ages of 7-18 years, which were carried out due to different reasons were evaluated retrospectively. The CBCT images of healthy total of 160 lower and upper right permanent first molar teeth were selected randomly and the volumes of the total pulp chamber were measured in mm3 with the 3D Slicer software program. We analyzed the collected data with statistical analysis methods and we evaluated whether there was any difference between the patients grouped according to the age in respect of volume changes in the total pulp chamber and whether there was any difference between the mean volume values and gender of the patients within the same group.

Results: Comparison of the volume measurements of the lower and upper first permanent molar teeth between the groups showed that the volume values of the total pulp chamber decreased depending on the age ($p<0.05$). Regarding gender, volume decrease related to age was statistically more significant among females. We determined in all age groups except age 7-9 group that the volume value of the total pulp chamber of the upper permanent first molar teeth was statistically higher than the volume value of the total pulp chamber of the lower permanent first molar teeth ($p<0,05$).

Conclusions: We believe that CBCT is an easy and conservative method for the 3D-imaging of the pulp chamber, volume measurement and examination of the dimensional changes of the total pulp chamber depending on deposition of secondary dentin.

Keywords: Volumetric measurement, cone-beam computed tomography, total pulp chamber

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Introduction

The hard and soft tissues of the teeth are continuously exposed to a change, which starts right after the tooth eruption and continues throughout the life. Age-related alterations are more obvious in the dentin (1).

There are three types of dentin in the human tooth: primary, secondary, and tertiary dentin. Primary dentin is the dentin structure, which determines the initial shape of the tooth and is formed before apical foramen is closed during tooth formation (2, 3). Most of the primary dentin is formed before tooth eruption but primary dentin formation continues for almost 3 years from tooth eruption to the completion of root formation (2). After the completion of root formation, secondary dentin is also formed by odontoblasts that generate primary dentin (4, 5). Secondary dentin is formed continuously in the rest of life without a significant stimulus but slowly compared to primary dentin (approximately 4 µm per day), with reduced dentin accumulation rate (approximately 0,5 µm per day) as a result of relatively slower apposition (2, 6-8). Tertiary dentin, on the other hand, is an irregularly structured dentin that is formed as a local reaction to environmental stimuli (8).

Pulp-dentin complex changes in time resulting in a reduction of pulpal chamber volume due to continuous secondary dentin accumulation with age (9). While secondary dentin accumulation is a physiological process that is associated with age, tertiary dentin is formed in reaction to environmental stimuli such as chemical stimulants, dental caries, mechanical, chemical and thermal irritation during cavity preparation, and attrition, at the inner surface of the pulpal chamber that is exposed to stimuli (2-4, 10-12). In our study, in order to eliminate the environmental factors that can affect the pulp, permanent first molar teeth without caries, restoration and anomaly were investigated. Therefore, we tried to eliminate tertiary dentin accumulation.

Recently the use of cone-beam computed tomography (CBCT) has become widespread and a useful tool in clinical applications in dentistry. It has a broad application field in the diagnosis, treatment, and follow-up after the treatments (13). Pulpal chamber size can be evaluated in detail by using axial, sagittal and coronal CBCT sections (14). Volumetric changes of pulpal chamber with age can be measured precisely and correctly by segmenting and reforming CBCT images (15, 16). This study was aimed to show in 3-dimension the anatomy of pulpal chamber of permanent first molar teeth in maxilla and mandible, to compare total pulpal chamber volume according to age and gender, and to evaluate pulpal chamber volume change with secondary dentin accumulation.

Materials and Methods

Materials used in the study

In this study, CBCT images of 7 to 18 year old patients, who were admitted for different reasons between 2009 and 2015, were identified by searching retrospectively the archives of Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Dicle University. Patients were not exposed to unnecessary or additional radiation. CBCT images that were already taken for diagnoses or treatment were used. This study was approved by Dicle University Faculty of Dentistry Local Ethics Committee (Approval number 2015-25).

CBCT images of a total of 160 right lower and upper permanent first molar teeth from 80 patients, who did not have dental caries, restoration, root canal treatment and veneer crown, taurodont anomaly, any tooth extraction or pathological process in the surrounding tissues, were randomly selected and assigned into four groups according to patient's ages (Table 1).

Acquisition of CBCT images and processing with 3D Slicer Software

All CBCT images were obtained with a CBCT unit i-CAT (Imaging Sciences International, Hatfield, PA, USA). Voxel size was defined as 0,3 mm in CBCT data, which were archived in DICOM (Digital Imaging and Communications in Medicine) format in the computer.

CBCT data, which were recorded in DICOM format, were transferred to 3D Slicer 4.5.0.1 (open source software, available: http://www.slicer.org, accessed: 2016 Jul 25) for semi-automatic segmentation and volume calculation of total pulpal chamber of right lower and upper permanent 1st molar teeth. Total pulpal chamber was segmented semi-automatically (Fig. 1).

3D model obtained after segmentation on 3D Slicer software was transferred to Rhinoceros software to acquire total crown pulpal chamber. By defining the deepest point of the pulpal chamber, a slice plane was formed over the root furcation point. Root pulp under this plane was excluded (Fig. 2).

Total crown pulpal chamber volume (mm3) was calculated by transferring the final model again to 3D Slicer. The first measurements of total crown pulpal chamber volume of 160 right lower and upper permanent first molar teeth were performed in 3D Slicer software.

Another researcher performed second measurements after 1 month in order to control individual drawing and measurement errors and to test the reliability of the measurements statistically.

Table 1. Distribution of teeth examined by tooth type, age and gender.

Groups	Ages (year)	Number of teeth examined with CBCT		
Group 1	7-9	40 permanent 1st molar teeth	20 upper permanent 1st molar teeth 20 lower permanent 1st molar teeth	10 Female upper permanent 1st molar teeth 10 Male upper permanent 1st molar teeth 10 Female lower permanent 1st molar teeth 10 Male lower permanent 1st molar teeth
Group 2	10-12	40 permanent 1st molar teeth	20 upper permanent 1st molar teeth 20 lower permanent 1st molar teeth	10 Female upper permanent 1st molar teeth 10 Male upper permanent 1st molar teeth 10 Female lower permanent 1st molar teeth 10 Male lower permanent 1st molar teeth
Group 3	13-15	40 permanent 1st molar teeth	20 upper permanent 1st molar teeth 20 lower permanent 1st molar teeth	10 Female upper permanent 1st molar teeth 10 Male upper permanent 1st molar teeth 10 Female lower permanent 1st molar teeth 10 Male lower permanent 1st molar teeth
Group 4	16-18	40 permanent 1st molar teeth	20 upper permanent 1st molar teeth 20 lower permanent 1st molar teeth	10 Female upper permanent 1st molar teeth 10 Male upper permanent 1st molar teeth 10 Female lower permanent first molar teeth 10 Male lower permanent 1st molar teeth

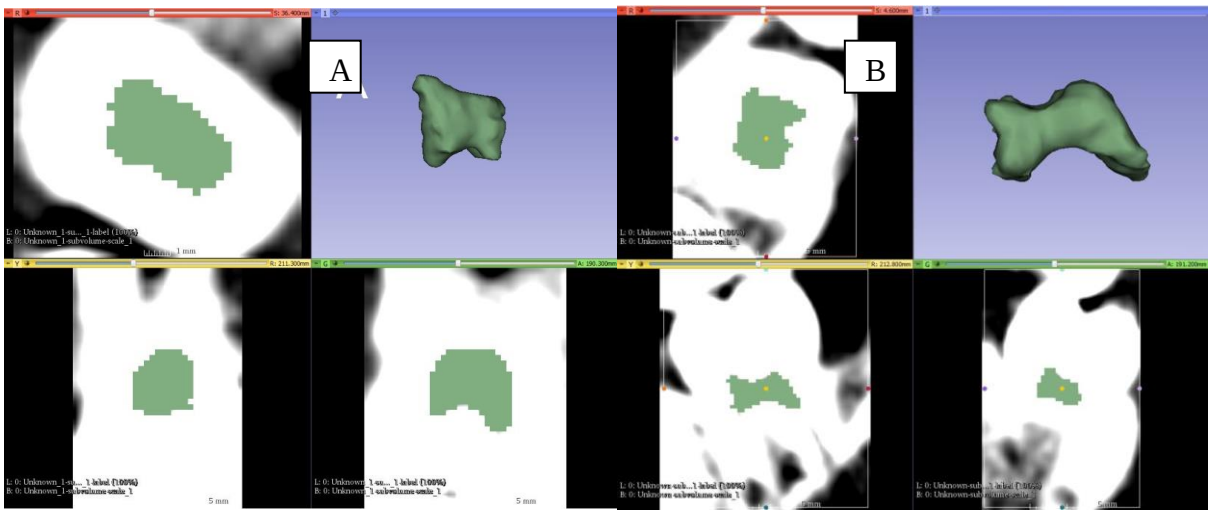

Figure 1. A) Segmentation of the total pulp chamber of the upper permanent first molar to obtain the 3D model, **B)** Segmentation of the total pulp chamber of the lower permanent first molar to obtain the 3D model

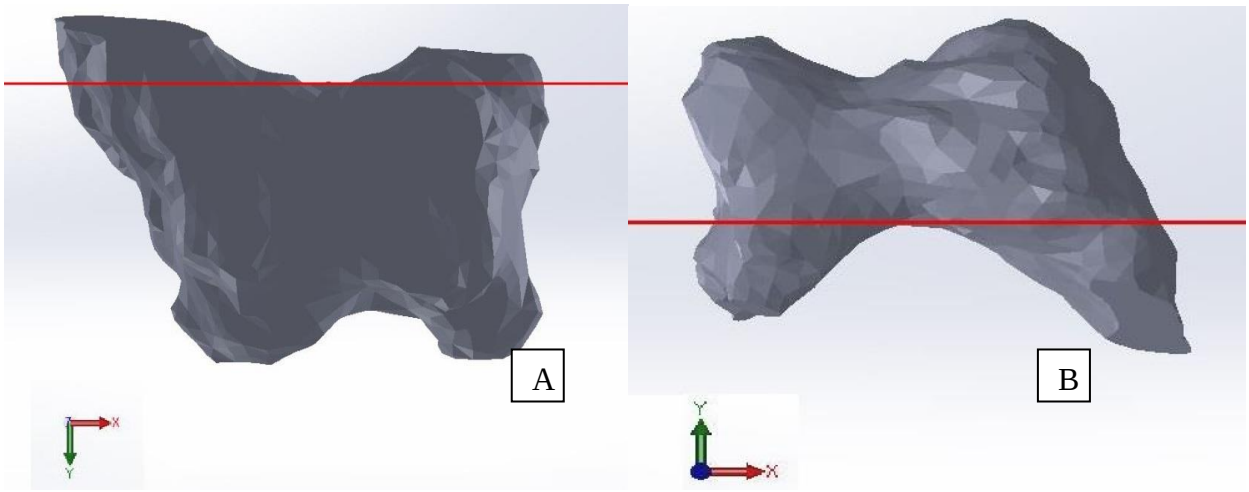

Figure 2. A) Cutting from the furcation point of the 3D model of the total pulp of the upper permanent first molar, **B)** Cutting from the furcation point of the 3D model of the total pulp of the lower permanent first molar.

Statistical Analysis

In this study, mean, standard deviation, the standard error for means, minimum, and maximum values were given as descriptive statistics. The normal distribution of the data was analyzed with Kolmogorov-Smirnow test and homogeneity of the data was analyzed with Levene test.

For the comparison of the mean values of the groups one-way analysis of variance (ANOVA) test, for the multiple comparison between the groups Tukey-HSD test and for the independent groups Independent-t test were implemented.

In order to determine the error rate of tomographic measurements, another researcher repeated all measurements. Measurement error was calculated by using Dahlberg formula, in which d is the difference between two measurements: $S = \sqrt{\sum d^2 / 2n}$

The confidence interval was 95% for all statistical tests and the accepted limit of significance was $p<0.05$.

Results

The age averages of the patients, who were 7 to 18 years old, were given in Table 2.

When the measurements of total pulpal chamber volume of lower and upper permanent first molar teeth by the age groups were evaluated, it was seen that total pulpal chamber volume decreased with age. When the total pulpal chamber volume between groups was compared with one-way analysis of variance (ANOVA), it was found out that reduction of total pulpal chamber volume with age is statistically significant (p=0,000) (Table 3).

The differences among the groups that are obtained by using the multiple comparison tests to analyze the total pulpal chamber volume of lower and upper permanent first molar teeth were displayed in Table 4.

In the comparison of total pulpal chamber volume measurements of lower and upper permanent first molar teeth according to gender between the age groups, age-related reduction of total pulpal chamber volume was seen in both females and males. In the comparison of total pulpal chamber volume among the groups according to gender by using one-way ANOVA, it was found out that reduction of total pulpal chamber volume with age is statistically significant($p<0,05$). Age-related reduction of total pulpal chamber volume of lower and upper permanent first molar teeth was more significant in females and less significant in males (Table 5).

The comparison of average total pulpal chamber volume of lower and upper permanent first molar teeth in females and males among the groups were shown in Table 6,7,8,9.

Table 2. The age averages of the groups.

Groups	n	Mean (year)	Std. Deviation	Std. Error Mean
Group 1	40	8,0958	0,83729	0,13239
Group 2	40	10,9750	0,71914	0,11371
Group 3	40	13,9583	0,88212	0,13948
Group 4	40	16,9708	0,75875	0,11997
Total	160	12,5000	3,41455	0,26994

Table 3. Mean, maximum and minimum volume values of the total pulp chamber of lower and upper permanent 1st molar between the groups, standard deviation, the standard error for means and results of one-way analysis of variance.

	Groups	n	Mean (mm^3)	Std. Deviation	Std. Error Mean	Min. (mm^3)	Max. (mm^3)	p value
Volume values of the total pulp chamber of lower permanent 1st molar	Group 1	20	48,3049	11,23298	2,51177	30,29	62,36	0,000
	Group 2	20	36,5472	9,72168	2,17383	18,23	55,93	
	Group 3	20	30,9429	9,95457	2,22591	16,54	51,21	
	Group 4	20	23,4952	9,73490	2,17679	9,34	41,50	
	Total	80	34,8225	13,51917	1,51149	9,34	62,36	
Volume values of the total pulp chamber of upper permanent 1st molar	Group 1	20	54,7269	9,10093	2,03503	40,92	69,87	0,000
	Group 2	20	45,2668	11,12423	2,48745	23,72	65,44	
	Group 3	20	42,6773	13,69153	3,06152	25,95	77,13	
	Group 4	20	33,1299	9,50026	2,12432	19,65	55,54	
	Total	80	43,9502	13,28028	1,48478	19,65	77,13	

Table 4. Comparison of the volume measurements of the lower and upper first permanent molar teeth between the groups.

Groups	n	Mean volume of the lower permanent 1st molar (mm^3)	Mean volume of the upper permanent 1st molar (mm^3)	Differences Between Groups ($p<0.05$)
Group 1	20	48,3060	54,7280	(2)(3)(4)
Group 2	20	36,5495	45,2685	(1)(4)
Group 3	20	30,9440	42,6785	(1)(4)
Group 4	20	23,4970	33,1310	(1)(2)(3)

Table 5. Mean, maximum and minimum volume values of the total pulp chamber of lower and upper permanent first molar between the groups by gender, standard deviation, the standard error for means and results of one-way analysis of variance.

Gender		Groups	n	Mean (mm^3)	Std. Deviation	Std. Error Mean	Min. (mm^3)	Max. (mm^3)	P value	F value
Female	Volumes of the total pulp chamber of lower permanent 1st molar	Group 1	10	47,0713	10,07816	3,18700	35,46	62,36		
		Group 2	10	35,4087	9,95597	3,14835	21,65	48,11		
		Group 3	10	25,8356	7,61100	2,40681	16,54	41,85	0,000	17,629
		Group 4	10	20,1585	7,53093	2,38149	11,58	36,85		
		Total	40	32,1185	13,40424	2,11940	11,58	62,36		
	Volumes of the total pulp chamber of upper permanent 1st molar	Group 1	10	52,2975	7,90735	2,50052	40,92	65,80		
		Group 2	10	42,2962	9,92344	3,13807	23,72	52,62		
		Group 3	10	36,3162	9,35805	2,95928	25,95	53,65	0,000	13,985
		Group 4	10	28,9459	5,48357	1,73406	19,65	39,11		
		Total	40	39,9639	11,80003	1,86575	19,65	65,80		
Male	Volumes of the total pulp chamber of lower permanent 1st molar	Group 1	10	49,5384	12,70546	4,01782	30,29	61,31		
		Group 2	10	37,6857	9,87530	3,12284	18,23	55,93		
		Group 3	10	36,0501	9,65948	3,05459	20,30	51,21	0,001	7,387
		Group 4	10	26,8318	10,89087	3,44400	9,34	41,50		
		Total	40	37,5265	13,24955	2,09494	9,34	61,31		
	Volumes of the total pulp chamber of upper permanent 1st molar	Group 1	10	57,1563	9,96067	3,14984	42,49	69,87		
		Group 2	10	48,2374	11,96504	3,78368	24,62	65,44		
		Group 3	10	49,0383	14,77342	4,67177	34,67	77,13	0,008	4,561
		Group 4	10	37,3138	11,02577	3,48666	21,20	55,54		
		Total	40	47,9365	13,61683	2,15301	21,20	77,13		

Table 6. Comparison of the volume measurements of the lower first permanent molar teeth in females between the groups.

Groups	n	Mean (mm^3)	Differences Between Groups (p<0.05)
Group 1	10	47,0730	(2)(3)(4)
Group 2	10	35,4110	(1)(3)(4)
Group 3	10	25,8370	(1)(2)
Group 4	10	20,1600	(1)(2)

Table 7. Comparison of the volume measurements of the upper first permanent molar teeth in females between the groups.

Groups	n	Mean (mm^3)	Differences Between Groups (p<0.05)
Group 1	10	52,2980	(2)(3)(4)
Group 2	10	42,2990	(1)(4)
Group 3	10	36,3180	(1)
Group 4	10	28,9470	(1)(2)

Table 8. Comparison of the volume measurements of the lower first permanent molar teeth in males between the groups.

Groups	n	Mean (mm^3)	Differences Between Groups ($p<0.05$)
Group 1	10	49,5390	(2)(3)(4)
Group 2	10	37,6880	(1)
Group 3	10	36,0510	(1)
Group 4	10	26,8340	(1)

Table 9. Comparison of the volume measurements of the upper first permanent molar teeth in males between the groups.

Groups	n	Mean (mm^3)	Differences Between Groups ($p<0.05$)
Group 1	10	57,1580	(4)
Group 2	10	48,2380	
Group 3	10	49,0390	
Group 4	10	37,3150	(1)

Within group analysis of total pulpal chamber volume of lower and upper permanent 1st molar teeth with independent samples test revealed that average total pulpal chamber volume of lower permanent 1st molar teeth was not statistically different from average total pulpal chamber volume of upper permanent 1st molar teeth in Group 1 ($p>0,05$). However, in Groups 2, 3, and 4, a statistically significant difference was observed ($p<0,05$) (Table 10).

In the comparison of average total pulpal chamber volume of lower and upper permanent first molar teeth in females and males within the same group, it was found out that while there was not a significant difference between genders in Group 1 and Group 2 ($p>0,05$), there were both statistically significant difference between genders for upper and lower first molar teeth in Group 3 and only for upper first molar teeth in Group 4 ($p<0,05$) (Table 11).

Table 10. Mean volume values of the total pulp chamber of lower and upper permanent first molar within the same group standard deviation, the standard error for means and statistical comparison of volume measurements.

Groups		n	Mean (mm^3)	Std. Deviation	Std. Error Mean	P value
Group 1	Volumes of the total pulp chamber of lower permanent 1^{st} molar	20	48,3049	11,23298	2,51177	0,054
	Volumes of the total pulp chamber of upper permanent 1^{st} molar	20	54,7269	9,10093	2,03503	
Group 2	Volumes of the total pulp chamber of lower permanent 1^{st} molar	20	36,5472	9,72168	2,17383	0,012
	Volumes of the total pulp chamber of upper permanent 1^{st} molar	20	45,2668	11,12423	2,48745	
Group 3	Volumes of the total pulp chamber of lower permanent 1^{st} molar	20	30,9429	9,95457	2,22591	0,004
	Volumes of the total pulp chamber of upper permanent 1^{st} molar	20	42,6772	13,69153	3,06152	
Group 4	Volumes of the total pulp chamber of lower permanent 1^{st} molar	20	23,4952	9,73490	2,17679	0,003
	Volumes of the total pulp chamber of üst permanent 1^{st} molar	20	33,1299	9,50026	2,12432	

Table 11. Mean volume values of the total pulp chamber of lower and upper permanent first molar within the same group by gender, standard deviation, the standard error for means and statistical comparison of volume measurements by gender.

Groups		Gender	n	Mean (mm^3)	Std. Deviation	Std. Error Mean	P value
Group 1	Volumes of the total pulp chamber of lower permanent 1st molar	Female	10	47,0713	10,078164	3,186995	0,636
		Male	10	49,5384	12,705462	4,017820	
	Volumes of the total pulp chamber of upper permanent 1st molar	Female	10	52,2975	7,907347	2,500523	0,243
		Male	10	57,1563	9,960675	3,149842	
Group 2	Volumes of the total pulp chamber of lower permanent 1st molar	Female	10	35,4087	9,955966	3,148353	0,614
		Male	10	37,6857	9,875302	3,122845	
	Volumes of the total pulp chamber of upper permanent 1st molar	Female	10	42,2962	9,923438	3,138067	0,242
		Male	10	48,2374	11,965036	3,783677	
Group 3	Volumes of the total pulp chamber of lower permanent 1st molar	Female	10	25,8356	7,610997	2,406809	**0,017**
		Male	10	36,0501	9,659477	3,054595	
	Volumes of the total pulp chamber of upper permanent 1st molar	Female	10	36,3162	9,358051	2,959276	**0,034**
		Male	10	49,0383	14,773423	4,671767	
Group 4	Volumes of the total pulp chamber of lower permanent 1st molar	Female	10	20,1585	7,530925	2,381488	0,128
		Male	10	26,8318	10,890871	3,443996	
	Volumes of the total pulp chamber of upper permanent 1st molar	Female	10	28,9459	5,483566	1,734056	**0,045**
		Male	10	37,3138	11,025774	3,486656	

Discussion

Until today several studies based on traditional radiography, in which pulpal chamber volumes were measured by using periapical, bitewing and panoramic radiographies, have been performed in order to obtain appropriate information about pulpal chamber anatomy. In these studies, the 2-dimensional measurements were made but these measurements do not give information about the 3-dimensional anatomy of the pulpal chamber (17-20). Furthermore, investigation of pulpal chamber changes especially with periapical and panoramic radiography techniques has disadvantages such as a tendency to unwanted situations including magnification, distortion, and superimposition (21, 22). Three-dimensional imaging methods are used to overcome these disadvantages (21).

With the increase of the use of 3-dimensional imaging methods in dentistry, a number of studies that used CBCT to make the measurements related to pulpal chamber anatomy have been published. In these studies, it was proposed that CBCT is a more useful tool to determine pulpal chamber parameters and it enables precise and correct measurement of age-related volume changes in dental tissues (9, 14, 16, 23).

In the literature, there are studies that performed qualitative and quantitative evaluation of 3D structure of pulpal chamber and root canal system without damaging dental integrity by using micro-computed tomography, which enables investigation of material structure at micron level with high resolution (15, 24-27). Micro-computed tomography has disadvantages such as having a limited scanning area that can only scan a single tooth and inability to scan permanent first molar tooth in patient's mouth without extracting the tooth (15). It is not ethically acceptable to extract a healthy permanent first molar tooth of individuals aged between 7 to 18 years of age in order to investigate age-related pulpal chamber changes.

Therefore, we preferred CBCT imaging technique in our study for the measurement of age-related pulpal chamber changes of permanent first molar teeth of individuals aged between 7 to 18 years.

Currently, there are studies that evaluated human tooth and canal morphology by using magnetic resonance imaging. It is possible to visualize both hard and soft tissues in 3-dimension with magnetic resonance imaging, a non-invasive diagnostic tool. It is presented as an alternative to CBCT because ionizing radiation is not used in magnetic resonance imaging (28-33). In our study, the patients were not exposed to unnecessary additional radiation for volume measurements since we used CBCT images that had already been taken for diagnostic or treatment purposes.

Ge et al. evaluated age-related pulpal chamber changes by using CBCT images and they reported that permanent upper second molar teeth should be used in pulpal chamber studies (15). However; to investigate a wider age range in our study, pulpal chamber volume of permanent first molar teeth was investigated with CBCT images since the first molar tooth is the one that erupts and finishes apical closure first among all molar teeth in individuals aged between 7 to 18 years.

Yang et al. used "iDixel", Porto et al. used "DentalSlice", Ge et al. used "ITK-SNAP 2.4", Vankatesh et al. used "Mimics", and Marković et al. used "3D Slicer" software as a semi-automatic program, in which CBCT images are segmented and volume measurements can be made after restructuring (15, 16, 21). In our study, pulpal chamber was segmented and volume measurements were made with 3D Slicer software, which was tested by Harvard Surgery Planning Laboratory and used in several studies in health sciences (34-43).

In the evaluation of our findings in this study, root development was not completed in Group 1 that consisted of individuals aged between 7 to 9 years and this group had the largest pulpal chamber volumes. After determination of primary dentin formation and pulpal chamber shape, secondary dentin accumulation in pulpal chamber was evaluated in Group 2 (10-12 years old), Group 3 (13-15 years old) and Group 4 (16-18 years old) and it was found that pulpal chamber dimensions were reduced (p=0,000). In our study, the reduction of pulpal chamber dimensions with increased age reveals similar findings with the previous studies by Shaw and Jones, Khojastepour et al., Bodrumlu et al., Tsatsoulis et al., Pinchi et al., Zaher et al., Porto et al., Ge et al., Agemetsu et al., Oi et al. and Iwaka (9, 15-17, 25-27, 44-47).

In the evaluation of total pulpal chamber volume measurements of lower and upper permanent first molar teeth according to gender among age groups, we found that total pulpal chamber volume decreased with age in both males and females. Age-related reduction of total pulpal chamber volume of lower and upper permanent first molar teeth was more significant in females (p=0,000 for both upper and lower permanent first molar teeth) and less significant in males (p=0,001 and p=0,008 for lower and upper permanent first molar teeth, respectively). In previous studies, it was proposed that odontoblasts in pulp tissue of women have estrogen receptors and estrogen has a strong effect on secondary dentin production (25, 48, 49). We think that age-related reduction of total pulpal chamber volume was more significant in females in our study because of the effect of estrogen hormone.

In their study, in which they used CBCT, Ge et al. reported that age-related reduction of total pulpal chamber volume of maxilla second premolar, first molar, second molar teeth, and mandible canine, first and second molar teeth were more significant in females (15). Agematsu et al. demonstrated that reduction of total pulpal chamber volume was more significant in females in the same age group (25). Pinchi et al., on the other hand, reported that reduction of total pulpal chamber volume was not statistically significantly different between genders (9).

Our findings were compatible with the findings of Ge et al. and Agemetsu et al, but were incompatible with the findings of Pinchi et al. We think that the conflicting results in the study of Pinchi et al. are due to low number of participants and disproportion of the number of male and female in their study.

In females, average total pulpal chamber volume of upper permanent first molar teeth in Group 2 and Group 3 was not statistically different (p>0,05) but there was a statistically significant difference between Group 2 and Group 3 for lower permanent first molar teeth (p<0,05). This finding shows that total pulpal chamber volume of lower permanent first molar teeth in females older than 12 years reduces more than upper permanent first molar teeth. We think that future studies that investigate total pulpal chamber volume changes of upper and lower permanent first molar teeth separately in females aged between 10 to 15 are needed.

In males, total pulpal chamber volume of both upper and lower permanent first molar teeth was not statistically significant between Group 2, Group 3, and Group 4 (p>0,05). We think that future studies that investigate total pulpal chamber volume changes of upper and lower permanent first molar teeth separately in males aged between 10 to 18 are needed.

In our study, we found that within the same group total pulpal chamber volume of upper permanent first molar teeth was more than total pulpal chamber volume of lower permanent first molar teeth. In the analysis of average total pulpal chamber volume measurements of upper and lower permanent first molar teeth, while there was no significant difference in Group 1 (p>0,05), there was a statistically significant difference in Groups 2, 3, and 4 (p<0,05).

Fanibunda measured the volumes of extracted teeth and found that total pulpal chamber volume of upper permanent first molar teeth was 23% larger than that of lower permanent first molar teeth (50). Chandler et al. reported that total pulp area of lower permanent molar teeth was bigger than that of upper molar teeth (9% in Mongolians and 18% in other races) (18).

While we found similar results with Fanibunda, our results differed from the results of Chandler et al. We think that two factors affected the measurements of upper and lower permanent molar teeth in the study of Chandler et al.: first; pulpal chamber was investigated in 2-dimensions with bitewing radiography, second; pulpal chamber of lower permanent molar teeth are seen more clearly on bitewing radiography.

In comparison of average total pulpal chamber volume of lower and upper permanent first molar teeth in males and females within the same group, it was found that while there was not a significant difference between males and females in Group 1 and Group 2 (p>0,05), there were both statistically significant difference between males and females for upper and lower first molar teeth in Group 3 and only for upper first molar teeth in Group 4 (p<0,05).

Khojastepour et al. did not find a significant difference in terms of pulpal chamber volume between genders (45). On the contrary, Chandler et al. found a significant difference between genders and reported that pulps of permanent first molar teeth have sexual dimorphism. Pulp dimensions of the permanent first molar tooth in males are bigger than that in females. Similar to the study of Chandler et al., Bodrumlu et al. also mentioned the difference between the genders and reported that pulp dimensions of permanent second molar teeth in males are larger than that in females (17).

Conclusions

A detailed examination of the pulp chamber anatomy and the changes in its dimensions is widely important determine the deposition of secondary dentin with age. According to our findings, it is seen that the differences between males and females start to form in lower and upper permanent first molar teeth after the age of 12. But, since a statistically significant difference between males and females in terms of average pulpal chamber volume of lower permanent first molar teeth was not observed in Group 4 consisting of 16 to 18 years old subjects, we believe that pulpal chamber dimensions should be investigated in a larger sample with regards to sexual dimorphism.

Ethical Approval: Ethics committee approval was received for this study from Dicle University (No:2015/25).

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