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Comparative evaluation of root canal morphology of mandibular premolars using clearing and cone beam computed tomography

Abbasali Khademi[1], Mojdeh Mehdizadeh[2], Maryam Sanei[1], Hamidreza Sadeqnejad[3], Saber Khazaei[1]

[1]Department of Endodontic and Dental Research Center, [2]Department of Oral and Maxillofacial Radiology and Dental Implant Research Center, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, [3]Endodontist, Private Practice, Lorestan, Iran

ABSTRACT

Background: Different techniques are used to evaluate the anatomy of root canal system. The present study was aimed to evaluate the root canal morphology of mandibular premolars using clearing and cone beam computed tomography (CBCT) techniques.

Materials and Methods: A total of 182 mandibular first and second premolars were evaluated *in vitro* using 100 μm CBCT cross sections. The root canal morphology of the teeth was determined based on Vertucci classification in relation to the prevalence of C-shaped canals, lateral canals, and furcation location. Having removed the pulp tissue with NaOCl solution and staining the root canals with India ink, the samples were decalcified with 5% nitric acid and dehydrated with isopropyl alcohol. Finally, the samples were cleared with methyl salicylate. Data were analyzed by SPSS 16 software using McNamara, *t*-test, and Kappa coefficient.

Results: After Type I, the most frequent morphologies in both first and second premolars were Type V followed by Type IV. The prevalence rates of C-shaped morphology in first premolars using clearing and CBCT were 4.4% and 6.6%, respectively. However, no C-shaped morphology was found in second premolars. The maximum and minimum levels of agreement between the two techniques were observed in Type IV and Type V root canal morphologies, respectively. Extra root canals were identified in 25% and 13% of the first and second premolars, respectively.

Conclusion: CBCT showed a higher accuracy in determining C-shaped root canal morphology than the clearing technique. It also showed the least accuracy in diagnosing lateral root canals.

Key Words: Clearing, technique, cone beam computed tomography, root canal, morphologhy

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Address for correspondence:
Dr. Maryam Sanei, Department of Endodontics, School of Dentistry, Lorestan University of Medical Sciences, Khorramabad, Iran.
E-mail: maryam.sanei@ymail.com

INTRODUCTION

Successful root canal treatment depends on a thorough knowledge of the root canal system morphology and three-dimensional cleaning, shaping, and obturation based on adequate knowledge about the anatomical variations of root canal system.[1]

Various studies have used different techniques to evaluate the root canal system anatomy. The most commonly used techniques are the clearing technique,[2-4] cross sections,[5,6] conventional radiography,[7,8] and digital radiography.[9] Root canal system staining followed by tooth clearing has been considered the gold standard in some studies for evaluation of root canal system morphology.[10,11] In recent years, cone beam

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computed tomography (CBCT) technique has been used to evaluate the root canal system morphology, which was first reported by Tachibana and Matsumoto in 1990.[12] The CBCT images provided by the CBCT technique are in sagittal, coronal, and axial cross sections and can decrease the superimposition of adjacent tissues. In addition, the patient radiation dose with CBCT techniques is less than that with conventional CT technique. Furthermore, it can be applied *in vivo*.[13-16] Slowey[17] demonstrated that mandibular premolars are the most challenging teeth for endodontic treatment with the highest failure rates (11.45%). Failure of endodontic treatment in mandibular premolars is attributed to a wide range of anatomical variations in root canal systems and difficult access to the second root canal, resulting in inability to carry out an effective root canal treatment in the entire root canal length.[18] Previous study have reported the prevalence of more than one root canal in these teeth to be about 46%.[6] In addition, some studies have shown the presence of C-shaped root canals in these teeth.[19] The lateral root canals are given off from the main root canal and are extended to the periodontium. The presence of accessory root canals and the ability to clean and seal these canals affect the prognosis of treatment.[20,21]

The aims of the present study were to evaluate and compare the anatomical variations of the root canal system in mandibular premolars, including the root canal type based on Vertucci classification, the distance between the furcation and the root apex and the presence of C-shaped and lateral root canals using tooth clearing and CBCT techniques.

MATERIALS AND METHODS

In this *in vitro* study, a sample size of 182 mandibular first and second premolars was determined based on 0.05 alpha errors and 80% power. All of the samples had sound mature apices and were stored in water and 2% thymol iodide (Sigma-Aldrich, Steinheim, Germany) until sample collection was completed. Then samples were rinsed in water and immersed in 2.5% NaOCl (Golrang, Tehran, Iran) to eliminate all the soft tissue remnants.

To stabilize the teeth for CBCT evaluations, red tape wax was used minimally to prevent interference with radiographic technique. CBCT (Scanora 3D; Soredex, Tuusula, Finland) unit was used to evaluate root canal morphology under the exposure conditions of mA = 6 and kVp = 89. Galileos software (SIDEXIS XG, Sirona dental X-ray imaging system version 3.7) was used with 100 μm thick cross sections for evaluation at different cross sections. The samples were evaluated in three different sagittal, coronal, and axial cross sections. All the three cross sections were used to evaluate the number of root canals, the root canal system anatomy, and the presence of lateral root canals. The coronal cross section was used to determine the distance of furcation to apex. The coronal and axial cross sections were used to determine the presence of C-shaped canals. All CBCT images were evaluated by a radiologist.

To carry out the tooth clearing procedures, first, a diamond fissure bur (DiaSwiss FG; Geneve, Switzerland) was used in a high-speed hand piece (NSK, Nakanishi, Japan) under water spray to prepare standard access cavities by one operator. The pulp chamber floor was evaluated by a DG 16 endodontic explorer (Ash Instruments, Dentsply, Gloucester, UK) to identify root canal orifices. However, files or barbed broaches were not used to avoid manipulation of the root canals, and only root canal irrigation was carried out. Then, the samples were separately immersed in 5.25% NaOCl solution (Golrang, Tehran, Iran) for 48 h to eliminate the remaining organic debris and pulp tissue remnants. Next, the teeth were rinsed under running water for 20 min to remove all the debris from the root canals, followed by 24 h of storage for complete drying. The teeth should be completely dry for penetration of dye during such procedures.

A 27-gauge needle in a syringe was used to inject India ink (Calder Colours Ltd., Ashby-de-la-Zouch, Leicester, UK) into the root canal orifices until the dye was visible in the apical area or at the apical foramen. Then, the samples were stored for 24 h for the dye to dry. Next, the teeth were immersed in 5% nitric acid (Kiankaveazma, Tehran, Iran) for 72 h for complete decalcification at room temperature. The acidic solution was refreshed every day because the demineralization process occurs predominantly on the surface of the acid. To ensure the completion of decalcification process, one sample underwent a radiographic examination. At the end of this stage, the teeth were rinsed to eliminate the residual acid and were then dried. Isopropyl alcohol (Ararat, Tehran, Iran) was used at increasing concentrations (80%, 90%, and 100%) to dehydrate the tooth samples. The samples were

stored in each solution for 24 h. This step was important for penetration of clearing agents into the next stage. After the samples were completely dried, they were immersed in 2% methyl salicylate solution (Merck, Darmstadt, Germany) until they became completely clear so that the root canal system was visible with the naked eye. After clearing the samples, they were evaluated under a stereomicroscope (Zeiss Stemi 2000-C; Carl Zeiss Jena GmbH, Germany) at ×4 magnification. The number of root canals and the root canal system morphology based on Vertucci classification, the distance between the furcation and the root apex, the presence of lateral canals, and the prevalence of C-shaped canals were evaluated.

Data were analyzed by SPSS 16 software (SPSS Inc., Chicago, IL, USA) using McNamara, *t*-test, and Kappa coefficient. $P < 0.05$ was considered statistically significant.

RESULTS

The most frequent morphologies in both first and second premolars were Type I followed by Type V and IV [Table 1]. Only 2 teeth were detected as Type II and only 1 tooth was Type III by both techniques. Out of 7 Type IV cases reported by the clearing technique, 6 cases were confirmed by CBCT technique, one being of Type V. Out of 22 cases of Type V by clearing technique, only 7 cases were confirmed to be Type V by CBCT technique; however, 14 teeth were of Type I and one was of Type IV. Out of 182 teeth, 160 teeth (87%) were classified to be similar by both techniques (Kappa = 0.688) [Table 2, Figure 1a and b].

The prevalence rates of C-shaped morphology in first premolars using clearing and CBCT were 4.4% and 6.6%, respectively, and no C-shaped morphology found in second premolars [Table 3]. Four C-shaped root canal morphologies were detected by clearing technique, which were confirmed by CBCT. In addition, 2 other C-shaped morphologies were reported by CBCT technique (Kappa = 0.795).

The mean distances from the furcation to the root apex were 3.26 and 4.14 mm by clearing and CBCT techniques, respectively.

Overall, 25 teeth (13.7%) had lateral canals using clearing technique, and 9 teeth (4.9%) had lateral canals by CBCT technique (Kappa = 0.493).

Table 1: Prevalence of canal configurations by two techniques

Techniques	First premolar (%)					Second premolar (%)				
	I	II	III	IV	V	I	II	III	IV	V
Clearing	75.8	2.2	1.1	5.5	15.4	87.9	1.1	0	2.2	8.8
CBCT	81.3	3.3	1.1	5.5	8.8	92.3	0	2.2	2.2	3.3

CBCT: Cone beam computed tomography

Table 2: Crosstable between clearing and CBCT in determining root canal configuration type

Type	CBCT					
	Type I	Type II	Type III	Type IV	Type V	Total
Clearing						
Type I	144	1	1	0	3	149
Type II	0	2	1	0	0	3
Type III	0	0	1	0	0	1
Type IV	0	0	0	6	1	7
Type V	14	0	0	1	7	22
Total	158	3	3	7	11	182

CBCT: Cone beam computed tomography

Table 3: Prevalence of C-shaped morphology and lateral canals and correlation between the two techniques

Techniques	C-shaped		Lateral canal	
	First premolar (%)	Second premolar (%)	First premolar (%)	Second premolar (%)
Clearing	4.40	0	13.20	14.30
CBCT	6.60	0	5.50	4.40
Kappa	0.795		0.493	

CBCT: Cone beam computed tomography

DISCUSSION

Proper knowledge about the root canal morphology is necessary for successful root canal treatment. The clinician should always be aware that there may be two root canals in one root or two apical foramina in one root canal.[5] Therefore, it is necessary to evaluate the root canal morphologies among different populations.

Based on the results of the present study, 24% and 12% of the teeth in mandibular first and second premolars had morphologic types other than Type I, Type V being the most prevalent. In a study on an Iranian population, the prevalence of Type I (72%) was reported to be similar to the results of the present study, but in the second premolars, the prevalence of Type I was 75%, which was lower than the results of the present study.[22] The differences in the results

Figure 1: Images of same tooth using cone beam computed tomography and clearing technique depicting morphology, (a): Type V. (b) Type IV based on Vertucci[4] classification.

of the two studies might be attributed to differences in classifications made in these two studies as these teeth had long pulp chambers in some cases and it was difficult to make a distinction between Type IV and Type V.

In a study on first premolars of an Iranian population, Khedmat *et al.*[5] showed that only 59% of the teeth on radiography had more than one root canal, in which Types I, V, and III were more prevalent. Rahimi *et al.*[23] used clearing technique in the second premolars and showed that 89% of the teeth had one root canal. Moreover, in another report with a larger sample size, they indicated that 28% and 17% of the first and second premolars had two root canals, respectively.[24]

In addition, the results of the present study are consistent with those of a study by Cleghorn *et al.*[10] on first premolars. In that study, 24% of the teeth had more than one root canal. However, in relation to the second premolars, the prevalence rate was less than that of the present study, and 9% of the teeth had more than one root canal.[10] The differences between the results of the present study and other studies might be attributed to differences in the populations under study, the sample sizes, and the techniques used to evaluate the root canal system morphology.

No comprehensive study has been carried out to date on Iranian populations. Apparently, the present study showed a slightly higher prevalence rate for the teeth with more than one root canal. In particular, Type IV morphology in first premolars and Type V morphology in second premolars were more prevalent.

Rahimi *et al.*[24] reported the prevalence rates of 2.4% and 2% for C-shaped canals in the first and second premolars, respectively. In a study by Khedmat *et al.*,[5] the prevalence rate of C-shaped canals was 3%, which were diagnosed as Type III on radiographs. However, the prevalence was higher in the present study and the majority of these cases were diagnosed as Type V on radiographs.

The results of the present study are consistent with those of a study by Lu *et al.*,[6] in which the prevalence of C-shaped canals was 6% and these canals were detected at 3- and 6-mm distances from the apex. Lu reported that the morphology of these root canals was different from those in second molars and they were rarely found in the coronal area.

The prevalence of lateral canals in the second premolars in the study by Rahimi *et al.*[23] (38%) was higher than that of the present study. Vertucci[4] reported the prevalence rates of 13% and 25% for lateral canals in the first and second premolars, respectively. De Deus *et al.*[20] reported a prevalence rate of 27% for these root canals, predominantly in the apical area. Use of NaOCl in association with EDTA facilitates the flow of obturation materials into the lateral canals.[25]

C-shaped canals are easily diagnosed in the axial views of CBCT technique. The least agreement rate between these two techniques is related to the diagnosis of lateral canals. The Voxel size of the CBCT unit used was 100 μm, equal to the size of a #10 file; the lateral canals might be smaller than this size. Therefore, they were not diagnosed in many cases. Use of micro-CT might be useful in such cases.[25]

It is very difficult to completely debride Type V and C-shaped canals. In such cases, extending the access cavity in the buccolingual direction may produce a more straight access to the root canal system. In addition, extra flaring is recommended in the coronal and middle thirds. Use of a microscope, debridement with the use of sonic and ultrasonic devices and thermoplastic obturation technique are proper techniques to achieve positive results in the endodontic treatment of such complex cases.

CONCLUSION

The highest agreement rate between the two techniques for the diagnosis of root canal morphologies was related to Type IV, with the lowest in Type V. CBCT exhibited a higher accuracy than clearing technique in the diagnosis of C-shaped morphology. However, it exhibited a lower accuracy in diagnosis of lateral canals.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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