8-2019

Evaluation of the root and canal morphology of mandibular first permanent molars in a sample of Pakistani population by cone-beam computed tomography

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RESEARCH ARTICLE

Evaluation of the root and canal morphology of mandibular first permanent molars in a sample of Pakistani population by cone-beam computed tomography

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Abstract

Objective: To evaluate the root canal morphology of permanent mandibular first molars using Cone Beam Computed Tomography.

Methods: The retrospective study was done at Aga Khan University Hospital, Karachi, and comprised medical records of patients who visited the dental clinics from December 2016 to March 2017. Mandibular first permanent molars were evaluated on Cone Beam Computed Tomography images. Frequency distribution of Vertucci's classification was determined, and so was the association between Vertucci's classifications and gender. SPSS 20 was used for data analysis.

Results: A total of 142 mandibular first permanent molars were evaluated on 78 Cone Beam Computed Tomography images. The most common Vertucci's classification was Type IV for mesial root 86(60.56%) and Type I for distal root 63(44%). There was no difference in the two genders for root canal morphology ($p>0.05$).

Conclusions: Type IV Vertucci's were prevalent in the mesial root and Type I were common in the distal root of permanent mandibular first molars.

Keywords: Root canal, Endodontics, CBCT, Vertucci's classification. (JPMA 69: 1084; 2019)

Introduction

The successful outcome of an endodontic therapy depends on certain factors in which the most important is root canal preparation.[1] One of the most common causes of root canal failure is inadequate debridement of root canal space, leaving pulp tissue remnants, microorganisms or their byproducts in the canal space. The remnants act as foci of infection, resulting in post-treatment disease.[2] For better treatment outcomes, it is essential for a clinician to have a detailed knowledge of the basic root and canal morphology or its morphological variants.[3,4] There are many factors responsible for root canal variations such as ethnicity,[5] gender[6] or the assessment method[7] used for its evaluation.

In the oral cavity, mandibular molars are the first permanent teeth to erupt and are the most common teeth that require endodontic treatment because of early caries.[5] Variability in the root canal morphology exists among different races.[6] Root canal morphology of mandibular first molar has been extensively studied among various population groups and their results demonstrate that it exhibits diverse morphologic variations.[8-13] Gu et al.[8] studied root canal anatomy in Chinese population and reported that the most common root canal configuration in the root was Type IV (64.4%) followed by Type II (11.1%). However, Zaatar et al.[9] reported in Kuwaiti population that the most common was Type II (56.5%) followed by Type IV (42.9%). Wasti et al.[10] found that Type IV (66.7%) was the most frequent canal morphology found in the mesial root of Pakistani population, followed by Type II (23.3%), and so did Faraz et al.[11] who observed Type IV (70.7%) and Type II (26.8%), respectively.

Regarding distal root canal morphology, Rwenyonyi et al.[12] reported in Ugandan population the frequency of Type 1 (84.8%), Type IV (9.4%) and Type II (1.3%). However, Ahmed et al.,[13] in Sudanese population reported the frequency of Type I (38%) followed by Type II (28%) and Type IV (22%). Wasti et al.[10] reported in Pakistani population frequency of Type I (30%), Type II (26.7%) and Type IV (20%). Faraz et al.[11] reported higher frequency of Type I (65.8%), Type IV (19.5%) and Type II (14.6%). Hence, variations in canal morphology exist among various population groups.

Various methods have been reported in literature for the evaluation of root canal anatomy. These include canal staining and clearing technique,[14,15] conventional and digital radiography,[16] clinical operating microscopy[17] and radiographic assessment enhanced with contrast medium.[18] Conventional or digital periapical radiographs are most commonly used for evaluation of canal morphology before and during the treatment.

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Nevertheless, due to inherent limitations, like overlapping of anatomical structures and distortions like elongation or shortening etc.,[19] these radiographs have limited diagnostic value. Cone Beam Computed Tomography (CBCT) was introduced in dentistry a few years ago and is considered an effective diagnostic modality as it provides three-dimensional (3D) information and is accepted as the most reliable in vivo method for visualising canal morphology in endodontics.[19,20] CBCT provides clinicians an opportunity to visualise root canal anatomy not only in cross-sectional, sagittal and coronal planes, but also in oblique planes. Provision of images in three different planes eliminates the overlap of anatomical structure, hence increasing the diagnostic accuracy. It helps clinicians in visualising the exact number of root canals and their convergence and divergence with precision.[19-22] These advantages enable clinicians to perform effective endodontic treatment with reduced chance of failure.[20,22]

Plenty of studies have been published on permanent mandibular first molar root canal anatomy among various population groups using CBCT.[21,22] In local literature, so far only two studies have been published on root canal morphology of these teeth.[10,11] However, none of the studies used CBCT as an assessment tool. The current study was planned to evaluate the root canal morphology of permanent mandibular first molars using CBCT.

Material and Methods

The retrospective study was conducted at the Aga Khan University Hospital (AKUH), Karachi, and comprised medical records of patients who visited the dental clinics between December 2016 and March 2017. After exemption was obtained from the institutional ethics review board, permanent mandibular first molars were evaluated on CBCT scans Using non-probability consecutive sampling technique. World Health Organisation (WHO) sample size calculator[23] was used. With prior knowledge,[24] it was assumed that 38% of the distal roots of mandibular first molars have Vertucci's Class I canal morphology. Taking this population proportion with 8% absolute precision at 95% confidence level, the sample size needed for the study was calculated.

CBCT scans having permanent mandibular first molars both males and females of Pakistani origin aged 16-60 years and mature roots with no root canal fillings were included. Scans with periapical pathology, indirect restorations and blurred images were excluded.

CBCT scans were obtained using Sirona Dental system (D-64625 Bensheim, Germany). The voltage was kept at 85 KVp and current was 7mAs. Three-dimensional scans in each plane were studied using GALAXIS version 1.9 (SICAT GmbH & Co. KG, Bonn, Germany) on a 10-inch monitor.

SPSS 20 was used for data analysis. Vertucci's classification[25] was used for categorising different canal types. Chi-square test or Fisher's exact test, as needed, were used to determine any association between gender and canal type. $P<0.05$ was taken as statistically significant.

Results

A total of 142 mandibular first permanent molars were evaluated on 78 CBCT images. Of them, 80(56.3%) belonged to males and 62(43.7%) belonged to females. In

Table-1: Frequency distribution of Vertucci's classification and number of apical foramina in the mesial and distal roots of mandibular first molar.

Canal Morphology	Mesial root				Distal root			
	Gender		Total n (%)	p-value	Gender		Total n (%)	p-value
	Male n (%)	Female n (%)			Male n (%)	Female n (%)		
Type I (1)				0.091	36 (25.2)	27 (18.9)	63 (44.1)	0.095
Type II (2-1)	24 (16.9)	20 (14.1)	44 (31)		17 (11.9)	15 (10.5)	32 (22.4)	
Type III (1-2-1)					4 (2.8)	10 (7)	14 (9.8)	
Type IV (2)	50 (35.2)	36 (25.4)	86 (60.6)		11 (7.7)	7 (5)	18 (12.6)	
Type V (1-2)					8 (5.6)	2 (1.4)	10 (7)	
Type VI (2-1-2)		4 (2.8)	4 (2.8)		3 (2.1)		3 (2.1)	
Type VII (1-2-1-2)					2 (1.4)		2 (1.4)	
Others	6 (4.2)	2 (1.4)	8 (5.6)			1 (0.7)	1 (0.7)	
Total	80 (56.4)	62 (43.6)	142		81 (56.6)	62 (43.4)	143	
	Number of apical foramina				Number of apical foramina			
One	44 (31)				110(76.8)			
Two	96 (67.6)				33 (23.2)			
Three	2 (1.4)							
Total	142				143			

* Chi- square test (Fisher's exact test) was applied at 5% level of significance.

terms of Vertucci's classification, Type IV 86(60.56%) and Type II 44(30.99%) were most frequent in mesial root. The two genders did not differ significantly for mesial root anatomy (p =0.09). Since one of the specimens had two distal roots, we had a total of 143 distal roots. The most frequent Vertucci's types in distal roots were Type I 63(44%) followed by Type II 32(22.3%). The anatomy of the distal root did not differ between the genders (p =0.09).

Table-1 also shows frequency of the apical foramen in the mesial and distal roots of mandibular first molars. Two apical foraminas were common in the mesial root 96(67.6%) followed by single apical foramen 44(31%) and three apical foramina 2(1.4%), respectively. In the distal root, the frequency of one and two apical foramina were 110(76.7%) and 33(23.2%) respectively (Table-1).

Discussion

The outcome of root canal treatment becomes predictable only if all the root canals are identified, adequately cleaned and filled-in 3D. Inadequate removal of pulpal tissue remnants, microorganism or their by-products can act as the foci of infection and cause eventual failure.[2] Hence, it is imperative that a clinician should be well aware of the canal morphology of a particular tooth, its variations along with typical features of different ethnicities, as this knowledge will aid in achieving favourable treatment outcomes. The chance of having a procedural error is higher in teeth with atypical root canal morphology. These errors includes perforation, ledge formation, canal perforation and apical zipping etc.[2,26]

A CBCT scan allows a clinician to visualise tooth anatomy in three anatomical planes i.e. sagittal, axial and coronal. All these planes can be viewed in thin slices, increasing its accuracy for the detection of small changes in the canal anatomy and the surrounding peri-apical tissues which were previously impossible.[27] In a CBCT software, several tools are available which makes it possible to provide images in an oblique plane, hence increasing its precision. Moreover, options such as contrast and brightness alteration are available that help to enhance the image quality. Similarly, tools are available that can help to decipher the nerves at the tooth apex with high precision. Therefore, CBCT can be considered one of the most valuable tools in dentistry.[27,28]

Quite a few studies have reported the number of apical foramina in the mesial and distal roots of lower first molars (Table-2). In our sample, two apical foramina were common in the mesial root whereas distal root had predominately one apical foramina. These results were comparable to those reported by Chen et al.[29] (68.3%) in Chinese population. Our results were also comparable to those reported in Pakistani population by Wasti et al.[10] (73.3%) and Faraz et al.[11] (73.1%). However, the high frequency of two apical foramina is reported by Wang et al.[21] i.e. 95.8% and the lowest frequency is reported by

Table-2: Frequency of number of apical foramina (%) in mesial and distal roots of mandibular first molars as reported in the literature.

Author/year/ sample size	Method	Mesial root				Distal root			
		One (%)	Two (%)	Three (%)	Other (%)	One (%)	Two (%)	Three (%)	Other (%)
Skidmore & Bjorndahl /1971 /45[3]	In vitro (Plastic cast)	40	60			88.9	9.1		
Vertucci et al. /1984 / 100[39]	Clearing method)	40	59	1		85	15		
Caliskanet al./ 1995 /100[40]	Clearing method	39	57.6	3.4					
Zaatar et al. / 1997 / 49[9]	In vivo (PA)	57.1	42.9			83.7	16.3		
Al-Nazhan et al. /1999 / 251[34]	In vivo (PA)	52.6	47.4			77.3	22.7		
Wasti et al.2001 /30[10]	Clearing method	23.3	73.3			56.7	43.3		
Gulavibala et al. /2002/ 118[32]	Clearing method	35.6	60.2	3.4		77	17.8	5.2	
Chen et al. / 2009 / 183[29]	Clearing method	31.7	68.3			67.2	32.8		
Rwenyonyi et al. /2009 / 224[12]	Clearing method	46.9	56.1			87.1	12.9		
Al-Qudah & Awawdeh/2009/ 330[33]	Clearing method	39.1	58.5	2.4		77	22.1	0.9	
Wang et al./ 2010 / 410[21]	CBCT	4.2	95.8			98.6	1.4		
Chourasia et al. 2012 / 150[30]	Clearing method	62.6	37.4			87.4	12.6		
Mukhaimer et al. /2014/320[41]	CBCT	42.5	57.5			90.6	9.4		
Faraz et al./ 2015/ 123[11]	Clearing method	26.9	73.1			80.5	19.5		
Estrela et al./ 2015 / 100[31]	CBCT		36	49	15	5	54	40	1
Akhlaghi et al. / 2017/ 150[37]	Clearing method	44.6	55.4			89.9	10.1		
Present study/ 2017/ 142	CBCT	67.3	31	1.4		76.8	23.2		

CBCT: Cone Beam Computed Tomography.

Table-3: Root canal configuration in mesial root of mandibular first molars according to various population groups.

Author/year/ sample size	Population	Method	Type II (%)	Type IV (%)	Type VIII (%)	Others (%)
Skidmore &Bjorndahl /1971 /45[3]	Caucasian	Clearing method	33.3	60		6.7
Vertucci et al. /1984 / 100[39]	N/A	In vivo (PA)	28	43	1	28
Caliskan et al./ 1995 /100[40]	Turkish	Clearing method	37.3	44.1	3.4	15.2
Zaatar et al. / 1997 / 49[9]	Kuwait	In vivo (PA))	56.5	42.9		0.9
Al-Nazhan et al. /1999 / 251[34]	Saudian	In vivo (PA)	52.6	47.4		
Wasti et al. 2001 /30[10]	Pakistani	Clearing method	23.3	66.7		
Sperber and Moreau/ 1998 / 480[35]	Senelgese	Invitro (sections)	16	84		
Gulavibala et al. /2001/ 139[36]	Burmese	Clearing method	23.3	66.7	3.3	7.7
Gulavibala et al. /2002/ 118[32]	Thai	Clearing method	28.8	38.1	0.7	32.4
Ahmed et al. / 2007/ 100[13]	Sudanese	Clearing method	14	73	2	11
Chen et al. / 2009 / 183[29]	Taiwenese	Clearing method	29.5	55.2	5.5	9.8
Rwenyonyi et al. /2009 / 224[12]	Ugandian	Clearing method	13.8	44.6	0	41.6
Al-Qudah & Awawdeh/2009/ 330[33]	Jordanian	Clearing method	36	52.7	0.3	11
Gu et al. / 2010 / 45[8]	Chinese	Invitro (mCT)	11.1	64.4	2.2	28.3
Wang et al. / 2010 / 410[21]	Chinese	CBCT	1.7	93.9	0.2	4.2
Chourasia et al. / 2012 / 150[30]	Indian	Clearing method	36.6	54		9.4
Mukhaimer et al. /2014/320[41]	Palestinian	CBCT	38.8	53.8		7.4
Nuret al./ 2014/ 966[38]	Turkish	CBCT	1	89	0.2	9.8
Faraz et al.2015/ 123[11]	Pakistani	Clearing method	26.8	70.7		2.5
Akhlaghi et al. / 2017/ 150[37]	Irani	Clearing method	41.3	55.3		
Present study/ 2017/ 142	CBCT	CBCT	60.56	30.99		8.45

CBCT: Cone Beam Computed Tomography
N/A: Not Applicable
PA: Periapical Radiograph
mCT: Micro Computed Tomography

Chourasia et al.[30] i.e. 37.4%. Estrela et al.[31] reported that the occurrence of three apical foraminas (49%) was highest in the mesial root followed by two (36%) and four (15%), but none of their subjects had single apical foramina.

In our sample, the frequency of single apical foramen was highest in the distal root (76.76%) followed by two foramina (23.24%). Regarding the frequency of the single apical foramen, our results were in agreement with those reported by Gulavibala et al.[32] (77%), Al-Qudah & Awwadeh[33] (77%) and Al Nazhan et al.[34] (77.3%). Our results were also comparable with those reported by Faraz et al.[11] (80.5%). However, Estrela et al.[31] reported that the prevalence of two apical foramina (54%) was highest in the distal root followed by three (40%) and one (5%).

Literature has quite a few studies evaluating root canal configuration in mesial root of mandibular first molars according to various population groups (Table-3). The most common types reported for mesial roots are Type IV and Type II.[3,10-12,29,30,32] In the current study, the highest frequency was of Type IV (60.5%) followed by Type II (30.9%) and Type V (2.8%). Our results were comparable to those reported by Skidmore and Bjorndahl[3] (Type IV: 60%) and by Gu et al.[8] (Type IVL 64.6%). These results were also comparable to those reported in Pakistani sub-population by Wasti et al.[10] (Type IV: 66.7%). Exception to these findings was reported by Al-Nazhan et al.[34] and Zaatar et al,[9] with Type II being the most frequent finding (52.6% and 56.5%, respectively). The high frequencies of Type IV (93.9% and 84%) were reported by Wang et al.[21] and Sperber and Moreau.[35] Moreover, we found canal types other than the Vertucci's eight types.[24] The frequency of such additional canal types reported in our sample was 5.63%. Out of 142, 5 mesial roots had 3-2 configuration which is Type XII, two roots had 2-3 configuration classified as Type XIII by Gulavibala et al.[36] and, 1 mesial root had 2-3-2 configuration categorised as Type XXI by Al-Qudah and Awwadeh.[33] It is often easy for a clinician to debride and obturate Type II and Type IV. However, presence of additional canal types requires substantial effort and manual dexterity. Failure to disinfect such a root canal system poses a challenge and may affect the outcome of the treatment.

Root canal configuration in distal root of mandibular first molars has also been studied frequently (Table-4). Of the 142 mandibular first molars in the current study, 1 tooth had two distal roots which means a total of 143 distal roots. The most common canal configuration reported for

Table-4: Root canal configuration in distal root of mandibular first molars according to various population groups.

Author/year/ sample size	Population	Method	Type I (%)	Type II (%)	Type IV (%)	Others (%)
Skidmore & Bjorndahl /1971 /45[3]	Caucasian	Clearing method	71.1	17.8	8.9	2.2
Vertucciet al. /1984 / 100[39]	N/A	In vivo (PA)	70	15	5	10
Zaatar et al. / 1997 / 49[9]	Kuwait	In vivo (PA))	70.7	12.9	16.4	
Al-Nazhan et al. /1999 / 251[34]	Saudian	In vivo (PA)	42.2	35.1	22.7	
Wasti et al. 2001 /30[10]	Pakistani	Clearing method	30	26.7	20	23.3
Gulavibala et al. /2001/ 139[36]	Burmese	Clearing method	66.2	15.8	10.1	7.9
Gulavibala et al. /2002/ 118[32]	Thai	Clearing method	61	4.2	15.3	19.5
Ahmed et al. / 2007/ 100[13]	Sudanese	Clearing method	38	28	22	12
Chen et al. / 2009 / 183[29]	Taiwenese	Clearing method	54.1	12.6	25.1	8.2
Rwenyonyi et al. /2009 / 224[12]	Ugandian	Clearing method	84.8	1.3	9.4	4.5
Al-Qudah & Awawdeh/2009/ 330[33]	Jordanian	Clearing method	54.2	17	9.4	19.4
Gu et al. / 2010 / 45[8]	Chinese	Invitro (mCT)	82.2	2.2	2.2	13.4
Wang et al. / 2010 / 410[21]	Chinese	CBCT	62.9	9.7	25.1	2.3
Chourasia et al. / 2012 / 150[30]	Indian	Clearing method	65.3	20.6	9.3	4.8
Mukhaimer et al. /2014/320[41]	Palestinian	CBCT	57.5	22.5	8.1	11.9
Nur et al./ 2014/ 966[38]	Turkish	CBCT	60	14	20	6
Faraz et al.2015/ 123[11]	Pakistani	Clearing method	66	14.5	19.5	
Akhlaghi et al. / 2017/ 150[37]	Irani	Clearing method	61.3	26.6	9.4	
Present study/ 2017/ 142	CBCT	CBCT	44.06	22.38	12.59	

CBCT: Cone Beam Computed Tomography.

distal root was Type I (44.0%) followed by Type II (22.3%), Type IV (12.5%), Type III (9.7%), Type V (6.9%), Type VI (2.1%) and Type VII (1.4%). One distal root had additional canal configuration i.e. 2-3-2, categorised as type XXI.[33] The predominance of Vertucci's Type I observed in our sample is similar to the findings reported by other studies ranging between 54% and 82%.[3,8,11,12,21,29,30,32-34,36-38] Our frequency was similar to that reported by Al-Nazhan et al.[34] (Type I: 42.2%) and Ahmed et al.[13] (Type I: 38%). In distal root, the frequency of Type I reported by Wasti et al.[10] in sub-Pakistan population was 30%, which shows that prevalence of Type I is variable.

In the light of our findings, CBCT is a valuable tool for evaluating canal morphology. However, it does not replace the peri-apical radiograph for diagnosis and management in daily endodontic practice. The use of CBCT should be reserved in cases where its benefits outweigh the harm from additional radiation exposure. Scenarios such as abnormal or complex canal morphology warrants use of CBCT for precise determination of the pulp anatomy, canal orifices location and canal configuration. It can help in the detection of additional canal types, hence improving the outcome of endodontic treatment.

To our knowledge, the current study is the first on canal morphology done in a Pakistani sub-population using CBCT. It identified canal morphology of permanent mandibular first molar and its variants which can be applied to endodontic practice to improve the quality of care and reduce the failures. The primary limitation of the present study is that the images were assessed by a single at a single centre. We recommend a larger sample size and in other populations which are poorly studied.

Conclusion

In a sample of Pakistani subjects visiting university dental clinics for the treatment of permanent mandibular first molars, Type IV Vertucci's was the most frequent canal configuration in the mesial root whereas Type I was the most prevalent in the distal root. There was no difference in terms of gender for root canal morphology.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

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