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AN EVALUATION OF MAXILLARY MOLARS ROOT CANAL MORPHOLOGY USING CONE-BEAM COMPUTED TOMOGRAPHY IN AN EGYPTIAN SUBPOPULATION

Marwa El-Sayed Sharaan* *and* Ahmad Mohamad Elrawdy**

ABSTRACT

Introduction: The aim of this study was to assess the root canal anatomy of maxillary permanent molars using cone beam computed tomography (CBCT), in an Egyptian Ismailia population.

Methods: Four hundred and thirty two maxillary molars were included in this study. CBCT scans were evaluated by an oral radiologist and an endodontist. Root morphology and number as well as root canal number were evaluated. Root canal configurations were classified according to Vertucci's method. Gender and bilateral symmetry were recorded. For root canal configurations, gender and bilateral sides, Pearson's chi-square test was used ($P \leq 0.05$).

Results: The 216 maxillary first (1st) molars that were included demonstrated only 3 roots configuration. On the other hand, 216 maxillary second (2nd) molars displayed wide variety of root configuration. The most common was 3 followed by 2 and the least single root configuration . Regarding maxillary 1st molars, the highest frequency of Vertucci's classification for the mesiobuccal root (MBR) were type II (82.4%), type IV (6.48%), type I (9.72%) and type III (1.39%). For the distobuccal root (DBR), the most common of Vertucci's classification were type I (98.15%) and type II (1.85%). Regarding maxillary 2nd molars, the highest frequency of Vertucci's classification for the MBR were type II (55.09%), type I (38.9%), type IV (3.70%) and type III (2.31%). For the DBR , the most common of Vertucci's classification were type I (99%) and type II (0.01%). Incase of 2 roots, 1.4%, 1.9% had Type I for the buccal and palatal roots respectively. Additionally, type II was found in 0.5% of the cases. For one root, only one case (0.5%) was found had Type I. No anatomic variation was found for palatal roots for maxillary 1st and 2nd molars. Although, there was significant difference between females and males in most of the cases, the frequency of having 2nd canal in the MBR is comparable in both genders. There was no statistical difference between both sides. C-shaped canals were noticed in maxillary molars. Bilateral symmetry was displayed.

Conclusion: Pre-assessment of the maxillary molars using CBCT imaging provides clear data for the root canal morphology that might increase the prognosis of the root canal treatment.

* Lecturer in Endodontics, College of Dentistry, Suez Canal University.
** Lecturer in Oral Radiology, College of Dentistry, Suez Canal University.

INTRODUCTION

Successful root canal treatment depends mainly on complete cleaning and shaping of all pulp spaces and hermetic seal by thorough obturation. It is crucial that operators should be acquainted by the common root canals (R.C) morphology and their variations [1,2]. R.C morphology varies from population to another. To study R.C morphology in various populations; several techniques are used, such as dye penetration, sectioning, clearing, pre- and post-operative radiographs, micro-computed tomography (μ CT) and CBCT [1-3]. In 1990, CBCT was introduced in the field of Endodontics. [3] Comparing CBCT, clinical and ex vivo to evaluate the internal morphology of maxillary 1st molars, they found that CBCT was an efficient tool. Because of the complex root canal anatomy of the maxillary molars , several studies have been tried to assess the common anatomy and its variation[1-6] . According to literature most of the maxillary molars have demonstrated 3 roots. However, few of them displayed some anatomical variation. [4-7] Kottoor et al. [7] presented a maxillary 1st molar that had 3 roots with 7 root canals: 3 in the MBR, 2 in the DBR and 2 in the PR. Studies for the Egyptian population is very minimal, only one recent study was published this year [8]. Additionally, there is no published study on the R.C anatomy of maxillary molars in the Egyptian Ismailia population. Hence, the goal of this study was to evaluate the root canal anatomy of the maxillary molars in this sub population using CBCT.

PATIENTS AND METHODS

The present retrospective study was performed on the CBCT records obtained from the archives of the outpatient clinic of the Oral Radiology Department, College of Dentistry, Suez Canal University. Out of respect for patient confidentiality, all personal information concerning the patients other than gender and age was hidden. CBCT images of maxillary molars were obtained during the period January 2015 to July 2017. The study was conducted on 108 CBCT scans of bilateral maxillary sides (432 maxillary first and second molar teeth) of both genders and ranging in age from 15 to 49 years. The CBCT scans included in the present study had to reveal the entire region of the maxillary molar teeth and be high quality images free from artifacts caused by metallic objects that may impair pulp chamber visualization. Inclusion criteria also included: absence of extracted maxillary 1st and 2nd molars: with fully matured apices and without apical periodontitis and no root canal fillings, posts, or full-crown restorations.

CBCT scanning protocol:

All CBCT scans used in the present study were obtained using the Scanora 3D imaging system (Sordex, Helsinki. Finland) using a CMOS flat panel detector with isotropic voxel size 133 μm,. The x-ray tube used to scan the patients possess a current intensity 10 mA, 90 Kvp and a focal spot size 0.5mm. The scanning time was 10 seconds of pulsed exposure resulting in an effective exposure time of 2.4 seconds to scan FOV (field of view) of 14 cm height ×16.5 cm width. FOV adjustment was guided by three laser light beams to centralize the area of interest within the scanning field. The primary reconstruction time for DICOM data set was 2 minutes. Then, the raw DICOM data set images were imported to the On-Demand software (Cybermed, Seoul, Korea) for secondary reconstruction.

Image analysis and assessment of the root and root canals of maxillary 1st and 2nd molars:

Serial axial, coronal, and sagittal CBCT images were acquired by an experienced radiologist according to the operation instructions. Reformatted images were examined by carefully rolling the

toolbar from the pulp chamber to the apex. All the images were assessed by a radiologist and an endodontist, and any disagreement between them was discussed until a consensus was reached. The number and configuration of the roots, the number of root canals, the root canal configurations according to Vertucci's classification, the incidence of extra canals in the MBR, DBR and the PR (**Figure 1**). The frequency of C-shaped R.C and symmetry in the number of R.C between adjacent and contralateral molars were also determined. The examiners assessed the images twice, then a week interval between the two evaluations. Statistical analysis was performed using Statistical Package for the Social Sciences software SPSS version 20 (Armonk, NY: IBM Corp, USA). The relationship between the patients' gender or the sides and the molar configuration was determined using the Pearson's Chi-square test. The level of significance was at 0.05 ($p \leq 0.05$). The incidence of additional canals was determined by frequency.

RESULTS

CBCT examination of maxillary 1st and 2nd molars were done for 432 patients, having 63.9% women and 36.1% men (69 females and 39 males).

Root and root canal configuration:

CBCT assessment of 216 maxillary 1st molars revealed neither single nor 2 rooted, the 216 teeth had 3 roots. The number of R.C in maxillary 1st was 3 in 10.1% of the female patients on the right side. One case (2.57%) of the male patients on the right side, 13 % of the female patients on the left side, 5.14% of the male patients on the left side. Four R.C were found in 89.9% of the female patients on the right side, 92.30% of the male patients on the right side, 87 % of the female patients on the left side, 89.72% of the male patients on the left side. Both 5 and C-shaped canals were noticed in one case (2.57%) per each side and gender. Of the 216 maxillary 2nd molars, there was one case (1.45%) single-rooted for the females on the right side, none for the males and on the other side for both gender. For the maxillary 2nd molars that had 2 roots, one case had 2 root canals in 1.4% , 2.6% of the female and male patients on the right side respectively, 1.4% of the female patients on the left side. Moreover, one case was represented by 3 canals in 2 rooted maxillary 2nd molars on the left side. For 3 rooted maxillary 2nd molars, regarding the number of canals, those having 3 canals, there were 25.6% for the male patients on the right side, 37.68 % for the females. For the left side, 28.2% for males and 42% for females. Those having 4 canals, there were 66.67% for the male patients on the right side, 59.42% for the females. For the left side, 61.5 % and 55 % for males and females respectively. None of the females having maxillary 2nd molars on both sides had 5 canals. On the contrary, there was only one case (2.6%) for the males on both sides. C-shaped canals were noticed in one case (2.56%) for males on the right side, whereas 7.7% of the males had C shaped canals on the right side. Using Pearson's Chi-square, there was statistically significance between females and males on both sides for the maxillary 1st molars ($p < 0.05$) **(Table 1)**. Statistically significance was found only between females and males on the left side only for the maxillary 2nd molars ($p < 0.05$) (**Table 2**). Although, there was significant difference between females and males in most of the cases, the frequency of having 2nd canal in the mesiobuccal root is comparable. The frequency of the number of root canals of the maxillary 1st and 2nd molars did not differ significantly between right and left sides ($p > 0.05$).

TABLE (1) Root and root canal configuration of maxillary 1st molars

Molar configuration		Right side n(108)		Left side n (108)	
	No. of root canals	**Male (39) n (%)**	**Female (69) n (%)**	**Male (39) n (%)**	**Female (69) n (%)**
3 roots, MB,DB,P	**3 canal**	1 (2.57)	7 (10.1)	2 (5.14)	9 (13)
	4 canal	36 (92.30)	62 (89.9)	35(89.72)	60 (87)
	5 canal	1 (2.57)	0(0)	1 (2.57)	0(0)
2 roots, BR,PR	**2 canal**	0(0)	0(0)	0(0)	0(0)
	3 canal	0(0)	0(0)	0(0)	0(0)
single-root	**conical**	0(0)	0(0)	0(0)	0(0)
c.shaped		1(2.57)	0(0)	1 (2.57)	0(0)
p- value (0.05) for male and female for each side		**0.006***		**0.007***	
p- value (0.05) for right and left side		**0.91 N.S**		**0.91** N.S	

MBR: Mesiobuccal root,DBR: Distobuccal root,PR: Palatal root **** statistically significant***

N.S: statistically not- significant

TABLE (2) Root and root canal configuration of maxillary 2nd molars

Molar configuration		Right (108)		Left (108)	
	Canal	**Male (39) n (%)**	**Female (69) n (%)**	**Male (39) n (%)**	**Female (69) n (%)**
3 root, MBR,DBR,PR	**3 canal**	10(25.64)	26(37.68)	11(28.2)	29(42)
	4 canal	26(66.67)	41(59.42)	24(61.5)	38(55)
	5 canal	1(2.56)	0(0)	1(2.6)	0(0)
2 root, BR,PR	**2 canal**	1(2.56)	1(1.45)	0(0)	1(1.4)
	3 canal	0(0)	0(0)	0(0)	1(1.4)
single-root	**conical**	0(0)	1(1.45)	0(0)	0(0)
C-shaped		1(2.56)	0(0)	3(7.7)	0(0)
p- value (0.05) for male and female for each side		**0.35 N.S**		**0.043***	
p- value (0.05) for right and left side		**0.71 N.S**			

MBR: Mesiobuccal root,DBR: Distobuccal root,PR: Palatal root **** statistically significant***

N.S: statistically not- significant

Frequency of root canal type:

For the maxillary 1st molars, 21 (9.72%) MBR with a Type I R.C morphology, whereas there were 178 ones (82.4%) with a Type II R.C morphology. Fourteen (6.48%) MBR of teeth had a Type IV R.C morphology. Only 3 (1.39%) of the MBR had Type III R.C morphology. Two hundred and twelve (98.15%) of the DBR with a Type I R.C morphology, whereas there were 4 (1.85%) with a Type II R.C morphology. All the palatal roots (216; 100%) had Type I R.C morphology (**Table 3**). Regarding the maxillary 2nd molars with 3 roots , 84 (38.9%) MBR with a Type I R.C morphology, whereas there were 119 ones (55.09%) with a Type II R.C morphology. Eight (3.70%) MBRs of teeth had a Type IV R.C morphology. Only five (2.31%) of the MBR had Type III R.C morphology. Two hundred and thirteen (99%) of the DBR with a Type I R.C morphology, whereas there were 3 (0.01%) with a Type II R.C morphology. All the palatal roots (216; 100%) had a Type I R.C morphology. For the 2 rooted , 1.4%, 1.9% had a Type I R.C morphology for the buccal and palatal roots respectively. Additionally, type II R.C morphology was found in 0.5% of the cases. In case of one root, only one case (0.5%) was found had Type I (**Table 4**).

TABLE (3) Frequency of root canal type of maxillary 1st molars

First molar n (216)							
Molar configuration	**Root**	**Type I**	**Type II**	**Type III**	**Type IV**	**Type V**	**Type VI**
3 -root	MBR	21(9.72)	178(82.4)	3(1.39)	14(6.48)	0(0)	0(0)
	DBR	212(98.15)	4(1.85)	0(0)	0(0)	0(0)	0(0)
	PR	216(100)	0(0)	0(0)	0(0)	0(0)	0(0)
2-root	BR	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
	PR	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Single root		0(0)	0(0)	0(0)	0(0)	0(0)	0(0)

TABLE (4) Frequency of root canal type of maxillary 2nd molars

Second molar n (216)							
Molar configuration	**Root**	**Type I**	**Type II**	**Type III**	**Type IV**	**Type V**	**Type VI**
3 -root	MBR	84(38.9)	119 (55.09)	5(2.31)	8(3.70)	0(0)	0(0)
	DBR	213(99)	3(0.01)	0(0)	0(0)	0(0)	0(0)
	PR	216(100)	0(0)	0(0)	0(0)	0(0)	0(0)
2-root	BR	3(1.4)	1(0.5)	0(0)	0(0)	0(0)	0(0)
	PR	4(1.9)	0(0)	0(0)	0(0)	0(0)	0(0)
Single root		1(0.5)	0(0)	0(0)	0(0)	0(0)	0(0)

MBR: Mesiobuccal root, DBR: Distobuccal root, PR: Palatal root

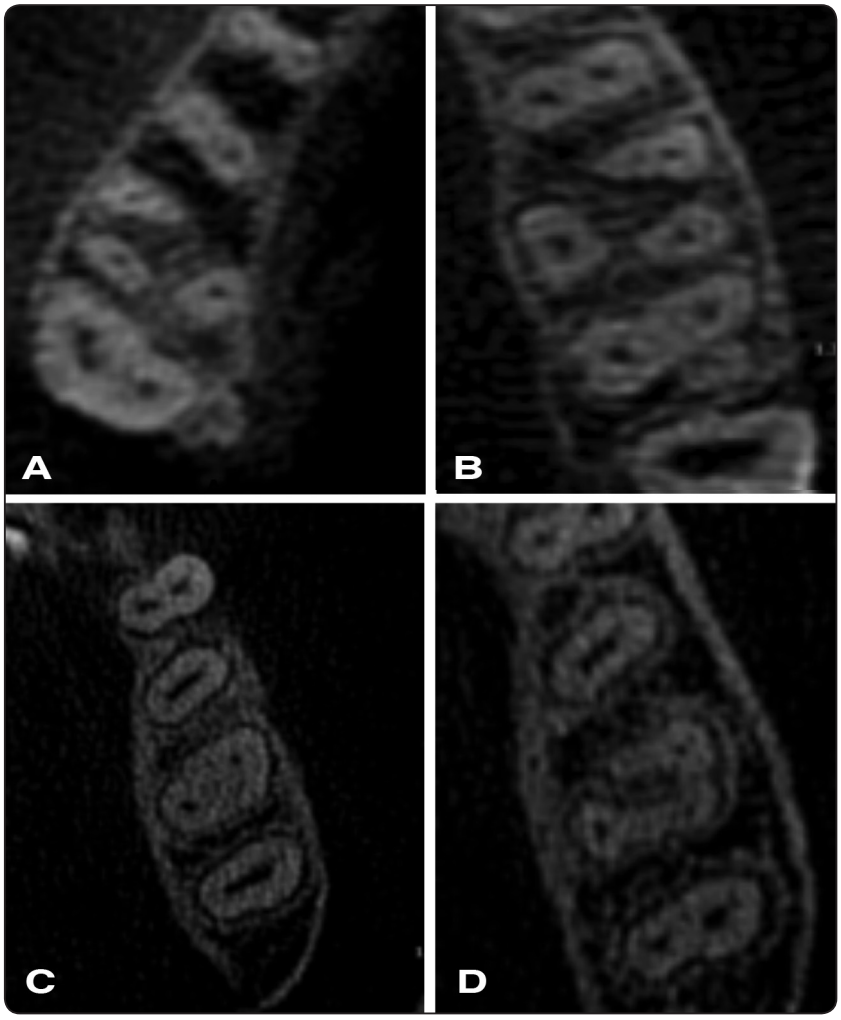

Fig. (1) Axial CBCT imaging displaying (A) 3 R.C for maxillary 2nd molar (B) 4 R.C for maxillary 1s molar (C) 5 R.C for maxillary 1st molar and 1 R.C for maxillary 2nd molar (D) C-shaped R.C for maxillary 1st and 2 R.C for 2nd molar.

DISCUSSION

Primary objective of the present retrospective study was to assess the R.C anatomy of the maxillary molars in addition to the frequency of extra canals in the Egyptian Ismailia subpopulation using CBCT. Several techniques were implicated to study root canal anatomy. For example, demineralization and staining techniques were well documented for their accuracy [2,9-11]. μCT utilizes an accurate and reliable image of the root canal morphology. But, some of the previously mentioned techniques are in vitro, so the sample size will be limited. Additionally, the contralateral evaluation in the same time might be inapplicable. Comparing CBCT to μCT imaging, both lower radiation dose and cost are of great advantages of CBCT over μCT. It was proved the CBCT demonstrated high accuracy which is comparable to canal staining and clearing techniques [12,13]. In spite of the development of many classifications, Vertucci's remains the gold standard that is widely used whenever there is a description and comparison of root canal morphology [2,5,9,14,15]. The findings displayed in the study showed that 100% of the maxillary first molars have 3 roots is in agreement with other studies carried out in Thai, Kuwaiti, Burmese and recently, Egyptian populations[6,8,14,16]. On the other hand, other populations such as Turkish, Indian, Chinese, Brazilian and Irish found some other variation than 3 separate roots[4,12, 17-19]. Variations in ethnicity might be the cause for the differences in root canal anatomy[4]. Our results were similar to those in several other studies

previously where maxillary 1st molars had 3 roots and 4 R.C [4,6,9,12,17,18,20-24].

We found high frequency (89.35%) of an extra R.C in the MBR which is greatly in agreement with observations from Turkey (93.5%)[9], Ireland (80.4%)[18], Italy (80%) [22] and Korea (71.7%).[23]. However, other investigations showed lower frequencies such as ; 2 CBCT Chinese studies(52.24% and 52%) [4, 17], Indian (48.2%)[12] and Iranian (53.6%)[24]. These dissimilarities might be because of the different methodology, population size and/or the regional population variety. Another possible explanation is the variation in interpretation of images and CBCT resolution. In our study, we found Type II, I, IV,I II R.C anatomy for MBR (82.4 %, 9.72%,6.48%, 1.39% respectively). These findings were in accordance with others [1,2,8,9, 14,16,17,19, 24]. Additionally PR did not show any variations in the R.C anatomy, which was displayed in many studies [1,2,8,9, 14,16,17,19, 24]. There were little variations in extra R.C in the DBR of the maxillary 1st molars, where we found Type I R.C in 98.15 % and Type II R.C in 1.85 % of the cases. These observations were in an agreement with previous reports [4-6,18,25] that demonstrated little deviation other than Type I R.C in this root. However, in an Egyptian study, Ghobashy et al. showed that all maxillary 1st and 2 nd molars had Type I R.C anatomy in the DBR [8]. As in accordance to other investigations in Brazil, India and Ireland [5,8,12,18], the observations from our study reported lower frequency of maxillary 2nd molars with 3 roots (97.69%) in comparison to maxillary 1st molars (100%). Our findings displayed that the most commonly noticed root configuration in the maxillary 2nd molars was 3 roots with 2 R.C in the MBR (59.72%) followed by 3 roots with 1 R.C in each root (35.18%). These observations are in contrast to other reports [6,13,14,25]. Interestingly, maxillary 2nd molars show and greater complicated R.C morphology in comparison to maxillary 1st molars: the frequency of a 1 root in the 2nd molars was 1.4 % and 4 teeth had 2 roots (1.85%). In the present study, we found Type II,I, IV, III R.C anatomy for MBR (55.09 %, 38.9%, 3.70%, 2.31% respectively). These findings were in accordance with others [1,2,8,9,16,17,19, 24]. Additionally PR did not show any variations in the R.C anatomy, which was displayed in many studies [1,2,8,9, 14,16,17,19, 24]. There were little variations in extra R.C in the DBR of the maxillary 2nd molars, where we found Type I R.C in 99 % and Type II R.C in 0.01 % of the cases. Moreover, having 2 roots with either 2 R.C or 3 R.C. were observed in a low frequency. Only a case with one root with 1 R.C was noticed. These observations were in an agreement with previous reports [4,5,6,18,25] that demonstrated little deviation other than Type I R.C in this root. Dissimilarities, were evident with other findings when they were compared to ours [6,8,17,25]. They reported that all of the maxillary 2 nd molars had 3 roots in their populations. As regard to the frequency of C-shaped R.C, we found only 2 cases / 216 (0.92%) in the maxillary 1 st molars, 4 C-shaped canals were found (1.85%) among 216 maxillary 2nd molars. These findings are in accordance with others that displayed low frequency for C shaped R.C in maxillary molars [1,5,26].

Comparing our results to the recent Ghobashy's study on an Egyptian population, neither Type V nor VI R.C was found [8]. However, we found C-shaped R.C was noticed, as well as Type II R.C in the DBR in both molars. For maxillary 1 st molars, gender did influence the frequency of additional canals. The only explanation is because the number of female patients were more than males. Regarding maxillary 2 nd molars gender did influence the frequency of additional canals on the left side only. Conversely, on the right side there was no significant results between males and females, which is in agreement with earlier studies [1,4, 8,19]. Nevertheless, there is always a confusing results regarding gender and the incidence of extra canals [4,9,27-29]. The incidence of the number of R.C of the maxillary 1st and 2nd molars did not differ significantly between right and left sides. The previous result was in a great agreement with many studies [8, 16-18].

CONCLUSIONS

According to the findings from the present retrospective study we concluded that:

1. Maxillary 2nd molars displayed more complex R.C anatomy than maxillary 1st molars.
2. For mesiobuccal roots of maxillary 1st molars, majority of the Egyptian Ismailia subpopulation have revealed type II then IV , I and the least IV of Vertucci classification. For 2nd molars, the most common types were type II, I , IV and III .
3. No anatomic variation was found for palatal roots for maxillary 1st and 2nd molars.
4. Distobuccal canals showed variations in the maxillary 1st and 2nd molars, where Type I was noticed more frequently followed by II.
5. C-shaped canals were noticed in maxillary molars but in low frequency.
6. Bilateral symmetry was displayed regarding extra canal.
7. Although, there was significant difference between females and males in most of the cases, the frequency of having 2nd canal in the mesiobuccal root is comparable for both genders.
8. Further studies are needed having larger population of patients.
9. Pre-assessment of the maxillary molars using CBCT imaging provides clear data for the root canal morphology that will help in increasing the prognosis of the root canal treatment.

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