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A Review on Root Anatomy and Canal Configuration of the Maxillary Second Molars

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ABSTRACT

Introduction: The complexity of the root canal system presents a challenge for the practitioner. This systematic review evaluated the papers published in the field of root canal anatomy and configuration of the root canal system in permanent maxillary second molars. **Methods and Materials:** All articles related to the root morphology and root canal anatomy of the permanent maxillary second molars were collected by suitable keywords from PubMed database. The exhaustive search included all publications from 1981 to December 2015. The articles relevant to the study were evaluated and data was extracted. The author/year of publication, country, number of the evaluated teeth, type of study (method of the evaluation), number of roots and the canals, type of canals and the morphology of the apical foramen was noted. **Results:** The highest studied populations were in Brazil and United States. A total of 116 related papers were found, which had investigated 11945 teeth in total. Across all the studied populations, the three-rooted anatomy was most common, while the four-rooted anatomy had the lowest prevalence. The presence of the second mesiobuccal canal ranged from 11.53 % to 93.7%, where type II (2-1) configuration was the predominant type in Brazil and USA and types II and III (1-2-1) in Chinese populations. In 8.8-44% of cases, fusion was observed. The main reported cases were related to palatal root. The major method of anatomical investigation in case reports was periapical radiography, and the chief method in morphological studies was CBCT. **Conclusion:** The clinicians should be aware of normal morphology and anatomic variations to reduce the treatment failure.

Keywords: Maxillary Second Molar; Root Canal Anatomy; Root Morphology; Systematic Review

Introduction

Cleaning, shaping and three-dimensional obturation of the root canal system are the keys to successful endodontic treatment, that requires knowledge of the anatomy of the root canal system [1-3]. However, an important challenge is the complexity of the root canal system and anatomical variations [3]. Therefore, the clinician should be aware of typical configuration and potential anatomical variations. In this case, the possibility of treatment failure due to untreated canals decreases [4]. There are various ways for evaluating the anatomy of the root canal system including preparation of access cavity and radiography while the file is in the root canal. Other methods include canal staining and tooth clearing, conventional and digital radiography, computed tomography (CT), cone-beam computed tomography (CBCT), serial sectioning and microscopic evaluation [5-9].

Anatomical variations are possible in every tooth, and the second maxillary molar is no exception [10, 11]. Typically, this tooth has three roots [12]. The mesiobuccal (MB) root of maxillary molars has always been a challenge, holding also true for the second molar [13]. A significant number of studies in many countries have dealt with the anatomical and morphological investigation of the root canal system of this tooth [14-18]. Various case studies have also been published in this regard [2, 19-21].

The copious number of articles was published regarding the root canal anatomy of the second maxillary molar most of which, studied populations and the number of examined teeth make the result interpretation difficult and time-consuming. In such cases, review papers can provide valuable information about the normal morphology and different variations present in the root canal system to readers. Since there was not any published review article regarding the root anatomy and canal configuration of the second maxillary molar, this systematic review was conducted on investigations and case studies published regarding the anatomy and morphology of the root canal system of the maxillary second molar.

Materials and Methods

An exhaustive search was undertaken to identify published literature related to the root anatomy and root canal morphology of the permanent maxillary second molar *via* PubMed database. English papers which evaluated one aspect of root morphology and root canal anatomy of the second maxillary molars were included in this review.

The searched keywords were Maxillary Second Molar, Root Morphology and Root Canal Anatomy. The search included all publications from 1981 to December 2015. Titles and abstracts were evaluated. The articles relevant to the study were evaluated regarding the following data: The author/year of publication, country, number of the evaluated teeth, type of study, number of roots and the canals, type of canals according to Vertucci's classification and the morphology of the apical foramen.

Results

In total, 116 papers were found according to the mentioned entry criteria, which had assessed a total number of 11945 teeth. Among these 56 papers were case reports, presented in Table 1 [2, 11, 12, 19-71]. In the majority of earlier studies, the applied method was radiography, whereas in more recent studies, the tendency has been towards CBCT. Twenty tree papers were related to palatal root, most of which involved reporting the presence of two separate palatal roots.

Among the examined studies, the number of roots of the second maxillary molar was investigated in 10 studies [6, 8, 14, 21, 72-77] (Table 2). In these investigations, three-rooted anatomy claimed the highest percentage, while the four-rooted morphology had the lowest percentage reported among all of the examined teeth. Moreover, CBCT technique was the most utilized method in these studies. As few as 6 studies dealt with root fusion in this tooth [6, 8, 73, 74, 78, 79] (Table 3), with the Brazilian and Iranian populations take the highest and lowest prevalence, respectively. Among the roots of the second maxillary molar, the mesiobuccal root appropriated the largest number of studies, with 33 papers being found in this regard [6, 8, 13, 16, 17, 72, 75, 78-104] (Table 4).

The presence of the second mesiobuccal canal ranged from 11.53% [105] to 93.7% [99]. The predominant reported canal type was related to the studied populations; where type II (2-1) was the predominant type in Brazil and USA and types II, III (1-2-1) were more prevalent in Chinese populations. The largest number of studies in this regard was conducted in Brazil and USA, where again CBCT method was found in many of the more recent studies.

Some investigations have evaluated the distance between the orifice of second mesiobuccal and first mesiobuccal canals. In one study, second mesiobuccal canal was located 2.2±0.54 mm palatally and 0.98±0.35 mm mesially, in relation with main mesiobuccal canal [13]. In another study, it was reported to be located 2 mm palatally and 1 mm mesially [8].

The two morphological studies on various dimensions of the mesiobuccal root, it was found that there was no difference between the diameter of the wall of the mesial and distal root in the apical and medial one third. However, in the coronal 1/3, the thickness of the distal wall of the root was 33% lower [89, 91]. In the second molar, unlike the first molar, the thickness of the distal wall of mesiobuccal canals in CEJ level and 2 and 4 mm apically than CEJ, was not different [91]. The shape of the pulp chamber floor in one study was rhomboid [106] but in another evaluation was quadrilateral [78].

A number of studies also explored the anatomy of distobuccal root. One study, using radiography and decalcification, indicated two canals in the distobuccal root by 4% in the mesiodistal dimension and 6% in the buccolingual dimension [81]. In the morphological study, it was reported that the prevalence of extra canal present in the distobuccal root as 0.3% [6]. In three studies, the presence of one canal in the distobuccal root was 96, 92 and 84.9%, respectively [16, 72, 105]. In one survey, in Chinese population using CBCT, the mean distance between the orifice of mesiobuccal and distobuccal canals was 0.7-4.8 mm, and between palatal and distobuccal was 0.8-6.7 mm [15].

Regarding the anatomy of the palatal root, one investigation evaluated 25 teeth by micro-CT method whereby 16 teeth were type I (two palatal roots are very divergent and often long and tortuous, which can be observed radiographically), 7 were type II (the palatal roots are shorter and parallel and root apices are blunt, with mesial and distal divergence on the buccolingual radiographic view) and 2 were type III (the roots have a constricted morphology with mesiobuccal, mesiopalatal and distopalatal roots engaged in a web-like radiographic view similar to type II) were reported [78]. In one research, the prevalence of two canals in the palatal root was reported to be 1.82% [6]. In one anatomic investigation using CBCT, it was stated that 11 out of 979 teeth (1.12%) had two palatal roots, in which gender and the jaw side were not influential [107]. The mean distance between the orifice of the mesiopalatal and distopalatal canals was 2.84±0.5 mm. The angle between two palatal roots was reported to be 34.6±16.1 mm [107]. In an *in vivo* study using CBCT in Chinese population, which investigated 1226 teeth [21]; they found that 12 cases had two palatal roots and the section of the distopalatal canal was larger. The presence of two canals in the palatal root was reported 6% [105] and 12.2% [16].

The symmetry of the second molar has been investigated in two studies [6, 108]. They reported that in 79.6% and 82.7% [109] of studied cases both the right and left molars were symmetric and had three root canals.

In one investigation, the degree of presence of two physiological foramen in the mesiobuccal root was 71.15%. Accessory foramens existed in 33% of cases and in 70% of cases, the foramen was oval shaped. The size of the foramen in the buccal canals ranged from 0.18-0.25%, which was 0.22-0.29 mm in the palatal canal [110]. In another anatomical study regarding the apical foramen, the predominant morphology of foramen and apex has been reported to be round shaped, where in 39.7% and 58.4% of cases, apex and foramen were in the center of the root, respectively [5].

In the some morphological studies [72, 73, 78, 111] prevalence of isthmus, apical delta and lateral canal in the mesiobuccal root was greater than in other roots. These cases were more present in apical 1/3. In one anatomical study, the isthmus tissue and 80% of accessory canals were positioned whiten 3.6 mm coronally from the apex [111].

The distance between the pulp floor and furcation was evaluated in two articles [78, 112] and was reported to be 3.05±0.9 and 0.57±2.15 mm, respectively. The distance between the buccal cusp and furcation and pulp floor was 11.15±1.21, 0.88±8.08%, respectively. Moreover, the height of the pulp chamber was stated to be 1.8±0.68 mm [112].

Presence of C-shaped canal in the second maxillary molar was investigated in some studies and reported about 4.9% for this anatomic variation [18, 113, 114]. Rare anatomical findings were observed in some morphological studies. Prevalence of enamel pearl in one study was 8% [78]. In one investigation in German population, the prevalence of taurodontism and pyramid-shaped molar was reported to be 18/800 and 15/800, respectively [115].

Discussion

The second maxillary molar has a complex root canal system and one of the reasons of failure in endodontic treatment is lack of locating and cleaning of the entire root canal system [2]. The complexity of the root canal system of the second maxillary molar is largely related to presence of the second mesiobuccal canal [102, 103, 134]. The first report published on the existence of excess canal in the mesiobuccal root of the second maxillary molar is related to the study by Hess and Zurcher in 1925 [135]. In this review study, a considerable number of case and morphological studies have dealt with reporting two canals in the mesiobuccal root.

Our investigation indicates a difference between the prevalence of the second mesiobuccal canal across several studies, possibly due to the evaluation techniques employed as well as the racial diversities. On the other hand, definition of the second mesiobuccal canal across studies is different. Some researchers have sufficed to stating presence of two individual orifices onto the pulp floor and primary localization [136]. According to Stropko [101], the second canal can be considered as the second mesiobuccal canal if the file can be inserted in the canal by 3-4 mm. More recent studies have considered a more accurate criterion, in which the second mesiobuccal canal is absolutely separate from the first mesiobuccal canal; and before reaching to each other in the apex, they are 5 mm away off each other; also, they should also remain separate from each other following instrumentation [95]. Various factors can affect the finding of an excessive canal like the second mesiobuccal canal. One of these factors is the practitioner's experience; it has been found that great experience of the practitioner helps in locating of the extra canals like MB2 [137].

In this review study, having investigated the papers related to the second mesiobuccal canal, it can be concluded that age is an important factor and has a significant effect on the number of found canals [79, 84, 88]. As the age increases by one, the chance of finding canals drops dramatically 0.98 times, related to calcification and morphological changes occurring by ageing. Further, in a decayed tooth, the possibility of finding an extra canals is 1.4 times greater than in non-decayed teeth [7, 84]. *In vitro* studies, compared to *in vivo* examinations, as well as in retreatment compared with primary treatment, report a higher chance of finding extra canals [95, 96]. Increased chance of finding extra canals with the help of magnification, especially microscope is a common finding across all of the investigated studies [98, 138, 139]. Only Sempira *et al.* [100], have stated that use of microscope is not effective.

The possibility of finding extra canal in the study by Sert and Byirli [140] was related to gender, however in another study, no relationship was found between these two variables [84]. Among the investigated studies, one has stated that there is an inverse relationship between the root zone and finding canal, and as the canal approaches the apical 1/3, the possibility of detection declines [84]. One of the factors highlighting this especially in more recent studies is use of novel imaging techniques such as tomography. Although in the majority of earlier studies, the clearing technique, as the gold standard, has been used. It is an *in vitro* model developed on extracted teeth. The size of samples is limited and lack of possibility of analyzing similar teeth in other quadrants is another flaw of it [141]. It should always be noted that it is still a valuable techniques which is accurate, simple and applicable *in vivo*. In some other studies, typical radiography was used, presenting a two-dimensional image of a three-dimensional object. There is a chance of distortion and superimposition, diminishing the possibility of complex morphological examinations [9]. The CBCT technique, as a variation of computer tomography, provides the possibility of three-dimensional understanding of morphology and high resolution with a low radiographic dose [9, 74, 86].

Table 1. Case reports on maxillary second molars

Authors	Type of study	Number of teeth	Description
Beshkenadze and Chipashvili	*In vivo* (PA radiographs)	2	2 roots, 2 canals, 3 roots, 4 canals
Chawala *et al.*	*In vivo* (CBCT)	1	6 canals, 2 in M, 2 in D, 2 in P
Hans *et al.*	*In vivo* (PA radiographs)	2	Microdontia
Jaikrishan *et al.*	*In vivo* (CBCT)	2	1 root and 1 canal
Radwan and Kim	*In vivo* (PA radiographies+CBCT)	2	Hyper taurodontism
Ahmad and Al-jadda	*In vivo* (PA radiographs)	2	2 roots, 2 canals, 3 roots,4 canals
Shah *et al.*	*In vivo* (PA radiographs)	1	2 canals in MB root
Ashraf *et al.*	*In vivo*(CBCT)	1	2 roots,4 canals, (2 M canals, 2 D canals)
Fakhari and Shokraneh	*In vivo* (PA radiographies+flap)	1	2 canals in P
Paul *et al.*	*In vivo* (PA radiographs)	1	2 independent P roots
Brito *et al.*	*In vivo* (loup+DOM+CBCT)	1	3 B roots and midbuccal canal
Simsek *et al.*	*In vivo* (CBCT)	1	2 roots, 4 canals, (2 M canals, 2 D canals)
Arora *et al.*	*In vivo* (MDCT)	1	3 canals in MB roots
Eskandarinekhad and Ghasemi	*In vivo* (PA radiographies+loup)	1	2 roots, 4 canals, (2 in P, 2 in B)
Shojaeian *et al.*	*In vivo* (PA radiographs)	1	2 P canals, Enamel pearl
Patel and Patel	*In vivo* (PA radiographs)	2	2 canals in P
Ioannidis *et al.*	*In vivo* (CBCT)	2	One root, one canal
Scarparo *et al.*	*In vivo* (PA radiographs)	5	2 canals in P root
Zhu and Zhao	*In vivo* (CT)	1	3 canals in MB root
Zha *et al.*	*In vivo* (PA radiographs)	1	5 canals, 2 in M, 2 in D, 2 in P
Wang *et al.*	*In vivo* (CBCT)	1	one root, one canal
Crincoli *et al.*	*In vivo* (micro radiograph)	1	Dens invagination
Singla and Aggarwal	*In vivo* (spiral CT)	1	C-shaped P Canal
Weinstein *et al.*	*In vivo* (endoscope)	1	Gemination
Prashanth *et al.*	*In vivo* (PA radiographs)	1	2 palatal canals
Morinaga *et al.*	*In vivo* (PA radiographs)	1	Dens invagination

Table 2. Number of roots in maxillary second molars

Authors	Number of teeth	Country	Type of the study	1 root	2 roots	3 roots	4 roots
Zhang *et al.*	210	China	CBCT	10%	8%	81%	
Rweuyonyi *et al.*	221	Ugandan	clearing			86%	
Ng *et al.*	77	London	clearing			100%	
Gu *et al.*	1226	China	CBCT				98%
Rouhani *et al.*	125	Iran	CBCT				1.6%
Georgia *et al.*	402	Greek	CBCT	5.4%	8.25%	85.07%	1.2%
Silva *et al.*	306	Brazil	CBCT			45.09%	
Libfeld	1200	Israel	Radiography/RCT	3%, 0.5%	6%, 12%	90.6%, 87%	0.4%
Kim *et al.*	821	Korea	CBCT	4.63%			
Peikoff *et al.*	520	Canada	Radiography	3.1%	6.9%	80.5%	1.4%

Table 3. Fusion in maxillary second molar

Authors	Number of teeth	Country	Type of the study	Fusion
Versiani *et al.*	25	Brazil	RCT	44%
Kim *et al.*	821	Korea	CBCT	10.71%
Zhang *et al.*	187	China	RCT	42.25% 22 partial-6 complete merge)
Rouhani *et al.*	125	Iran	CBCT	8.8%
Rwenyonyi *et al.*	221	Ugandan	Clearing	13.1% (MB with DB: 6.8% -MB with P: 6.3%)
Al-shalabi *et al.*	40	Irland	Clearing	43%

Table 4. Mesiobuccal root canal system configuration

Author	Number of teeth	Country	Type of study	Prevalence of MB2 canal
Betancourt *et al.*	225	Chile	*In vivo* (CBCT)	48%
Singh *et al.*	100	India	*In vitro* (clearing)	19.4% Type II:15.3% Type IV:2.7% Type V:1.4%
Silva *et al.*	306	Brazil	*In vivo* (CBCT)	34/32%
Li *et al.*	50	China	*In vitro* (CBCT)	41.3%, Type I: 54.4%
Al-Fouzan *et al.*	162	Saudi Arabia	*In vivo* (radiography)	19.7%
Domark *et al.*	14	USA	*In vitro*(CBCT, Digital RG)	57%
Reis *et al.*	185	Brazil	*In vivo* (CBCT)	Right molars 87.5% Left molars 79.3%
Silveria *et al.*	43	Brazil	*In vitro* (CBCT,DOM)	Negotiable 80.2%-81.4%
Vizzotto *et al.*	89	Brazil	*In vitro* (CBCT)	67%
Versiani *et al.*	25	Brazil	*In vitro* (micro CT)	Type I :16 Type 2:7 Type 3: 2
Kim *et al.*	821	Korea	*In vivo* (CBCT)	34/39%
Bauman *et al.*	12	USA	*In vitro* (CBCT)	92%
Zhang *et al.*	210	China	*In vivo* (CBCT)	22% Type II:18% Type IV:58% Type V:10% Type VI:3%
Lee *et al.*	467	Korea	*In vivo* (CBCT)	42.2%, Mainly Wien's type II and III
Neelakatan *et al.*	205	India	*In vitro* (CBCT)	50%
Degerness and Bowles	63	USA	*In vitro*(Serial Section and stereomicroscope)	60.3%
Zhao *et al.*	118	China	*In vitro* (RG)	49.15% Type I:46.30% Type II:12.96% Type III:31.48%
Gao *et al.*	334	China	*In vitro* clearing+spiral CT scanning)	49.70%
Xoshioka *et al.*	208	Korea	*In vivo* DOM and troughing	48%
Walcott *et al.*	2038	USA	*In vivo* (RCT and radiography)	35% Initial treatment 34% Retreatmentn40%
Wang	52	China	*In vivo* (RCT and radiography)	11.53% Negotiable 7.69%
Zhang *et al.*	113	China	*In vitro* (OM)	52.2% Negotiable64.3%
Wolcott *et al.*	680	USA		Initial treatment 35% Retreatment 44%
Buhrley *et al.*	104	USA	*In vivo* (Loup, DOM)	Without magnification 20% Loup40.5% DOM36.1%
Schwarze *et al.*	50	Germany	Loup, DOM,sectioning	24.6% (section) 41.1%(loup) 93.7% (DOM)
Ng *et al.*	77	UK	*In vitro* (clearing)	49% (canal type mainly II and IV)
Sempira and Hartwell	100	USA	*In vivo* (DOM)	Negotiable 24.3%
Al-Shalabi *et al.*	40	Ireland	*In vitro* (clearing)	58% (mainly type IV)
Stropko *et al.*	611	USA	*In vivo* (clinical RCT with DOM)	45.6%
Eskoz and Weine	73	USA	*In vitro* (Radiography)	41.3% Type II 20.9% Type III 16.4% Type IV 3%
Singh *et al.*	50	Punjab	*In vitro*(decalcification)	78% in MD and 20% in BL direction
Pecora *et al.*	200	Brazil	*In vitro* (clearing)	42%
Gilles and Header	37	Columbus	*In vitro* (SEM)	70%

Examination of the papers evaluating various techniques for finding the second mesiobuccal canal indicates that there is not any difference between CT and CBCT, but both methods are better than digital radiography [83]. There is no significant difference between CT and CBCT in comparison with serial sectioning and clearing, either [4, 83, 90]. In another study, the results of CBCT and transparent tooth technique were congruent [80]. In a study regarding voxel size in CBCT, 0.3 mm was stated as suitable for CBCT [86]. In another study with a voxel size of 0.4 mm, the reliability of detection was 60.1% and with a voxel size of 0.125, was reported to be 93.3% [87].

In the majority of studies, the significance of utilizing magnification especially microscope has been underscored [85, 98, 99, 103, 139]. However, as found by Sempira and Hartwell [100], there is no difference between the ability of finding the second mesiobuccal canal in those in which access cavity has been modified with no microscope in comparison with presence of microscope.

In the conducted studies, it has been emphasized that removal of the obturation materials from the canal resulted in better detection of the extra canals and morphological complexities by this method [4, 86, 142]. On the other hand, this method is suitable in detecting the mapping of canals, rather than detecting the negotiability of the canal [85]. CBCT is not usable for a tooth in typical clinical practice.

In a study, it was reported that the CMOS (complementary metal oxide semiconductor) imaging technology enhanced reliability of the second mesiobuccal canal detection and when radiography is of interest, it has an optimal exposure [143].

Another point mentioned with regard to the second mesiobuccal canal was the negotiability of the found orifice. A number of studies, in addition to examining the extent of MB2 canal, evaluated its negotiability as well [85, 97, 100]. Aggregation of the dentin debris and other debris produced through pathfinding, presence of anatomical variations, diffused calcification of the pulp and presence of pulp stone are factors influencing the negotiation of the canal [144].

To have a successful canal treatment in the second maxillary molar, cleaning should not focus only on the second mesiobuccal canal and mesiobuccal root. Investigation of the studies published on the morphology of this tooth indicates that anatomical variations are also present considerably in palatal root (Table 1), where presence of two canals has been the most reported case. However, the distobuccal canal should not be overlooked.

Anatomical landmarks, the dimensions of the pulp chamber together with the thickness of root walls, presence of isthmii and peripheral canals, as well as the size and position of the apical foramen have also been taken into consideration in a limited number of studies [5, 89, 106, 145]. These studies were valuable because of reducing the probability of perforation and gouging during treatment and enhancing cleansing the entire pulp system.

Conclusion

The complexity of the canal system is influenced by genetics and this factor should be considered before interpreting and comparing the results of various morphological studies, in addition to factors like age and gender.

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