10.5005/jp-journals-10015-1201
ORIGINAL RESEARCH

An *in vivo* Study of Variations in the Canal Anatomy of Maxillary and Mandibular First Molar using Surgical Operating Microscope

Sayed Abrar Bashir Ahmed, Mansing Ganpati Pawar

ABSTRACT

Introduction: The success of endodontic therapy depends upon the ability of the clinician to locate, clean, shape and completely obturate all the root canal systems present in a tooth. In the recent times number of additional canals *vs* traditional canals has been very striking and pointing toward a greater degree of variation in the root canal morphology which needs to studied, understood and born in mind during practice so as to enhance the success. Introduction of surgical operating microscope is a major breakthrough in enhancement of vision in endodontics which not only gives required magnification but also coaxial illumination and video output. These facilities should be of a great help in location of small otherwise difficult to locate accessory canals.

Materials and methods: This *in vivo* study was planned to study variations in the canal anatomy of maxillary and mandibular first molar using surgical operating microscope using 200 first molar teeth, 100 maxillary and 100 mandibular groups, each group to be divided into 50 males and 50 female subgroups. After access opening chambers were cleaned, dried and observed and imaged under the microscope.

Results: The observations were recorded and incidences of variations in anatomy were analyzed subjecting the same to SPSS version 16.0.

Conclusion: It was observed that surgical operating microscope enhances clinician's ability to locate additional canals in the teeth.

Keywords: Root canal, Anatomy, Variations, Magnification, Precision, Middle mesial.

How to cite this article: Abrar BAS, Pawar MG. An *in vivo* Study of Variations in the Canal Anatomy of Maxillary and Mandibular First Molar using Surgical Operating Microscope. World J Dent 2013;4(1):47-55.

Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

The success of endodontic therapy depends upon the ability of the clinician to locate, clean, shape and completely obdurate all the root canals present in the tooth. Wein[1] stated that 'if a canal is not detected it can not be cleaned and filled and is a potential cause of endodontic failure'. Vertucci[2] pointed out that a canal is often left untreated because the dentist fails to recognize its presence so it is of utmost importance for every clinician to have a thorough knowledge of normal internal anatomy of the teeth and its common variation. In the recent years number of additional canals versus traditional canals has been very striking. Timely, various investigations have been done to study the routine variations in the root canal anatomy exhibiting perplexing results and there exists no consensus about the incidence of variations in the number of canals present in the teeth.

Maxillary and mandibular first molars are the initial permanent teeth to erupt and undoubtedly strategically one of the most important teeth in the arch. They are most commonly attacked by caries[3] and endodonticaly treated.[4] From the studies done so far it can be said that opinions regarding variations in root canal anatomy of these teeth remains widely divided. Most of the studies done in this line are *in vitro*. There exists a vast discrepancy between the high incidences of additional canals shown in the laboratory studies which have never been demonstrated by the clinical studies. This may be indicative of inability of the clinician to visualize and locate the additional canals which may be present in these teeth.

Surgical operating microscope provides higher degree of magnification with coaxial illumination which greatly enhances the clinicians ability to visualize the micro-anatomical details of the pulp chamber and helps in detection of fine, otherwise hidden canals.

MATERIALS AND METHODS

In this study a total of 200 first molar teeth were randomly selected from patients belonging to the age group of 15 to 40 years from the OPD of Department of Conservative Dentistry and Endodontics, Government Dental College and Hospital, Mumbai. Patients were divided into groups and subgroups as follows:

Group A—100 Maxillary First Molar Teeth

- Subgroup I – 50 maxillary first molar teeth of females (UF-50)
- Subgroup II – maxillary first molar teeth of males (UM-50)

Group B—100 Mandibular First Molar Teeth

- Subgroup III – 50 mandibular first molar teeth of females (LF-50)
- Subgroup IV – 50 mandibular first molar teeth of males (LM-50)

All the teeth included required endodontic treatment because of pulpal involvement by progressive caries. Teeth needing endodontic therapy because of noncarious etiologies were excluded. Endodontic procedures were performed using surgical operating microscope (PICO, OPMI Carl Zeiss, Germany). Procedures were performed as per the standard protocol of endodontic care. Microscope was positioned appropriately as per the ergonomic convenience. Intensity of fiberoptic illumination was optimally adjusted to avoid either darkness or dazzling in the field. Initial focus was done on ×4 magnification for orientation of the operating field. Output cable from the integrated video camera was then connected to the computer monitor/LCD projector for display, photography and video recording. Once the procedure of access opening was started the magnification was shifted to ×10 and ×16. Thorough examination of the pulp chamber floor was done using the higher magnification[5] of ×25. Facility of the fine focus was utilized to further enhance sharpness of the field.

Access Cavity Preparation for Maxillary First Molars

Access cavities were made in all the teeth strictly adhering to the standard norms by a single operator to avoid interoperator variation. As recommended, the preparations were made with slightly greater flare to allow more light to enter the chamber and improve the vision. After debridement the floor of the pulp chamber was keenly observed for the location of the palatal canal which is usually located below the palatal cusp, mesiobuccal canal which is generally found below the mesiobuccal cusp and distobuccal canal which is generally found distal and palatal to the mesiobuccal canal orifice. When the MB2 orifice was easily located at this stage it was gently negotiated with small size K files. When MB2 orifice was not located, the access cavities were modified to a rhomboidal shape as recommended by Wellers.[6] The MB2 orifice was searched for slightly mesial to the an imaginary line between MB1 and palatal orifice generally at a distance of 2 to 5 mm from the orifice. If the cervical lip of the dentin covered the dentinal map (anatomical groves) to the MB2 orifice it was removed using an explorer or a long shank round bur at a slow speed. In situations where a small discolored area was seen in the location of MB2 canal orifice (indicative of calcified MB2) attempts were made to enter it with a fine instrument. When the orifice was found and the canal could be negotiated to the length of at least 5 mm from the orifice, presence of fourth canal was recorded. If no orifice was found a bur was used to a depth not more than 2 to 2.5 mm in an attempt to negotiate it. As directed by Wein utmost care was taken to avoid undue cutting of the dentin to avoid possibility of perforation and weakening of the teeth.

Access Cavity Preparation for Maxillary First Molar

As recommended trapezoidal access cavities were prepared in all the teeth with slightly greater flare to allow more light to enter the access and improve vision. After debridement the floor of the pulp chamber was keenly observed for the location of the distal canal which is usually located in the middle of the tooth mesiodistally and slightly buccal or in the center of the tooth, buccolingually. Mesiobuccal orifice was then looked for below the mesiobuccal cusp. Mesiolingual orifice was located in the middle of the mesiolingual and mesiobuccal cusp. The distal canal is generally wide buccolingually and commonly has a kidney or C-shaped orifice. In cases where the distal orifice appeared round and located on more toward buccal or lingual side and deroofing of the chamber appeared incomplete, attempts were made to locate the second distal canal. The distal canal may have one orifice leading to either two separate canals or a canal having narrow isthmus posing a challenge for cleaning and shaping. Higher magnification on surgical operating microscope clearly shows the presence of any bifurcation present or narrow isthmus in the coronal or middle one-third of the root. During instrumentation when an instrument could not be passed from one part of the canal to other through the isthmus, the tooth was recorded to have two distal canals.

After location of the mesiobuccal and mesiolingual canal orifices attempts were directed toward removal of the cervical lip of the dentin covering the groove connecting these orifices in order to locate a third mesial canal if present. It can be located in between the mesiobuccal and mesiolingual orifices or close to any of them. When this orifice was located the canal was gently negotiated using appropriate instrument.

All such access cavities prepared for maxillary and mandibular first molar teeth were completely debrided, hemorrhage if present was controlled; chambers were irrigated with sodium hypochlorite and dried. All the access cavities were observed under ×25 magnification for in detail visualization of their anatomical details using Carl Zeiss OPMI PICO Surgical Operating Microscope.

RESULTS

Group A—100 Maxillary First Molar Teeth

As seen in Table 1 out of 100 (100%) maxillary first molar teeth examined under this group, 25 (25%) teeth had three

Table 1: Association of gender with total number of canal orifices in maxillary first molars

Gender		*Total no. of canal orifices*		*Total*
		3	4	
Female	No.	13	37	50
	%	26	74	100
Male	No.	12	38	50
	%	24	76	100
Total	No.	25	75	100
	%	25	75.00	100
Chi-square test	*Value*	*df*	*p-value*	*Association*
Pearson Chi-square	0.053	1	0.817	Not significant

and remaining 75 (75%) had four separately detectable root canal orifices.

All the maxillary first molar teeth exhibited one palatal as per Table 2, distobuccal and on mesiobuccal-1 orifices each as seen in Tables 3 and 4 respectively. In all the teeth studied, fourth canal observed invariably was the mesiobuccal-2 as seen in Table 5.

Subgroup I—Maxillary First Molar Teeth in Females (UF-50)

1. Table 1 shows that in 13 (26%) of the teeth had three and 37 (74%) of the teeth had four root canal orifices each (Graph 1).
2. Mesiobuccal-2 canal orifices could be detected in 37 (74%) of the cases.

Subgroup II—50 Maxillary First Molar Teeth in Males (UM-50)

1. Table 1 shows that 12 (24%) teeth had three and 38 (76%) of the teeth had four root canal orifices each (see Graph 1).
2. Mesiobuccal-2 canal orifice could be detected in 38 (76%) of the cases (refer Graph 5).

Group B—100 Mandibular First Molar Teeth

1. As observed in Table 6, 66 (66%) of the teeth in this group had three, 30 (30%) had four and 4 (4%) teeth had five separate root canal orifices (refer Graph 4).

Table 2: Association of gender with number of palatal canal orifices in maxillary first molar teeth

Gender		*No. of canal orifices: Palatal*	*Total*
		1	
Female	No.	50	50
	%	100	100
Male	No.	50	50
	%	100	100
Total	No.	100	100
	%	100	100

Table 3: Association of gender with number of distobuccal canal orifices in maxillary first molar teeth

Gender		*No. of canal orifices: Distobuccal*	*Total*
		1	
Female	No.	50	50
	%	100	100
Male	No.	50	50
	%	100	100
Total	No.	100	100
	%	100	100

Table 4: Association of gender with number of MB1 canal orifices in maxillary first molar teeth

Gender		*No. of canal orifices: MB1*	*Total*
		1	
Female	No.	50	50
	%	100	100
Male	No.	50	50
	%	100	100
Total	No.	100	100
	%	100	100

Table 5: Association of gender with no. of MB2 canal orifices in maxillary first molar teeth

Gender		*No. of canal orifices: MB2*		*Total*
		0	1	
Female	No.	13	37	50
	%	26	74	100
Male	No.	12	38	50
	%	24	76	100
Total	No.	25	75	100
	%	25	75	100
Chi-square test	*Value*	*df*	*p-value*	*Association*
Pearson Chi-square	0.053	1	0.817	Not significant

2. Tables 7 and 8 all the teeth in this group had one mesiobuccal and mesiolingual canal orifice.
3. Common variation observed was presence of two separate distal canal orifices in 23 (23%) cases (Table 9) remaining 77 (77%) teeth had only one distal canal.

Table 6: Association of gender with total number of canal orifices in mandibular first molars

Gender		*Total no. of canal orifices*			*Total*
		3	4	5	
Female	No.	33	15	2	50
	%	66	30	4	100
Male	No.	33	15	2	50
	%	66	30	4	100
Total	No.	66	30	4	100
	%	66	30	4	100
Chi-square test	*Value*	*df*	*p-value*	*Association*	
Pearson Chi-square	0.000	2	1.000	No difference	

Table 7: Association of gender with number of MB canal orifices in mandibular first molars

Gender		*No. of canal orifices: MB*	*Total*
		1	
Female	No.	50	50
	%	100	100
Male	No.	50	50
	%	100	100
Total	No.	100	100
	%	100	100

Table 8: Association of gender with number of ML canal orifices in mandibular first molars

Gender		*No. of canal orifices: ML*	*Total*
		1	
Female	No.	50	50
	%	100	100
Male	No.	50	50
	%	100	100
Total	No.	100	100
	%	100	100

Table 9: Association of gender with number of distal canal orifices in mandibular first molar teeth

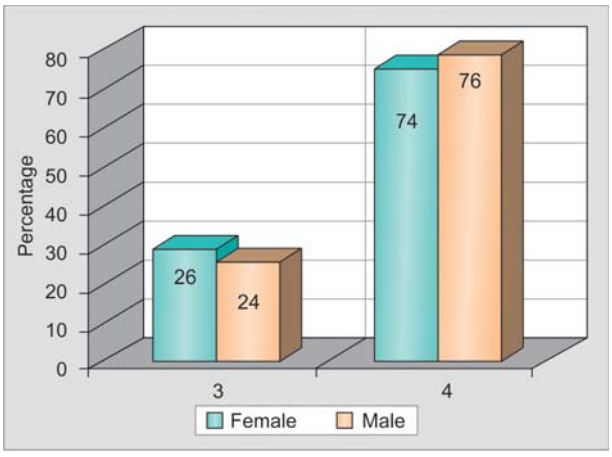
Gender		*No. of canal orifices: Distal*		*Total*	
		1	*2*		
Female	No.	39	11	50	
	%	78	22	100	
Male	No.	38	12	50	
	%	76	24	100	
Total	No.	77	23	100	
	%	77	23	100	
Chi-square test	*Value*	*df*	*p-value*	*Association*	
Pearson Chi-square	0.056	1	0.812	Not significant	

Table 10: Association of gender with number of MM canal orifices in mandibular first molars

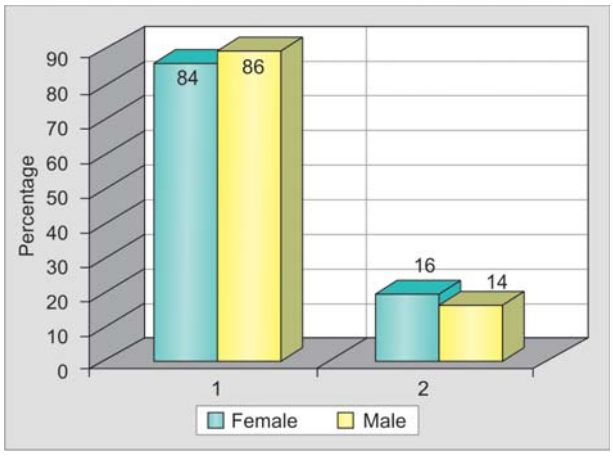
Gender		*No. of canal orifices: MM*		*Total*	
		0	*1*		
Female	No.	42	8	50	
	%	84	16	100	
Male	No.	43	7	50	
	%	86	14	100	
Total	No.	85	15	100	
	%	85	15	100	
Chi-square test	*Value*	*df*	*p-value*	*Association*	
Pearson Chi-square	0.078	1	0.779	Not significant	

Table 11: Association of age with number of MM canal orifices in mandibular first molars

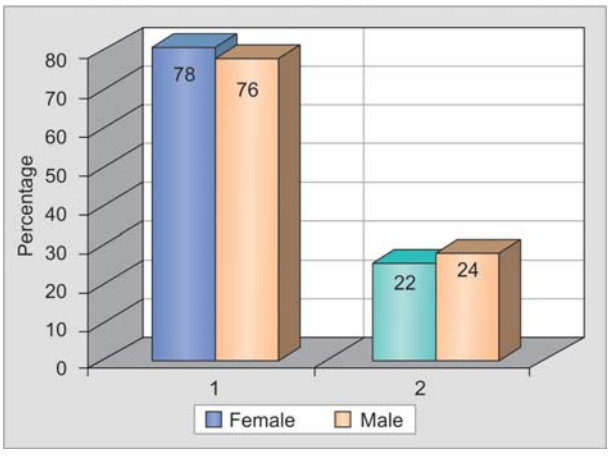
Age groups		*No. of orifices/canals: MM*		*Total*
		0	1	
a. 15 to 24	No.	35	11	46
	%	41.20	73.30	46
b. 25 to 30	No.	29	2	31
	%	34.10	13.30	31
c. 30 to 34	No.	10	1	11
	%	11.80	6.70	11
d. 35 and more	No.	11	1	12
	%	12.90	6.70	12
Total	No.	85	15	100
	%	100	100	100
Chi-square test	*Value*	*df*	*p-value*	*Association*
Pearson Chi-square	5.362	3	0.147	Not significant



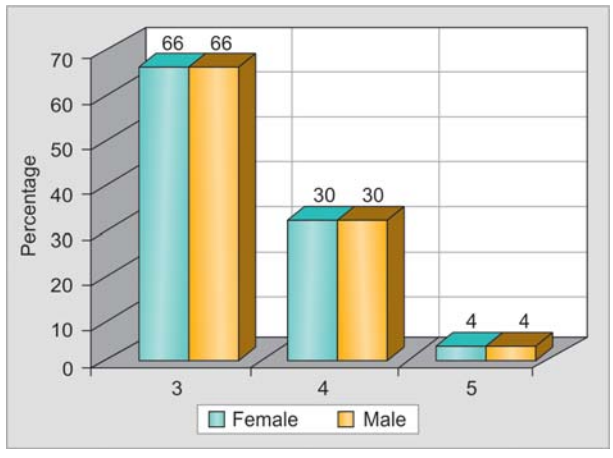
Graph 1: Association of gender with total no. of canal orifices in maxillary first molar



Graph 3: Association of gender with no. of MM canal orifices in mandibular first molar



Graph 2: Association of the gender with no. of distal canal orifices in mandibular first molar



Graph 4: Association of gender with total no. of canal orifices in mandibular first molar

4. Another variation as observed in Table 10 is presence of a third middle mesial canal orifice in the mesial root between the mesiobuccal and mesiolingual canal orifices in 15 (15%) of the teeth.

Subgroup III—Mandibular First Molar Teeth in Females (LF50)

1. As observed in the Table 6, 33 (66%) of teeth in this group had three, 15 (30%) had four and 2 (4%) teeth had five separate root canal orifices.
2. As shown in Table 9, 11 (22%) teeth exhibited two separate distal canal orifices. As remaining 39 (78%) exhibited a single distal canal orifice.
3. Eight (16%) of the teeth exhibited a separate, middle mesial canal orifice in the mesial root between the mesiobuccal and mesiolingual canal orifices (Table 10).

Subgroup IV—50 Mandibular First Molar Teeth of Males (LM-50)

1. As observed in the Table 6, 33 (66%) teeth in this group had three, 15 (30%) had four and 2 (4%) teeth had five separate root canal orifices.
2. As shown in Table 9 and Graph 2, 12 (24%) teeth exhibited two separate distal canal orifices and remaining 38 (76%) exhibited a single distal canal orifice.
3. Seven (14%) of the teeth exhibited a separate, middle mesial canal orifice in the mesial root between the mesiobuccal and mesiolingual canal orifices (Table 10 and Graph 3).

DISCUSSION

It has been pointed out by Ingle[7] that a major cause of failure of endodontic therapy is inability to recognize the presence of and adequately treat all the root canal systems present in the tooth. Repository of the pulp tissue takes up many shapes. It is extremely important for the clinicians to have thorough knowledge of the expected internal anatomy of the teeth and anticipate the unexpected as aberrations are more common than expected.

Various studies have been done to study the routine variations in the canal anatomy with perplexing results without consensus. Many of these studies are *in vitro*,[1,8-23] whereas *in vivo* studies are limited.[24-31] On the other hand most of the observations have been done by naked

eye[1,9,11-18] whereas relatively very few have used magnification.[18,21,22,29-33] Results of studies using microscope[18,29,30,34,35] are very surprising and indicative of efficiency and utility of using microscope for such observations. Studies in the past have also shown that developing proper skill, adopting proper methodology makes a significant difference in the proper visualization/location of the anatomical variations.[36] Stropko[29] while studying the maxillary first molar could locate MB2 canal in 73.2% of the cases, but with more experience, sufficient time and effort for location, use of operating microscope and specific instruments MB2 canals were located in 93% of cases.

Furthermore, number of canals demonstrated in *in vitro* studies has been very high as compared to the clinical studies,[36]which may be indicative of inability of the clinician to visualize and locate these canals. Absolute isolation of the tooth, cleaning and drying of the access cavity along with proper illumination are very important factors in visualization of the pulp chamber anatomy. Surgical operating microscope not only provides stepwise higher magnification but also fiberoptic coaxial illumination thus, enhancing operator's ability to locate all small hidden and accessory canal orifices.

Buhrley and others in their *in vivo* study concluded that accessory canal detection rate with microscope is approximately three times more than that of nonmagnification group. In this study total 200 first molars were divided into group A: 100 maxillary and group B: 100 mandibular. Each group was further divided into two subgroups on the basis of genders. All access cavities were prepared and observed under microscope, findings were recorded and results were tabulated and analyzed.

Group A—100 Maxillary First Molar Teeth

Out of the 100 maxillary teeth examined under group A 25 teeth exhibited three canals namely, mesiobuccal, distobuccal and palatal. Seventy-five teeth exhibited the fourth canal namely MB2 in the mesiobuccal root. Incidence of four canals in males is on a higher side as out of 50 males 38 show MB2 whereas out of 50, 36 females exhibited four canals. Incidence of four canals in male was found to be 76% and in females it was found to be 74% in the study.

Anatomical variations in maxillary first molar have been extensively studied with widely varying results, most common variation being presence of MB2 canal in the mesiobuccal root. It was first described by Hess[9] and Okumura[11] in 1925 and 1927, but its significance was not established until Wein[1] in 1969 studied and described that frequent failure of endodontic treatment of these teeth can be due to failure to locate and fill these canals. Since, then numerous studies have been performed to explain its occurrence, for example, *in vitro* studies by Kulid[8] (96%), Pomeranz[37] (69%), Seidberg[13] (64%), Gorduysus and others[22] (80%) and many more whereas the *in vivo* studies have suggested comparatively lower incidences, Hartwell and Bellizzi[38] (18%), Weller and others[36] (39%) and Semipara[33] (33%).

From this it can be said that the result of the present study are moreover on the same line as compared to the other *in vivo* studies carried out using surgical operating microscope.[30,39] Observing the floor of the pulp chamber under microscope at various magnifications simplified the detail observation of the microanatomical structures while performing this *in vivo* study. Seventy-five percent incidence of MB2 canals observed in this study was very close to other *in vivo* studies done in the past using surgical operating microscope. This study indicated 2% higher incidence of MB2 in males as compared to males but the difference is statistically insignificant. Further studies with larger sample size will be able to give more dependable results in this regard.

Group B—100 Mandibular First Molar Teeth

Out of 100 mandibular first molars including 50 males and 50 females examined under this group, 66 teeth exhibited three canals namely mesiobuccal, mesiolingual and distobuccal. Thirty exhibited four canals and remaining four teeth exhibited five canal orifices. Out of 30 teeth exhibiting four canals 11 teeth had three mesial namely mesiobuccal, mesiolingual and middle mesial and one distal canal, and the remaining 19 teeth had two mesial namely mesiobuccal, mesiolingual and two distal canals, namely distolingual and distobuccal. And remaining four teeth which showed five canals had three mesial namely mesiobuccal, mesiolingual and middle mesial and two distal canals.

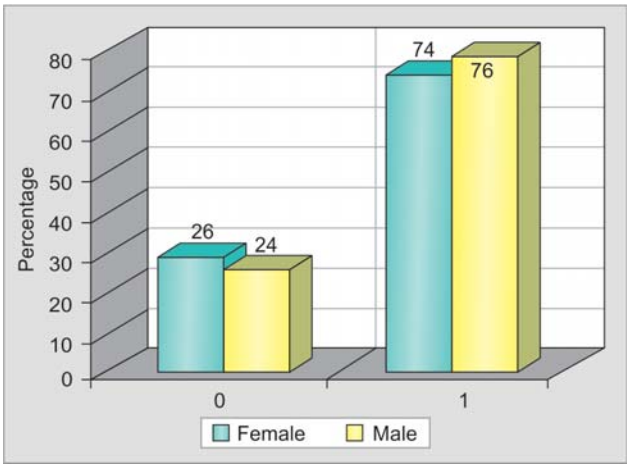
That means 66% teeth had three, 30% had four and 4% had five canals.

Anatomy of the mandibular molar was first studied by Hess[9] in 1925. He found two canals in 10% teeth, three canals in 85% of teeth and four canals in 5% teeth, with no distinction being made between first and second molars. It was not until 1971 when Skidmore and Bjorndal[12] studied anatomy of mandibular first molar, they found two root canals in 6.7% of the teeth, three in 64.4% and four in 28.9%. Studies investigating the incidence of variations in the number of canals found in this tooth are very scanty in the literature. Finding of incidence of three and four canals in the study are very close to the findings of Skidmore and others who have shown it to be three in 64.4%, four in 28.9% and also 31% occurrence of four canals shown by Vande

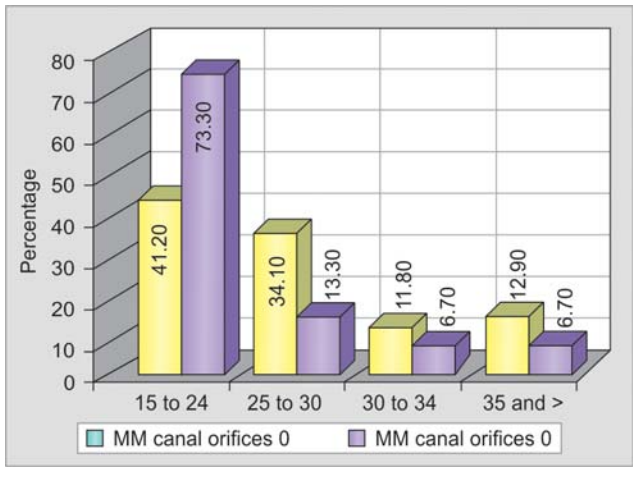
Voorde et al.[27] In this study it was also observed that in 23% of the cases distal root had two separate canal orifices. This finding of the present study carried out in the Indian population indicated occurrence of two distal canals to be lower than the previous studies carried out by Fabra-Campos,[25] Skidmore,[12] Wasti[40] in other races who have shown it to be 47, 30 and 47% respectively, suggesting that this variation in the root canal systems may be attributed to the racial divergence. Considering gender wise, two separate canal orifices were observed in 24% of males and 22% of female patients suggesting a higher occurrence in males.

The idea of middle mesial canal was first suggested by Hess as early as in 1925, but after that it was not properly studied till the *in vivo* investigation by Pomeranze[28] who found it in 11.4% of the cases.

In the present study separate middle mesial canal in the mesial root was observed in 15% of the cases. Finding of this study is higher than the findings of Vertucci,[2] Martinez and Berna and Fabra-Compas[25] who showed it to be 1, 1.5 and 2.1% respectively. Our findings are similar to Goel et al[16] who performed his study in the Indian population. Considering the occurrence gender wise, middle mesial canal was observed in 16% of the females and 14% of the males examined in this study. So in females occurrence of middle mesial canal was found to be 2% more than the males. One more interesting finding observed in this study was 11 out of 15 (i.e. 73.3%) of the patients showing middle mesial canals who were having their age below 24 years (Graph 6).



Graph 5: Association of gender with no. of MB2 canal orifices in maxillary first molar



Graph 6: Association of age with no. of MM canal orifices in mandibular first molar

CONCLUSION

From the result of this study and its relations with the review of literature it can be said that:

- A clinician cannot ignore the importance of having a thorough knowledge and understanding of normal internal anatomy of pulp cavity and its common variations to render a quality treatment with predictable success.
- The objective of access cavity preparation should be to gain a straight line access to the root apex and not merely to locate the canal orifice.
- Isolating the tooth with rubber dam followed by concept of debridement, drying and illumination of the access cavity provides best possible visualization.
- Magnification of the area with a suitable tool definitely makes a difference in assessing the floor of the pulp chamber in respect to the dentinal map and its importance in the location of canal orifices.
- Surgical operating microscope having different stepwise magnifications, fiberoptic coaxial illumination, stereoscopic vision and built in video camera becomes an indispensable tool not only to visualize the complexity of the root canal anatomy but also for better communication.
- The reports of *in vitro* studies have shown higher incidences of anatomical variations of the pulp spaces.
- *In vivo* studies using surgical operating microscopes have demonstrated a higher incidence of the anatomical variations of the pulp space.
- The *in vivo* studies using surgical operating microscopes are very limited.
- In this *in vivo* study 75% of the maxillary first molars had four canals which were suggestive of higher occurrence of MB2 canals in these teeth.
- Incidence of MB2 canals was found to be higher by 2% in males.
- In this study 66% of mandibular first molars exhibited three canals, 30% exhibited four canals and 4% exhibited five canals.

- 30% mandibular first molars showing incidence of four canals in this study was related to either one additional distal canal or an additional middle mesial canal.
- Out of 30 teeth showing four canals in the mandibular first molars 19 had an additional distal canal and remaining 11 had an additional middle mesial canal.
- All 4% mandibular first molar teeth exhibiting five canals had three canals in the mesial root and two canals in the distal root.
- The incidence of two separate distal canals in the mandibular first molar was found to be 23%.
- The incidence of two separate distal canals in the mandibular first molar was found to be 2% higher in males.
- The incidence of middle mesial canal in mandibular first molars was found to be 15%. This incidence was higher in females but being 2% it remains statistically insignificant.
- From the results of this study occurrence of middle mesial canal can also be related to the age group between 15 and 24.

REFERENCES

1. Weine FS, Healey HJ, Gerstein H, Evanson L. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. Oral Surg Oral Med Oral Pathol 1969;28(3):419-25.
2. Vertucci FJ. Root canal anatomy of human permanent teeth. Oral Surg 1984;58:589-99.
3. Finn SB. Chapter 20: Clinical pedodontics (4th ed). Philadelphia, PA: WB Saunders 1973;465.
4. Wayman BE, et al. Relative frequency of teeth needing endodontic treatment in consecutive 3350 endodontic patients. J Endod 1994;20:399-401.
5. Kim S, et al. The Dental Clinics of North America. Microscopes in Endodontics. USA: Philadelphia: WB Saunders 1997; 41(3):418.
6. Weller RN, Niemczyk SP, Kim S. Incidence and position of canal isthmus. Part I. Mesiobuccal root of maxillary first molar. J Endod 1995 July;21(7):380-83.
7. Ingle JI. Endodontics (1st ed). Philadelphia: Lea and Febiger 1965;61-65.
8. Kulild JC, Peters DD. Incidence and configuration of canal systems in the mesiobuccal root of maxillary first and second molars. J Endod 1990 Jul;16(7):311-17.
9. Hess W. Anatomy of the teeth of permanent dentition. London: John Bale and Sons and Danielson 1925;1-36.
10. Gilles J, Reader A. An SEM investigation of the mesiolingual canal in human maxillary first and second molars. Oral Surg Oral Med Oral Pathol 1990 Nov;70(5):638-43.
11. Okumura T. Anatomy of the root canals. JADA 1927;14:632.
12. Skidmore AE, Bjorndal A. Root canal morphology of mandibular first molar. Oral Surg 1971;32:778-84.
13. Seidberg BH, Altman M, Guttuso J, Suson M. Frequency of two mesiobuccal root canals in maxillary permanent first molars. J Am Dent Assoc 1973;87(4):852-56.
14. Vertucci FJ. The endodontic significance of the mesiobuccal root of the maxillary first molar. US Navy Med 1974;63(5): 29-31.
15. Chopra P, Bal CS. Study of root canals and their configuration in buccal roots of maxillary first permanent molar. Indian J Dent Res 1989 Jan-Mar;1(1):3-14.
16. Goel NK, Gill KS, Taneja JR. Study of root canals configuration in mandibular first permanent molar. J Indian Soc Pedod Prev Dent 1991 Mar;8(1):12-14.
17. Ting PC, Nga L. Clinical detection of the minor mesiobuccal canal of maxillary first molars. Int Endod J 1992 Nov;25(6): 304-06.
18. Baldassari-Cruz LA, Lilly JP, Rivera EM. The influence of dental operating microscope in locating the mesiolingual canal orifice. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002 Feb;93(2):190-94.
19. Vertucci and Williams. Root canal anatomy of mandibular first molar. JN Dental Association 1974;48:27-28.
20. Jacobsen EL, Nii C. Unusual palatal root canal morphology in maxillary molars. Endod Dent Traumatol 1994 Feb;10(1): 19-22.
21. Ibarrola JL, Knowles KI, Ludlow MO, McKinley IB Jr. Factors affecting the negotiability of second mesiobuccal canals in maxillary molars. J Endod 1997 Apr;23(4):236-38.
22. Gorduysus MO, Gorduysus M, Friedman S. Operating microscope improves negotiation of second mesiobuccal canals in maxillary molars. J Endod 2001 Nov;27(11):683-86.
23. Johal S. Unusual maxillary first molar with 2 palatal canals within a single root: A case report. J Can Dent Assoc 2001;67:211-14.
24. Neaverth EJ, Kotler LM, Kaltenbach RF. Clinical investigation (in vivo) of endodontically treated maxillary first molars. J Endod 1987 Oct;13(10):506-12.
25. Fabra-Campos H. Unusual root anatomy of mandibular first molars. J Endod 1985 Dec;11(12):568-72.
26. Slowley RR. Radiographic aids in the detection of extra root canals. Oral Surg Oral Med Oral Pathol 1974;37(5):762-72.
27. Vande Voorde HE, Odendahl D, Davis J. Molar 4th canals: frequent cause of endodontic failure? III Dent J 1975;44(12): 779-86.
28. Pomeranz HH, Eidelman DL, Goldberg MG. Treatment considerations of the middle mesial canal of mandibular first and second molars. J Endod 1981;7(12):565-68.
29. Stropko JJ. Canal morphology of maxillary molars: Clinical observations of canal configurations J Endod 1999 Jun;25(6):446-50.
30. Buhrley LJ, Barrows MJ, BeGole EA, Wenckus CS. Effect of magnification on locating the MB2 canal in maxillary molars. J Endod 2002 Apr;28(4):324-27.
31. Schwarze T, Baethge C, Stecher T, Geurtsen W. Identification of second canals in the mesiobuccal root of maxillary first and second molars using magnifying loupes or an operating microscope. Aust Endod J 2002 Aug;28(2):57-60.
32. Fogel HM, Peikoff MD, Christie WH. Canal configuration in the mesiobuccal root of the maxillary first molar: A clinical study. J Endod 1994 Mar;20(3):135-37.
33. Sempira HN, Hartwell GR. Frequency of second mesiobuccal canals in maxillary molars as determined by use of an operating microscope: A clinical study. J Endod 2000 Nov;26(11): 673-74.
34. Yoshioka T, Kobayashi C, Suda H. Detection rate of root canal orifices with a microscope. J Endod 2002 Jun;28(6):452-53.
35. Sidow SJ, West LA, Liewehr FR, Loushine RJ. Root canal morphology of human maxillary and mandibular third molars. J Endod 2000;26(11):675-78.

36. Weller RN, Hartwell GR. Impact of improved access and searching techniques on detection of the mesiobuccal canals in maxillary molars. J Endod 1989 Feb;15(2):82-83.
37. Pomeranz HH, Fishelberg G. The second mesiobuccal canal of maxillary molars. J Am Dent Assoc 1974;88(1):119-24.
38. Hartwell G, Bellizzi R. Clinical investigation of in vivo endodontically treated maxillary and mandibular first molar. J Endod 1982;12:555-57.
39. Ruddle CJ. Microendodontics: Identification and treatment of MBII system. J Calif Dent Assoc 1997 Apr;25(4):313-17.
40. Wasti F, Shearer AC, Wilson NH. Root canal systems of the mandibular and maxillary first permanent molar teeth of South Asian Pakistanis. Int Endod J 2001 Jun;34(4):263-66.

ABOUT THE AUTHORS

Sayed Abrar Bashir Ahmed (Corresponding Author)

Assistant Professor, Department of Conservative Dentistry and Endodontics, Government Dental College and Hospital, Mumbai Maharashtra, India, Phone: 09323204344, e-mail: abrars79@gmail.com abrarsayed_in@yahoo.com

Mansing Ganpati Pawar

Dean, Department of Conservative Dentistry and Endodontics Government Dental College and Hospital, Mumbai, Maharashtra, India