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Detection of Additional Canals and Position of Isthmii in the Mesiobuccal Root of Maxillary First Molars: An Invitro Study.

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Abstract
The main objective of root canal therapy is the chemical and mechanical cleansing of root canal system and three- dimensional filling with a bio compatible obturation material. The operator should have a thorough knowledge of the root canal systems and the various abberations. One of the reasons for failure of root canal therapy is the failure to locate the additional root canals. Maxillary and mandibular first molars are usually affected by caries at an early age. Hence it becomes imperative to locate and clean the additional canals in the mesiobuccal root of maxillary first molar for the long- term retainment of the tooth in the oral cavity.
The aim of this in vitro study was to detect the prevalence of the MB2 canal in the maxillary first molars of Kerala population and to find out the efficacy of various diagnostic techniques to detect its presence.
The position and various configurations of isthmii play an important role while root end filling in the endodontic surgery. This study also aims at studying the various configurations of isthmii at different sections of the root.
Materials & Methods:
139 permanent maxillary first molars were included in the study. Teeth were collected from the Department of Oral & Maxillofacial Surgery, Govt. Dental College Thiruvananthapuram. Calculus and stains were removed using an ultrasonic scaler. They were stored under 10% buffered formalin solution under room temperature. The crowns were removed at the level of the proximal cement enamel junction and pulp tissue was removed. Access cavities were prepared using air rotor handpiece and round bur and refined with Endo Z bur. The floor of the pulp chamber was then explored in order to locate the MB 1 and 2 canals in three stages.
Stage 1*: Initially the canals were located using an endodontic explorer DG-16. (Hu Friedy). The canal was negotiated and confirmed by the insertion of a size 10 file (Dentsply India).*
Stage 2*: Further efforts to locate the canals were carried out under magnification using a surgical microscope (Seiler surgical microscopes, USA.) and the canals were then located using a no 10 file.*
Stage 3*: Dentin on the chamber floor was removed (troughing) within 3 mm from the MB1 canal towards the palatal canal in a groove 2 mm deep using a small round bur under magnification with a dental operating microscope to locate the MB 2 canal.*
The number of canals detected by each stage was analysed statistically and observations were made.
Stage 4*: Clearing of the teeth. Finally the teeth were subjected to progressive decalcification and clearing, after injection of Indian ink into the root canal system, the canal configurations were studied and classified based on Yoshioka's classification.*

Location And Position Of Isthmii
Serial sections were taken at a distance of 3, 4 and 5 mm from the apex of the mesiobuccal root of 35 maxillary first molars. These sections were stained with methylene blue and were observed under surgical operating microscope. The data obtained were tabulated and evaluated.
Results:
In this study, we found out that 50% of the teeth examined had MB2 canals and 54% of the roots had a single canal in the root. There was a statistically significant difference between the efficacy of the diagnostic tests employed in the detection of the canal. In the second part of the study, we found out that the type of isthmii at 3, 4 and 5 mm do not vary significantly from each other.
Conclusion.
Within the limitations of this study, it can be concluded that
50 % of the teeth evaluated had MB2 canal. Hence identification and debridement of the canal is important in providing long term endodontic success.
The use surgical operating microscope and selective dentin removal is highly recommended in the endodontic treatment of teeth.
The type of canal isthmii do not vary significantly at a distance of 3, 4 and 5mm from the apex of the mesiobuccal root.
Key Words: MB 2 canal, Maxillary First Molar, Surgical Operating Microscope, Selective Dentin Removal, Isthmus.

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I. Introduction

The main objective of endodontic therapy is thorough mechanical and chemical cleansing of the entire pulp cavity and its complete obturation with an biocompatible filling material. The hard tissue surrounding the dental pulp can take a variety of configurations and shapes. A thorough knowledge of the tooth morphology, careful interpretation with the help of angled radiographs, and adequate access to the tooth's interior are prerequisites for treatment. Only after the successful completion of this phase of therapy can the clinician perform shaping and cleaning to determine the apical limits and dimensions of the preparations, and to perform microsurgical procedures successfully.

Permanent first molar teeth may become carious at an early age and may require root canal treatment for long-term retention. But several cases of endodontically treated first molar are subjected to failure. A major cause of endodontic failure when treating maxillary molars is the inability to locate, debride, and fill the frequently present second mesiobuccal canal.

Before an article written by Weine et al in 1969, mesio buccal root of maxillary first molar was thought to have only one canal. Since then, many papers have been published concerning the types of canal systems present in that root and their percentage. The most common cause of endodontic failure is apical percolation and subsequent diffusion into the root canal.

The canal anatomy of the MB root has been described by a number of investigators and the incidence of the second MB canal in first and second maxillary molars ranges widely. This large variation may be because of the different criteria used for evaluating the presence of this canal. Factors such as sample size, illumination and magnification may also contribute to the varied results reported in the literature.

Several magnification systems have been advocated over the years. The most convenient and popular have been loupes with varying degrees of magnification. The use of surgical headlamps and dental loupes has evolved into the use of the surgical operating microscope (SOM). The introduction of the ***surgical operating microscope*** **(SOM)** to endodontics has dramatically changed the practice of the specialty. The SOM provides the clinician with superior lighting and magnification and the ability to treat cases that previously may have been deemed untreatable or resulted in a compromised prognosis.

The purpose of this study was to identify the MB2 canals in the mesio buccal roots of maxillary molar teeth using a three -stage technique: direct visualization and use of probe, magnification and dentine removal (troughing) and use of magnification.

The maxillary molar and its mesiobuccal root are also often treated surgically **(1).** However the success rate of these teeth is lower than mandibular first molar after surgery **(2).** The difference between these teeth may be due to anatomical factors such as ramii and isthmii.

An isthmus is a narrow ribbon shaped communication between two root canals that contain pulp tissue. It is also known as the corridor **(3),** a lateral interconnection **(4)** or a transverse anastomosis **(5)**. Any root containing two canals has a high incidence of isthmuses. In the past not only was the canal isthmus overlooked but was also difficult to prepare even if located. But now with the advent of microscopic endodontic techniques

it is possible to visualize the resected root surface and identify the isthmus and prepare it with ultrasonic tips and fill it with appropriate materials. The incidence of an isthmus was greatest in the apical 3-5 mm. In teeth with two canals, a complete or partial isthmus was always present in sections at 4 mm from the apex.

The morphology of the resected MB root ends of the maxillary first permanent molars was investigated and the location of the canal isthmus and the accessory canals between the two MB canals were evaluated.

DETECTION OF ADDITIONAL CANALS IN THE MESIOBUCCAL ROOT OF MAXILLARY FIRST MOLARS

MATERIALS AND METHODS

139 permanent maxillary first molars were included in the study. Teeth were collected from the Department of Oral & Maxillofacial Surgery, Govt. Dental College, Thiruvananthapuram. Calculus and stains were removed using an ultrasonic scaler. They were stored under 10% buffered formalin solution under room temperature.

Collection, storage, sterilization and handling of extracted teeth to be used for educational purposes at the dental branch follows Occupational Safety And Health Administration (OSHA) and the Center For Disease Control And Prevention (CDC) recommendations and guidelines.

The crowns of 104 teeth were removed at the level of the proximal cemento enamel junction and pulp tissue was removed. Access cavities were prepared using air rotor handpiece and round bur and refined with Endo Z bur. The floor of the pulp chamber was then explored in order to locate the MB 1 and 2 canals in three stages.

Stage 1: Initially the canals were located using an endodontic explorer DG-16. (Hu Friedy). The canal was negotiated and confirmed by the insertion of a size 10 file (Dentsply India).

Stage 2: Further efforts to locate the canals were carried out under magnification using a surgical microscope(Seiler surgical microscopes, USA.) and the canals were then located using a no 10 K file.

Stage 3: The MB2 canal was located using a dental operating microscope. This was done by removing the dentin (troughing) on the chamber floor within 3mm from the MB1 canal towards the palatal canal in a groove 2mm deep using a small round bur under magnification.

Stage 4: Canal staining and clearing technique.

The teeth were then immersed in 3% sodium hypochlorite solution for 24 hours to dissolve any pulp tissue. The teeth were washed in running water for 2 hours, air dried for 24 hours and then root canal systems injected coronally with drawing ink using a hypodermic needle assisted by vacuum suction apically. After another 12 hours drying, the teeth were decalcified in 8% nitric acid for 8 – 10 hours. Decalcification was monitored periodically and continued until the teeth could be pierced by a sharp explorer. Decalcified teeth were washed in running water tap water for 4 hours and dehydrated in ascending concentrations of isopropyl alcohol (75%, 90%, 100%) each for 12 hours. The teeth were then rendered transparent by immersing in methyl salicylate. The cleared teeth were examined under a magnifying glass (X3 magnification).

The following observations were made:

Number of root canals per tooth. (defined as root canal orifices in the pulp chamber)

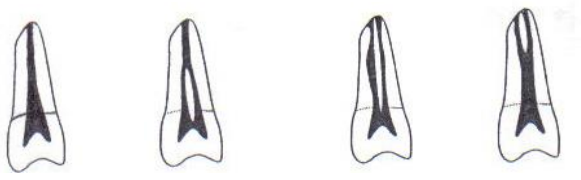
Root canal configuration in each root.

Presence and location of lateral canals and intercanal communications.

Yoshioka et al in 2004 has classified canals into 5 categories. Types I-IV followed Weine's (1996) classification. It was difficult to distinguish type III from type IV because dentin removal (troughing) under magnification prevented the determination of the level of canal division, so the number of these canals were aggregated. Type V was defined as the root canal configuration having more than 2 main canals. Any anatomical structure that branched off from the main canal more than 3mm from the apex, with its egress located within 3 mm of the apex, was defined as another main canal. Those canals that did not meet these criteria were considered as accessory canals. Those branches of main canals that diverged at right or oblique angles to exit on the lateral aspect of the root were defined as lateral canals. Those complex canal ramifications that ran from and between main canals but did not communicate with the root surface were defined as intercanal communications. The number of canals detected by each stage was analysed and tabulated.

WEINS CLASSIFICATION OF ROOT CANAL MORPHOLOGY

Type I Type II Type III Type IV



LOCATION AND POSITION OF ISTHMII

METHOD 35 permanent maxillary first molars were included in the study. The mesiobuccal root of the molars were sectioned from 3, 4 and 5 mm from the root apex perpendicular to the long axis of the root using a precision saw (Isomet 1000, Buehler, USA). These positions closely resembled the level of sectioning in endodontic surgery. The sections were stained with methylene blue and were examined under the surgical operating microscope. The data were tabulated and isthmus configurations were classified.

STATISTICAL ANALYSIS

Data were analyzed using, Statistical Package for Social Sciences (SPSS) version 10, computer software. Data are expressed in its frequency and percentage as well as mean, median and standard deviation. To elucidate the associations and comparisons between different parameters, Chi square (χ^2) test was used as nonparametric test. Different diagnosis stages and different isthmus groups were compared using Kruskal Wallis ANOVA. For all statistical evaluations, a two-tailed probability of value, < 0.05 was considered significant.

II. Results

Table 1 Number of maxillary molars classified by root canal types

Parameter	Type I	Type II	Type III & IV	Type V	Total
No. of Maxillary First Molar	54 (51.92%)	30 (28.85%)	20 (19.23%)	0 (0.00%)	104 (100%)

Of the 100 teeth tested, 54(51.92%) have type I canal configuration.
Type II canal configuration is shown by 30 (28.85%) teeth. 20 teeth
(19.23%) show either Type III & IV configuration. 3 root canals (Type V) are not seen in any of the teeth tested.

Table 2 Number of teeth classified by the number of MB canals confirmed in each stage

Stage	Number of Canals			Total
	0	1	2	
Stage 1	2	86	16	104
	1.90%	82.70%	15.40%	100.00%
Stage 2	2	79	23	104
	1.90%	76.00%	22.10%	100.00%
Stage 3	1	70	33	104
	1.00%	67.30%	31.70%	100.00%
Stage 4	–	54	50	104
		51.92%	48.08%	100.00%

Chi square = 36.692; P < 0.001

When the teeth classified by the number of MB canals confirmed in each stage, stage 1 showed that 86(82.7%) of the teeth had only I canal while 2 canals were seen in 16(15.40%) of the teeth. No canals were detected in the mesiobuccal root of the remaining 2 teeth in stage 1.

On proceeding to stage 2, the total number of teeth having 2 canals in the mesiobuccal root increased to 23(22.10%), while 79(76.00%) of the teeth were found to have single canal.

In stage 3, the number of teeth having 2 canals in the mesiobuccal root increased upto 33(31.70%). And the number of teeth with 1 canal decreased to 70(67.3%). No canal was detected in 1 tooth even in stage 3.

Upon clearing the teeth, 50 (48.08%) tested teeth had 2 canals belonging to type II, III and IV configurations. 54 (51.92%) teeth had 1 canal in the mesiobuccal root.

Table 3 Comparison of mean number of root canals in each stage

Stage	Mean	Median	+ SD	Kruskal Wallis H value	p value
Stage 1	1.13[a]	1.00	0.40	36.512	< 0.001
Stage 2	1.20[ab]	1.00	0.45		
Stage 3	1.31[b]	1.00	0.48		
Stage 4	1.51[c]	2.00	0.50		

a, b, c – Means with same superscript do not differ each other (Duncan's Multiple Range Test)
Statistical analysis was done to evaluate the usefulness of surgical operating microscope and selective dentin removal. It was found out that the number of root canals found out in stage 3
(Selective dentin removal under surgical operating microscope) are statistically significant when compared to that found out using stage 1 (endodontic explorer & no 10 K file).

Table 4 Distribution of maxillary first molars with respect to the confirmed number of MB canals in stage 3 and true number of MB canals.

True number of MB canals (cleared tooth)	Confirmed number of MB canals in stage 3			Total
	0	1	2	
1	1 0.96%	53 51.9%	0 0.0%	54 51.9%
2	1 0.0%	16 15.38%	33 31.7%	50 48.1%
3	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Total	1 0.96%	70 67.3%	33 31.7%	104 100.0%

53 teeth were recognized to be having one canal in stage 3. Out of 50 teeth with 2 mesio buccal canals, 33(66%) were recognized as having 2 root canals in stage 3. From this table it is clear that 16 teeth with 2 canals were diagnosed as single canal in stage 3.

When the teeth classified by the number of MB canals confirmed in each stage, stage 1 showed that 86(82.7%) of the teeth had only I canal while 2 canals were seen in 16(15.40%) of the teeth. No canals were detected in the mesiobuccal root of the remaining 2 teeth in stage 1.
On proceeding to stage 2, the total number of teeth having 2 canals in the mesiobuccal root increased to 23(22.10%), while 79(76.00%) of the teeth were found to have single canal.
In stage 3, the number of teeth having 2 canals in the mesiobuccal root increased upto 33(31.70%). And the number of teeth with 1 canal decreased to 70(67.3%). No canal was detected in 1 tooth even in stage 3.

Table5 Classification of teeth based on the type of isthmii.

Canal Type	Isthmus Group		
	3 mm Type	4 mm Type	5 mm Type
One canal	22 62.90%	20 57.10%	17 48.60%
Two canals	8 22.90%	7 20.00%	11 31.40%
Two canals, one of which showed partial isthmus formation	2 5.70%	3 8.60%	2 5.70%
Two canals joined by an isthmus	3 8.60%	5 14.30%	5 14.30%
Total	35	35	35

Chi square = 2.545; P > 0.05

At 3mm sections; 22 teeth (62.9%) showed single canal configuration. 8 teeth (22.90%) showed two separate canals. 2 teeth (5.7%) showed two canals with partial isthmus formation. 3 teeth (8.60%) showed 2 canals joined by an At 4 mm sections, 20 teeth (57.10 %) showed single canal configuration .7 teeth (20.00%)

showed two separate canals. 3 teeth (8.60%) showed two canals with partial isthmus formation. 5 teeth (14.30%) showed 2 canals joined by an isthmus

At 5 mm sections, 17 teeth (48.60 %) showed single canal configuration. 11 teeth (31.40%) showed two separate canals. 2 teeth (5.70%) showed two canals with partial isthmus formation. 5 teeth (14.30%) showed 2 canals joined by an isthmus.

Table 6

Isthmus Group	Mean	Median	+ SD	H value	p value
3 mm Type	1.60	1.00	0.95		
4 mm Type	1.80	1.00	1.11	1.360	> 0.05
5 mm Type	1.86	2.00	1.06		

The table shows that there is no significant difference between the type of isthmii at 3, 4and 5 mm.

III. Discussion

In the study of human anatomy, root canal morphology is considered as the most difficult to classify [(3)]. Even though the external surfaces may appear relatively simpler and uniform, the internal anatomy could be complex. From the consistency of certain anatomical features in tooth type as well as different races, it is apparent that such features are genetically determined [(6,7,8,9)].

Apart from the surprising variations revealed in such anatomical studies, there are important anthropological implications [(6, 10, 11)] in the findings as well as important inferences for the endodontist [(12)]. Even more surprising, the success rates are not apparently related to tooth type [(13,14)]. The explanation must lie in as yet undiscovered microbial ecological events [(15)] associated with the treatment procedures, rather than on the host response .

Successful root canal treatment depends on adequate cleaning, shaping and filling of the root canal system. The operator should have a detailed knowledge of the root canal morphology of each individual tooth being treated.

Traditionally, most endodontic canal detection procedures have relied on the doctor's tactile dexterity and mental image of the canal system, because the ability to visualize the canal orifices was severely limited. This has changed with the utilization of enhanced vision systems in endodontics. The use of surgical headlamps and dental loupes has led into the introduction of the surgical operating microscope (SOM). The SOM provides the clinician with superior lighting and magnification and the ability to treat cases that previously may have been deemed untreatable or resulted in a compromised prognosis [(16,17)]. The magnification range of dental loupes is from X2.0 to X6.0. The SOM can be equipped with a range from X4.0 to X30.0, if desired. The fiber optic light of the SOM provides 2 to 3 times the light of a surgical headlamp [(18)].

The SOM is widely used in all phases of endodontics, including locating calcified canals. Calcified canals can be located with help of endodontic explorer, troughing with burs or ultrasonic tips, and close visual inspection of the root anatomy, which gives clues to the location of the hidden canal. But overzealous troughing with the help of burs and other ultrasonic tips can lead to accidental perforation. Using the SOM gives intimate detail of an area that otherwise would be under-illuminated and under-magnified, requiring guesswork and great caution [(16,17)]. Many studies have reported on the incidence of the MB2 canal in maxillary molars [(18, 19, 5)] and these studies have produced variable results. The incidence of the MB2 canal has been reported to be as low as 18.6% in an in vivo study conducted by **Hartwell and Bellizzi ,1982[(22)]**, and as high as 95.2% in an in vitro study conducted by **Kulild and Peters ,1990[(23,24)]**. Comparison of data from these studies cannot be done as each study has its own means of research. Some studies were conducted in vitro on extracted teeth, whereas others were performed in a clinical setting. Different methods for locating the mesiolingual canal result in differing conclusions as to its incidence.

Seidberg et al. in 1973[(25)] and Pomeranz and Fishelberg[(26)] in 1974 published results of both in vitro and in vivo studies. The Seidberg et al. in vitro study found that out of 100 teeth, 62% had an MB2 canal. Their in vivo study, however, reported that out of 201 teeth, only 33.3% had an MB2 canal. Pomeranz and Fishelberg's in vitro study found that out of 100 teeth, 69% had an MB2 canal. The in vivo study reported that out of 100 teeth, 31% had two canals. In a clinical setting, limited access and visibility can prevent the operator from detecting additional canals. The risk of perforation could also deter the operator from exploring for additional canals. This may explain the lower incidence of MB2 canals found when compared with in vitro studies. It is possible that if one had a greatly enhanced view of the operating field via the SOM or loupes, the ability to locate the MB2 canal would increase.

In our study, we found that 50(48.07%) teeth had 2 canals in the mesiobuccal root. Teeth were classified based on Weine's classification. Type II canal configuration is shown by 30 (28.85%) teeth. 20 teeth (19.23%) show either type III & IV configuration. 54 (51.92%) teeth had 1 canal in the mesiobuccal root.

When evaluating each step statistically using multiple Duncan test, it was found out that that the number of canals found out in stage 3 differed significantly from stage 1. This can be attributed to selective dentin removal done in stage 3.

The MB2 canal is often located anteriorly to line from the MB1 and palatal canals. Troughing the chamber floor within 3 mm from the MB1 canal towards the palatal canal with an ultrasonic tip under the microscope can make the detection of the MB2 canal more successful. Dentin removal exposed the MB2 canals effectively since the orifices of the MB2 canals were calcified or located more apically than the pulp chamber floor. This was also advocated by **Go¨rduysus et al.** [(27)] who selectively removed dentine from the pulp chamber floor and at the mesial-axial line of the cavity, along the mesiobuccal subpulpal groove. But the gouging of pulp dentin floor should be done with caution lest it might lead to accidental perforation. Perforations may ultimately compromise the prognosis of root filled teeth [(28,29)]. It is thus recommended that negotiation of the MB2 should be performed carefully within a safety limit.

Hence the use of selective dentin removal under surgical operating microscope is highly recommended as a diagnostic aid to unravel hidden canals.

However; it is also found that the number of canals found out using stage 3 significantly differed from stage 4. 16 teeth with an additional canal in their mesiobuccal root were not detected even in stage 3. This can be attributed to the presence of the following factors like orifice calcification or diversion of the canals at a lower level.

The success rate of endodontic therapy has been quoted as ranging from 78-94% [(30)]. Teeth which appear well obturated in the radiographs have shown to undergo failure after a few years. This may be attributed to the presence of a persistent apical periodontitis due to the missed additional canals which cannot be accessed clinically due to their lower diversion.

Even though nonsurgical procedures are the treatment of choice in endodontics, surgical procedures are also performed more frequently performed to rectify cases in which nonsurgical root canal therapy has been unsuccessful. With the use of surgical operating microscope with high power illumination and magnification, the operator can see the intricate anatomy of the root canal system. The use of micro- mirror magnification coupled with newly designed ultrasonic tips allows better, more conservative and more accurate preparation of the root end to receive the root ending filling material.

Long-term results of surgical endodontic therapy show a success rate of 44.1% (for an observation period of 6 months to 8 years) for 136 roots of premolar and molar teeth [(31)]. In another study complete healing was observed in 65% of 424 recall cases [(1)]. Another group of authors reported that 72% of 46 molar apicoectomies were successful [(32)].

It has been suggested that many of the surgical procedures were a failure due to the lack of seal of the resected root [(16,17)]. This could be attributed to the failure to properly prepare the isthmus area of the posterior teeth.

In our study; we took serial sections at 3, 4 and 5 mm from the apex using a Precision Saw, Isomet 1000, Buehler. These levels closely resembled the level of sectioning in endodontic surgery.

We found that the sections at the 3, 4 and5mm levels in the same root often showed similar canal configurations. Consequently, it can be concluded that the level of root sectioning in the surgical procedure is irrelevant.

The concept of partial isthmus formation is difficult to articulate. The cross-section of this canal is similar in shape to a comma. The tail extension of the canal may come about in several ways. First, it may be part of the fin or loop of the root canal.

Second, the root may be sectioned at the point where one canal starts to twist and turn to merge with the second canal. Third, this feature may actually be a partial isthmus with a complete isthmus formed elsewhere in the root.

IV. Conclusion

The following conclusions were drawn:

1. Among the 104 teeth tested, 50(48%) teeth have an additional canal in the mesiobuccal root.
2. 66 % of the additional canal in the mesiobuccal canal was found out using selective dentin removal under surgical operating microscope.
3. 16 (33%) teeth with an additional canal in their mesiobuccal root were not detected even with selective dentin removal under magnification.
4. The type of isthmii seen at 3, 4 and 5 mm from the apex of the mesiobuccal root does not significantly differ from each other.

Our study has shown selective dentin removal under surgical operating microscope to be a useful diagnostic aid in endodontics. Also we can conclude that the level of sectioning is not that relevant in the apicoectomy of the mesiobuccal root as long as root end preparation and filling is properly done.

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