Analysis of Root Canal Anatomy & Morphological Variations of Maxillary 1st Molar by Different Methods - An In Vitro Study

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Abstract:
Background: Successful endodontic treatment involves accurate diagnosis, good understanding of the biological principles and excellent execution of the treatment. To execute an excellent treatment, it’s imperative that the clinician has comprehensive knowledge of the root canal anatomy and then know-how to locate and treat this anatomy.
Objective: To analyze the internal anatomy of the maxillary first molar, to report the incidence of fourth root canals by comparing the efficacy of three diagnostic methods, Operating microscope, Cone beam computerized tomography and clearing technique.
Material methods: A sample size of 126 sound non carious, intact human maxillary 1st molar were taken for the study and were divided into three groups according of method of analysis of root canal system- (Group 1: operating microscope, Group 2: Cone beam computerized tomography, Group 3: clearing technique). Anatomical variation in form of additional canal in mesiobuccal root was analyzed for total incidence.
Results: For statistical analysis, Mean and Standard deviation were calculated for each group by using chi square test which revealed statistically significant difference between group 2 and 3 and non-significant difference between group 1 and group 2.

Keywords: Maxillary first molar, mesiobuccal second canal, operating microscope, Cone Beam Computerized Tomography.

Introduction:
The objective of successful endodontic therapy is thorough mechanical and chemical cleansing of entire root canal system and its complete obturation with inert filling material. Along with diagnosis and treatment planning, thorough knowledge of root canal morphology and its variation is a basic requirement for successful endodontic therapy. Thus the knowledge of internal morphology of root canal system, which is usually complex, is extremely important issue regarding planning and execution of endodontic therapy¹.

Variations in dental anatomy are found in all groups of teeth, and knowledge of these variations is the key to successful endodontic therapy as the ability to find and properly treat all these root canals may prevent future failures². Maxillary first molars are particularly noteworthy for anatomical variations of the root canals. The most common form of the permanent maxillary first molar has 3 roots and 3 canals.³ According to literature review maxillary 1st molar have 3 roots in 95.9% cases and 3 root canals in 56.8% and 4 root canals in 43.1% cases respectively. Presence of 4th canal is usually reported in mesiobuccal root in 95.6% cases because of its broad buccolingual dimension and associated concavities on its mesial and distal surface. Less variations occur in distobuccal and palatal root containing 1 canal in 98.3% and 99% cases respectively and the failure often is due to presence of this 4th additional canal which clinician fails to detect, debride and obturate.

Hess et al (1925) reported presence of 4 canals in 54% of maxillary molars.⁴ Where as Wein et al. (1969) reported an incidence of 4th canal to be 62% in maxillary molars.⁵ Pineda and kuttler (1972) reported an incidence of 51.5% of additional canals in maxillary first and second molar.⁶ Root canal anatomy is studied by both in vivo (clinical) and in vitro (laboratory) methods. In vivo methods include clinical treatment of a tooth followed by radiographic evaluation of the root canal anatomy. In vitro methods include direct observation, microscopic observation, macroscopic sectioning, microscopic sectioning, dye, filling and decalcification, filling and clearing, radiography, contrasting media (hypaque), cone beam tomography. In comparing laboratory and clinical findings, Seidberg et al. (1973) noted a 62% versus a 33.3% incidence of two canals in the mesiobuccal root of maxillary first molars.⁷

An important aid for locating root canals is the dental operating microscope (DOM), which was introduced into endodontics by Bauman in 1997 to provide enhanced lighting and visibility. It brings minute details into clear view. It enhances the dentist’s ability to selectively remove dentin with great precision, thereby minimizing procedural errors.

Cone beam computerized tomography is another recently introduced technique designed specifically for hard tissue evaluation in maxillofacial region commonly used to produce undistorted three dimensional view of root canal anatomy with a
significantly lower effective radiation dose compared with conventional computed tomography. Huumonen et al. (2006) evaluated 39 root filled maxillary molars with suspected apical periodontitis using CBCT and found that the MB root had two canals in 30 teeth of which 27 had an MB2 canal that was not filled. Canal staining by clearing technique is another commonly used laboratory method to analyze root canal anatomy of teeth. The advantage of this method is that it is non distractible easy to perform which allow detection of intricate details owing to penetration of dye along with highest degree of accuracy. Weller et al (1995) studied the morphology of MB root of maxillary molar using clearing technique and showed that 60% of mesiobuccal root had 2 canals with type 2 configuration.

Therefore, this in vitro study was conducted to analyze the internal anatomy of the maxillary first molar to report the incidence of fourth root canals by comparing the efficacy of three diagnostic methods, Operating microscope, Cone beam computerized tomography and clearing technique.

Material and Methods:
Methodology:

In this study 126 freshly extracted sound maxillary 1st molars were taken from the Department of Oral and Maxillofacial Surgery. The presence of any root fracture or cracks was ruled out by visually inspecting these teeth with naked eye. Surface of all the selected teeth were debrided of adhering tissue using no 15 scalpel blade. These teeth were then disinfected by overnight immersion in 5.25% sodium hypochlorite solution and then stored in normal saline solution until usage.

These teeth were then randomly divided into three groups for analyzing variations in anatomical & morphological features of root canal anatomy in the form of additional 4th canal according to different methods.

Group 1: In this group 42 maxillary 1st molar were analyzed for presence of additional canal in mesiobuccal root by using dental operating microscope.

Group 2: In this group 42 maxillary 1st molar were analyzed for presence of additional canal in mesiobuccal root by using cone beam computerized tomography.

Group 3: In this group 42 maxillary 1st molar were analyzed for presence of additional canal in mesiobuccal root by using clearing technique.
Preparation of Specimen for Dental Operating Microscope Evaluation
In each sample conventional access preparation was done with airotar by using endo access burs, sharp explorer, mirror, and 2.5% sodium hypochlorite was used for irrigation and canals were negotiated by using #08 and #10 K-files under unaided vision. Since palatal canal is usually largest in diameter, it was negotiated at first by 10-k file from buccal direction. Mesiobuccal and distobuccal canals were then negotiated by keeping direction k-file in Disto/palatal and Mesiopalatal side. To uncover the additional canal orifice (MB2) in mesiobuccal root, dentin was selectively removed from the pulp chamber at the mesial-axial line angle of the cavity, along the mesiobuccal subpulpal groove. Once the mesiobuccal-2 canal orifice was located, attempts were made to negotiate the canal with size 6, 8, or 10 number K files. If these attempts were unsuccessful more dentin was removed further apically to pursue the mesiobuccal-2 canal deeper into the root, and attempts to negotiate the canal were repeated. This procedure was conducted using intermittent irrigation with 5.25 % NaOCl and saline. Radiographs of all these samples were taken by using an XCP, 70 KVP, 10 mA, and 0.4 second of exposure at angulations of 20° mesial and 0° vertical for analyzing canal morphology. Then all these samples in which the mesiobuccal-2 canal was not located and those in which the canal was located were submitted to further investigation under the operating Microscope. To allow the unimpeded microscopic view these access cavities were further extended from already established conventional outline form. To negotiate mesiobuccal-2 canals under Operating microscope further selective dentin removal along the sub pulpal groove was done by using tapered fissure bur. Mesiobuccal-2 canals were then negotiated by using 8 number k file along with other three canals. Once the mesiobuccal-2 canal was negotiated all the four orifice present at pulpal floor was widened by using SX protaper hand file along with glyde and copious irrigation. At this stage pulp chamber were photographed through the Operating microscope at 20x magnification as shown in figure 4.

Preparation of Specimen for Cone Beam Computerized Tomography Evaluation
For analysis of unusual root canal anatomy by cone beam computerized tomographic method two ‘U’ shaped templates mimicking the natural arch was made using with modeling wax. Out of total 42 samples of this group, 21 samples of maxillary molar were embedded in each arch with roots inside the wax and occlusal surface exposed. The base of the wax template was made flat enabling the plate to sit stationary on top of the plastic bite plane roughly centered in focal trough area. The prepared sample plates were then placed onto the bite plane of Sinora orthophos XG CBCT unit. To confirm presence of additional canal, axial section CBCT images were taken with Sinora orthophos XG CBCT unit with tube voltage 85 KV, tube current of 6 Ma and exposure time of 14.4 seconds as show in figure 5.

Preparation of Specimen for Clearing Technique
In all 42 samples of group 3, conventional access preparation was done with airotar using endo access bur (safe end cutting bur) and canals were negotiated by using number 8 and 10 K-files. These samples were then placed in container of 5.25% sodium hypochlorite for 24 hours to remove organic debris and then washed.
in tap water. These samples were again placed in 5% Nitric acid for decalcification for next 4 days at room temperature. The nitric acid was changed daily and samples in container were agitated several times each day. After decalcification these samples were again washed in tap water and submitted to dehydration in 70% ethyl alcohol solution overnight, followed by 90% solution for 1 hour and three 100% ethyl alcohol rinses for an hour each as shown in figure 3. At the end of this period no opacity remained in these samples. Placing these samples in methyl salicylate for 15-30 minute for 3 days completed clearing procedure. At the end of third day these samples become completely transparent. Then methylene blue dye was injected into the root canals with the help of 27-gauge luer hook needle. After the dye had dried, root canal morphology was analyzed to record additional 4th canal and photographs were taken as shown in figure 6.

Total Number of teeth and individual teeth in each group with mesiobuccal - 2 canal were calculated. Readings were tabulated and subjected to statistical analysis using Chi square test. Mean deviation and statistical significance among inter groups were calculated using Chi square and one way ANOVA test.

![Maxillary first molar with mesiobuccal 2 root canal after die penetration in Clearing Technique](image)

**Observations and Results:**

<table>
<thead>
<tr>
<th>Table I- Total incidence of number of root canals in each root of maxillary first molar in three groups</th>
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</thead>
<tbody>
<tr>
<td>Root canal type</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Palatal</td>
</tr>
<tr>
<td>Mesiobuccal 1</td>
</tr>
<tr>
<td>Mesiobuccal 2</td>
</tr>
<tr>
<td>Distobuccal 1</td>
</tr>
<tr>
<td>Distobuccal 2</td>
</tr>
</tbody>
</table>

- **Table I**- Shows incidence of different root canals in each root of maxillary first molar analyzed by three different methods (Groups)
- **Group 1**: Operating microscope, Group: 2 Cone beam computerized tomography (CBCT) and Group 3: Clearing technique.
- **In group 1 (operating microscope)**: All 42 maxillary first molars showed 100% incidence for mesiobuccal 1 root canal, palatal root canal and distobuccal root canal.
- Incidence of mesiobuccal 2 root canal was found to be 66.66%.
- None of sample in this group showed distobuccal 2 canals.

- **In group 2(CBCT):**
  - All 42 maxillary first molars showed 100% incidence for mesiobuccal 1 root canal, palatal root canal and distobuccal root canal.
  - Incidence of mesiobuccal 2 root canal was found to be 76.19%.
  - Whereas distobuccal 2 canal showed an incidence of 4.76%.

- **In group 3 (clearing technique):**
  - All 42 maxillary first molars showed 100% incidence for mesiobuccal 1 root canal, palatal root canal and distobuccal root canal.
• Incidence of mesiobuccal 2 root canal was found to be 52.38%.
• Whereas distobuccal 2 canal showed an incidence of 2.38%.

Table II - Prevalence of Mesiobuccal 2 root canal (MB2) In Maxillary First Molar of three groups:

<table>
<thead>
<tr>
<th>Type of root canal</th>
<th>Group 1 (N=42)</th>
<th>Group 2 (N=42)</th>
<th>Group 3 (N=42)</th>
<th>Total incidence (126)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesiobuccal 2 root canal (MB2)</td>
<td>28 (66.66%)</td>
<td>32 (76.19%)</td>
<td>22(52.38%)</td>
<td>65.08%</td>
</tr>
</tbody>
</table>

- Table 11- Shows prevalence of Mesiobuccal 2 root canal (MB2) canal in maxillary first molar analyzed by different methods (groups).
- Total incidence of MB2 root canal in maxillary first molar was found to be 65.08%.
- Cone beam computerized tomography (Group 2) showed maximum incidence of mesiobuccal 2 root canal (76.19%) followed by operating microscope group (66.66%) and clearing technique (52.38%).

Discussion:

The root canal anatomy shows considerable variation and complexity that requires special attention while performing root canal therapy. A thorough knowledge of root canal morphology is a fundamental prerequisite to help ensure optimal outcomes of root canal treatment. There is a wide range of variation in the literature on maxillary first molars with respect to the number of canals in each root, the number of roots, and the incidence of root fusion. Thus for this study maxillary molars were analyzed for variation in root canal anatomy particularly in relation to mesiobuccal canal which shows maximum variation.

According to Jin lee et al. (1991) the mesiobuccal root canal anatomy of maxillary first molar teeth presents an endodontic challenge due to their considerable morphological variability and complexity. Special attention should be given during their endodontic management to prevent the undesirable consequences when they are left untreated with missed root canals. Allan et al. (2001) noticed that about 8.8% of endodontic failure cases that need retreatment were due to presence of untreated missed canal.

Traditionally, many methods like "champagne or bubble test" with warmed 2.6% NaOCl, staining the chamber with 1% methylene blue, the use of sharp explorers, looking for bleeding signs, red line test, white line test and obliquely angled preoperative radiographs are used to locate extra canals. But now a days with advancement in technology and introduction of newer techniques some newer methods like use of magnifying loupes, operating microscopes, computerized radiographic techniques like conventional computerized tomography, cone beam computerized tomography, X-ray computed transaxial microtomography are also introduced. All these newer methods greatly enhanced the negotiation of mesiobuccal root canal systems in maxillary molar.

Thus this study was carried out to analyze the root canal system of maxillary first molar by comparing efficacy of three different methods which were operating microscope, cone beam computerized tomography and clearing technique. The first method used to report the incidence of mesiobuccal 2 canal in present study was dental operating microscope. Microscopes have been used for decades in various medical specialties and have recently been introduced to endodontics. Reasons for this introduction to endodontics include enhanced visibility and lighting. According to Stropko (1999) Operating Microscope clinically enhance the ability to identify MB2 canals in maxillary first molars from 20%, to 92%. Thus Operating microscopes not only provide great amount of light to illuminate the pulp chamber but also magnifies the chamber anatomy in great detail. In present study after extended access preparation and negotiation of palatal, mesiobuccal and distobuccal canal orifice under naked eye, more constricted MB2 orifice were located by removing dentin along the arc joining mb1 and palatal canal orifice under 20x magnification of dental operating microscope. The result of this group 1 showed that 24 out of 42 (Table -2) teeth showed MB2 canal orifice when viewed under naked eye by using mirror and sharp explores. When these teeth were further viewed under dental operating microscope at 20x magnification 28(66.66%) teeth showed mesiobuccal 2 canal orifice. These results correlate with the study conducted by Harry H. Peeters (2011) in which they conclude that of the 308 maxillary first molars studied under dental operating microscope, 211(68.5%) had an MB2 canal in their mesiobuccal root. These results were also in agreement with those of Tayfun Alaçam et al (2007) who reported an incidence of 67% with the use of the operating microscope and 74% with combined use of microscope and ultrasonics in cases of maxillary first molar. Therefore this study concluded that operating microscope greatly enhance the negotiation of mesiobuccal 2 canal in maxillary molars. Thus, with sufficient Operating Microscope training and experience, the efficiency of pursuing difficult MB-2 canals is improved, reducing both clinical time and risk.
In this study, second method used for analysis of root canal morphology was cone beam computerized tomography. Until recently, most of this core information on root canal anatomy would be obtained from conventional radiographs, but the main disadvantage with these conventional film-based radiographs is that they provide only a 2-dimensional image of a 3-dimensional object, resulting in superimposition of images. Now days this disadvantage is being overcome by a relatively newer diagnostic imaging modality which is Cone Beam Computerized Tomography.

In present study when teeth were analyzed under CBCT, 32(77%) teeth showed mesiobuccal 2 canal orifice, while palatal root had only single canal orifices in all 42 teeth analyzed for this study. Out of 42 teeth analyzes 2 teeth showed distobuccal 2-canal orifice, whereas rest 40 teeth showed only single distobuccal canal orifice (table 1). These results were almost similar to those reported by Shenoi R et al. (2012) who reported an incidence of 80% MB2 canals under CBCT evaluation. However, R. Bauman (2011) in contrary to present study showed much higher incidence of MB2 up to 92% under CBCT evaluation.

The third method used for analysis of root canal anatomy for this study was clearing technique. The advantage of using this technique is that it demonstrates three dimensional, morphological accurate, dyed pulpal spaces of a tooth that would be correctly positioned within a transparent tooth structure (O.E Omar 2001). In present study after access cavity preparation teeth were decalcified under Nitric acid and then dehydrated using different concentrations of absolute ethyl alcohol. After this these samples were cleared using methyl salicylate and methylene blue dye was injected to root canal under negative pressure of suction tip. Once the dye penetrates into various complexities of root canals, number of teeth with MB2 canal were selected and analyzed. The results of this group 3 analyzed using clearing technique showed that out of total 42 samples 22(52%) teeth showed presence of MB2 canals which were almost similar to those reported by Okamura in 1927 and Hess in 1925. However in contrast to present study Caliskan et al. (1995) and T. Yoshioka (2005) showed much less incidence of MB2 about 41% and 48% respectively by this clearing technique. All 42 teeth analyzed showed single canal in palatal root. Whereas only 1teeth showed distobuccal 2 canal and rest 41 teeth showed single canal. These results are also corresponds to study conducted by Yang et al (2007) who showed an incidence of 51.7% for mesiobuccal 2 canal detection by using dye method.

Overall statistical analysis of this study showed a total incidence of 65.08% for MB2 canal with maximum incidence in cone beam computerized tomography (Group 2) technique followed by operating microscope and clearing technique. Although this result was not statistically significant among intergroups (operating microscope, cone beam computerized tomography and clearing technique) for analysis of root canal anatomy yet overall these methods are more effective in negotiating mesiobuccal 2 canal as compared to routine clinical techniques.

Conclusion:
Based on the results of this study and comparing them to previous studies, it can be concluded that a pre-operative CBCT image and operating microscope images during treatment can increase the effectiveness of clinical identification of MB2 although difference was not statistically significant. Clearing technique is a simple and inexpensive technique for in vitro examination of root canal system in its natural state and modified it remains useful as teaching /research tool with little or no clinical applicability.

Thus, both magnification in form of operating microscope and cone beam computerized tomography are more effective in detecting the MB2 than direct visualization. So to achieve long-term success, clinician must use all the armamentaria at their disposal to locate and treat the entire root canal system.

Bibliography:
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