

CLINICAL ARTICLES

Canal Morphology of Maxillary Molars: Clinical Observations of Canal Configurations

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An examination of 1732 conventionally treated maxillary molars was made in an attempt to determine the percentage of MB2 canals that could be located routinely. The teeth examined were 1096 first molars, 611 second molars, and 25 third molars. The results were recorded on a modified computer program over an 8-yr period of time. An interesting trend was noted. The MB2 canal was found in 802 (73.2%) first molars, 310 (50.7%) second molars, and 5 (20.0%) third molars. It occurred as a separate canal in 54.9% of first molars, 45.6% of second molars, and joined in all third molars. However, as the operator became more experienced, scheduled sufficient clinical time, routinely employed the dental operating microscope, and used specific instruments adapted for microendodontics, MB2 canals were located in 93.0% of first molars and 60.4% in second molars.

The presence of a second (mesiobuccal (MB)) (MB2) canal in the MB root of the maxillary molars has been the subject of many discussions and studies (1-14). Hess and Zurcher's (1) landmark study in 1925 showed the mesial root of the lower first molar, and the MB root of the upper molars had the most ramifications of any teeth. The results of these studies have shown from 18.6% (2) to 96.1% (3) occurrence of the fourth (MB2) canal in maxillary first molars, depending on which method was used. The literature shows both clinical (in vivo) and laboratory (in vitro) results (1-14) and that more MB2 canals can be found in the laboratory than were found clinically (4). In short, the incidence varies widely, depending on the method used: whether done with or without dye penetration, radiographically, various sectioning techniques, record reviews, different social groups, different age groups, with or without magnification, etc. These studies are important; however, they do not necessarily relate to the routine, daily observations in the clinical practice of endodontics.

The purpose of this study was to determine what could be achieved in a clinical endodontic practice, to identify, treat, and

record the number of canals and their relationship to each other in the maxillary molars of the human dentition. The study took place over an 8½-yr period of time. The author made changes as new knowledge, instruments, equipment, and techniques were developed and became available.

MATERIALS AND METHODS

From July 1989 to the end of 1997, a period of 8½ yr, 6528 teeth were endodontically treated, and the canal morphology documented. A PC-File computer software program (Buttonware, Inc., Bellevue, WA; version 7) was modified to record the findings. There were 1732 maxillary molars in the study, and only those data are presented in this paper. Data are presented for the maxillary first (U1M), second (U2M), and third molars (U3M), the number of canal systems present (1, 2, 3, or 4), whether the canals joined or were separate, and, finally, whether all the canals located could be instrumented and filled to their terminus. On a few occasions, five, or even six, canals were located and filled; but, for the purposes of this study, the teeth were classified as having only four canals. The status of the pulp (vital, necrotic, retreatment) was recorded, but was not relevant to the morphology of the canal system. The MB2 canal was considered to be present if the author was able to instrument the canal to a depth of 3 to 4 mm after a reasonably thorough troughing process. If the radiographic terminus or working length was unable to be negotiated, no determination was made of canals being separate or joined, and the canal was recorded as "unfilled." In other words, all percentages presented regarding "joined" or "separate" are based only on the teeth that could be completely instrumented and filled.

The access preparations were made more rhomboidal in anticipation that a MB2 would be present and properly instrumented. In most cases, the mesial marginal ridge was infringed upon to achieve enough access to reveal the mesially positioned and mesially inclined MB2 canal. A majority of the contents of the pulp chamber and canal systems were removed, and the canal was irrigated with 2.6% warmed sodium hypochlorite solution. In some cases, 17% EDTA solution was also used to enhance the bactericidal and cleansing action (5). In the event of a retreat, the contents of the canals were removed with instruments and/or solvents, dried, and reirrigated with the warm sodium hypochlorite solution.

TABLE 1. Overall: U1M

Canals	No. of Teeth (%)	No. Filled (%)	No. Joined (%)	No. Separate (%)	No. Unfilled (%)
2	3 (0.3)	3 (100.0)	1 (33.3)	2 (66.7)	N/A
3	291 (26.6)	283 (97.3)	1 (0.4)	282 (99.6)	8 (2.7)
4	802 (73.2)	665 (82.9)	300 (45.1)	365 (54.9)	137 (17.1)

N/A, not applicable.

Enhanced vision was always used as a visual aid to locate the MB2 canals. During the first 2 yr of the study, surgical telescopes ($\times 2.5$ and $\times 4.0$ Designs for Vision) and fiberoptic light wands (MDT) or headlamps (Designs for Vision) were routinely used. As the dental operating microscopes (Seiler Instrument & Manufacturing Co., Inc., St. Louis, MO) were integrated into the operating rooms, they were put to use on a more regular basis. During the last 18 months of the study, a dental operating microscope (DOM) was available in all rooms and routinely utilized on all cases.

To further enhance vision when using the microscope, the pulpal floor was dried with a Stropko Irrigator (Spartan, St. Louis, MO) fitted with a Blue Micro Tip (Ultradent, South Jordan, UT). This permitted a precise and regulated stream of air, or water, to be directed onto the desired site. Dryness was essential for maximum visual inspection of the anatomy occurring on the pulpal floor. In most cases, a 27-gauge irrigating needle (Monoject) was attached onto another Stropko Irrigator and bent to follow the internal contours of the access preparation. This allowed the assistant to gently remove the microdust from the end of the bur, or ultrasonic instrument, continuously maintaining the doctor's vision during the entire troughing process. If a pulpal stone was encountered, it was removed in the same manner, to permit better visibility of the anatomical markings on the pulpal floor. On some occasions, the MB2 canal was readily seen; but, in older patients, or those with extensive previous dental work, the MB2 was often severely calcified, completely hiding any indication of its existence. When surgically treating the MB root, it is common to visualize the isthmus that exists between the MB1 and MB2 canals (6). Normal observation of the pulpal floor with the DOM reveals the isthmus appearing as a thin and white or red line, unless it has calcified over.

In retreatment cases, the previous attempt at endodontic treatment may have completely eliminated the normal pulpal floor anatomy that would have indicated the presence of a MB2 canal. In these situations, either a long shank Mueller bur (191-090, Brasseler USA, Savannah, GA) on a slow-speed handpiece and an appropriate Carr CT (EIE) or Ruddle CPR (Spartan) ultrasonic instrument was used in an attempt to locate and define the line representing the isthmus. The troughing process was continued until the presence of the MB2 was ruled in or out. It was sometimes necessary to first clean and shape the MB1 canal to observe the "line" emanating from deep within the confines of the prepared canal. On occasion, it was necessary to trough to depths of 4 mm, or more, to locate and instrument the often calcified and tortuous MB2 canal. A few times, troughing the "line" did not lead to an orifice, or the line disappeared when instrumented in an apical direction. In that case, it was not recorded as a MB2, but rather considered as a "fin" off the MB1 canal.

To determine canal length, working films were not taken on a routine basis. An apex locator (Root ZX; J. Morita Corp., Tustin, CA) was generally used to establish the working length. All canals were filled with vertically compacted warm gutta-percha (Obtura

Corp, St. Louis, MO) after lightly coating the walls with Kerr Pulp Canal Sealer EWT (Kerr Co., Romulus, MI).

When the MB2 canal system was present and instrumented to its terminus, a sterile absorbent point was inserted into the MB2 to determine if it joined with the MB1. If the fluid level in the other canal decreased in volume upon insertion of an absorbent point, it was considered to have joined the MB1 canal. In the last half of the study, a capillary tip (Ultradent) attached to the high-speed evacuator proved to be an easier, faster, and more effective method to determine whether the MB1 and MB2 canals had joined or had separate portals of exit (POEs). If the fluid level did not change in volume upon insertion of an absorbent point, or the capillary tip, the canals were classified as separate.

Two radiographs (deep pack and final) were routinely taken after placement of sealer and packing with warm gutta-percha. On a few occasions, an off-angle film revealed a separate POE that had been filled with vertically compacted warm gutta-percha and/or sealer. The canals had indeed joined but separated again before exiting the confines of the root. In that case, a MB2 previously classified as "joined" was reclassified as "separate."

The final determinations were immediately recorded on small brown envelopes and entered into the computer at the end of each day. The patient's chart was coded for future retrieval if necessary. Data were programmed so all results could be retrieved from the computer as either an overall or an annual report.

RESULTS

The results are presented showing the three groups of maxillary molars (U1M, U2M, and U3M) with the overall 8½ yr of data in Tables 1 to 3. Tables 4 to 7 show the data recorded for U1M and U2M for the individual 1996 and 1997 years. U3M data were not significant for 1996 and 1997 (only 2 were treated), and thus were not presented individually for those 2 yr. Of the 1732 maxillary molars in this study, 1446 were treated during the first 6½ years, an average of approximately 223 teeth per year. In 1996 and 1997, a total of 283 maxillary molars were recorded, an average of only 141.5 teeth per year.

Overall results for 1096 treated U1M are shown in Table 1. Three teeth (0.3%) had 2 canals, 1 (33.3%) joined, 2 (66.7%) had separate POE, and all teeth were instrumented (filled) to their terminus. There were 291 (26.6%) with three canals present, 283 (97.3%) were filled to their terminus, 1 (0.4%) joined one of the other canals, and 8 (2.7%) were unable to be completely instrumented. MB2 canals were present in 802 (73.2%) teeth, 665 (82.9%) were filled to their terminus, 300 (45.1%) were determined to join the MB1 canal, 365 (54.9%) had separate POEs, and 137 (17.1%) were unable to be completely instrumented (filled).

Overall results for 611 treated U2M are shown in Table 2. One tooth (0.2%) had a single canal, and it was filled to the terminus. Twenty-three (3.8%) had two canals, 7 (30.4%) joined, 16 (69.6%)

TABLE 2. Overall: U2M

Canals	No. of Teeth (%)	No. Filled (%)	No. Joined (%)	No. Separate (%)	No. Unfilled (%)
1	1 (0.2)	1 (100.0)	N/A	N/A	N/A
2	23 (3.8)	23 (100.0)	7 (30.4)	16 (69.6)	N/A
3	277 (45.3)	273 (98.6)	8 (2.9)	265 (97.1)	4 (1.4)
4	310 (50.7)	261 (84.2)	142 (54.4)	119 (45.6)	49 (15.8)

N/A, not applicable.

TABLE 3. Overall: U3M

Canals	No. of Teeth (%)	No. Filled (%)	No. Joined (%)	No. Separate (%)	No. Unfilled (%)
2	5 (20.0)	5 (100.0)	N/A	5 (100.0)	N/A
3	15 (60.0)	15 (100.0)	2 (13.3)	13 (86.7)	N/A
4	5 (20.0)	4 (80.0)	4 (100.0)	N/A	1 (20.0)

N/A, not applicable.

TABLE 4. U1M: 1996

Canals	No. of Teeth (%)	No. Filled (%)	No. Joined (%)	No. Separate (%)	No. Unfilled (%)
3	16 (16.5)	16 (100.0)	N/A	16 (100.0)	N/A
4	81 (83.5)	74 (91.4)	43 (58.1)	31 (41.9)	7 (8.6)

N/A, not applicable.

TABLE 5. U1M: 1997

Canals	No. of Teeth (%)	No. Filled (%)	No. Joined (%)	No. Separate (%)	No. Unfilled (%)
3	6 (7.0)	6 (100.0)	N/A	6 (100.0)	N/A
4	80 (93.0)	72 (90.0)	27 (37.5)	45 (62.5)	8 (10.0)

N/A, not applicable.

TABLE 6. U2M: 1996

Canals	No. of Teeth (%)	No. Filled (%)	No. Joined (%)	No. Separate (%)	No. Unfilled (%)
2	3 (6.7)	3 (100.0)	1 (33.3)	2 (66.7)	N/A
3	19 (42.2)	19 (100.0)	1 (5.3)	18 (94.7)	N/A
4	23 (51.1)	22 (95.7)	12 (54.5)	10 (45.4)	1 (4.3)

N/A, not applicable.

had separate POEs, and all were filled to their terminus. Of the 277 (45.3%) with three canals, 273 (98.6%) were filled to their terminus, and 4 (1.4%) were unable to be completely instrumented. MB2 canals were present in 310 (50.7%) teeth, 261 (84.2%) were filled to their terminus, 142 (54.4%) were determined to join the MB1 canal, 119 (45.6%) had separate POEs, and 49 (15.8%) were unable to be completely instrumented (filled).

Overall results for 25 treated U3M are shown in Table 3. Five teeth (20.0%) had 2 separate canals and all were filled to their terminus. Of the 15 (60.0%) with 3 canals, 2 (13.3%) were joined to another canal, 13 (86.7%) had separate POEs, and all 15 (100.0%) were filled to their terminus. MB2 canals were only present in 5 (20.0%) teeth, 4 (80.0%) were filled to their terminus and 100.0% joined the MB1 canal. Only one (20.0%) was unable to be completely instrumented (filled).

Results obtained in 1996 for 97 treated U1M are shown in Table 4. Sixteen teeth (16.5%) had three separate canals present, and all could be completely instrumented to their terminus, 81 (83.5%)

had MB2 canals. Of these, 74 (91.4%) were filled to their terminus, 43 (58.1%) were determined to join the MB1 canal, 38 (41.9%) had separate POEs and 7 (8.6%) were unable to be completely instrumented.

Results obtained in 1997 for 86 treated U1M are shown in Table 5. Six teeth (7.0%) had three separate canals and all were filled to their terminus. MB2 canals were present in 80 (93.0%) teeth, 72 (90.0%) were filled to their terminus, 27 (37.5%) were determined to join the MB1 canal, 45 (62.5%) had separate POEs, and 8 (10.0%) were unable to be completely instrumented (filled).

Results obtained in 1996 for 45 treated U2M are shown in Table 6. Three teeth (6.7%) had two canals, 1 (33%) joined before exiting, 2 (66.7%) had separate POEs, and all were filled to their terminus. Nineteen (42.2%) had three canals, 1 (5.3%) joined another canal, 18 (94.7%) had separate POEs, and all were filled to their terminus. MB2 canals were present in 23 (51.1%) teeth, 22 (95.7%) were filled to their terminus, 12 (54.5%) were determined

TABLE 7. U2M: 1997

Canals	No. of Teeth (%)	No. Filled (%)	No. Joined (%)	No. Separate (%)	No. Unfilled (%)
2	5 (9.4)	5 (100.0)	2 (40.0)	3 (60.0)	N/A
3	16 (30.2)	16 (100.0)	2 (12.5)	14 (87.5)	N/A
4	32 (60.4)	30 (93.8)	14 (46.7)	16 (53.3)	2 (6.2)

N/A, not applicable.

to join the MB1 canal, 10 (45.4%) had separate POEs, and 1 (4.3%) was unable to be completely instrumented (filled).

The results obtained in 1997 for 53 treated U2M are shown in Table 7. Five teeth (9.4%) had two canals, 2 (40.0%) joined, 3 (60.0%) had separate POEs, and all were filled to their terminus. Sixteen (30.2%) had three canals, 2 (12.5%) joined with another canal, 14 (87.5%) had separate POEs, and all were filled to their terminus. MB2 canals were present in 32 (60.4%) teeth, 30 (93.8%) were filled to their terminus, 14 (46.7%) were determined to join the MB1 canal, 16 (53.3%) had separate POEs, and 2 (6.2%) were unable to be completely instrumented (filled).

DISCUSSION

In this ongoing study, some interesting patterns emerged from the data in Tables 1 to 7. The incidence of only two canal systems being present in the maxillary molar teeth was U1M (0.3%), U2M (3.8%), and U3M (20.0%). The incidence of a second canal in the MB root (MB2) decreased between the same teeth. Depending on the method used; there was a higher frequency of MB2 canals (73.2 to 93.0%) in the U1M than the U2M (50.7 to 60.4%) and a smaller percentage (20.0%) in the U3M. A higher incidence of separate MB2 canals (54.9 to 62.5%) was recorded in U1M than in U2M (45.6 to 53.3%).

With the routine use of the DOM, specific instruments were necessary to increase the efficiency and the effectiveness of the clinical procedure. As previously mentioned, a troughing process was utilized if the MB2 orifice was not easily identified. It was essential to locate most MB2 canals, and can either be accomplished with burs or ultrasonic instruments. In the beginning years of the study, the ultrasonic instruments were not as efficient as the more recent generations. With the advent of newer designs of ultrasonic instruments designed for more efficiency (Ruddle CPR), combined with dependable ultrasonic units (Spartan), the troughing process has become faster and cleaner.

In most teeth, the location of MB2 canal orifices agree with the findings of several authors (2, 3, 7, 8). The MB2 orifice openings were usually found mesial to an imaginary line between the MB1 and palatal orifices, and commonly, about 2 to 3 mm palatal to the MB1 orifice. This imaginary line is more appropriately described as an arc with an apogee toward the mesial, following the contours of the mesial surface of the root.

The MB2 canal can be challenging to negotiate. The MB1 canal normally departs the pulpal floor with only a slight mesial inclination. However, the MB2 canal usually has a marked mesial incline immediately apical to its orifice in the coronal 1 to 3 mm. When an attempt is made to instrument the MB2, the tip of the file tends to catch against the mesial wall of the canal, preventing apical progress. Because the MB2 canal is smaller and usually more calcified than MB1, the problem is exacerbated. After locating the MB2 orifice, inclining the dental or ultrasonic handpiece to the distal, as far as the access preparation permits, allows the first

few millimeters of this overlying "roof" of calcified tissue to be safely eliminated. After this "refinement" of the access preparation, a more desired straight line access can be achieved. With the DOM, the sharp mesial inclination of MB2 was obvious, because in no case did the orifice move distally during refinement of the mesial wall of the access preparation. To facilitate location and instrumentation of the MB2 canal, the access has to be rhomboidal in shape to allow the necessary mesially directed shaping.

On occasion, MB2 shared an orifice with MB1. When there was a shared, or common orifice, many times the opening was more oval in shape. Infrequently, but on occasion, the MB2 orifice was harbored within, or just apical to, that of the palatal canal. In either of the above instances, it would have been very difficult, if not impossible, to observe the MB2 orifice if the DOM was not being utilized. Some MB2 canals were unable to be located until the MB1 canal was completely instrumented and ready to be filled. The smear layer was removed with 17% aqueous EDTA, the canals were rinsed with a solution of 95% ethanol, and air-dried with a Stropko Irrigator fitted with an 27-gauge notched endodontic irrigating needle (Monoject). This procedural sequence afforded better visualization, which on occasion revealed the MB2 orifice on the palatal surface of the MB1 canal. The operator must always be looking for the existence of additional canals throughout the entire process.

It is important that the clinician has a strong conviction the MB2 system is present 100% of the time in all maxillary molars. In conjunction with the DOM, a rhomboidal access, and the use of specific instruments, other aids were occasionally used to enhance the visualization of MB2 systems. They included the "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, and obliquely angled preoperative radiographs (8). In approximately 16% of the teeth, the MB2 canal systems could not be fully instrumented and were thought to be a rudimentary canal that did not exist in the apical one-half of the root (9), have an acute angle, or be blocked by stones or other debris in the canal system (10). It is of interest to note the studies utilizing microscopes have reported a significantly higher percentage of MB2 canal system occurrences (3, 8, 11) than studies using other means of determination (1, 12-14).

Reviewing the results recorded during the first 6½ yr, the percentage of MB2 systems located and treated was quite stable. However, with the increased use of the DOM, during the latter years of the study, it was interesting to note that the identification and treatment of the MB2 systems significantly increased (Tables 4 to 7). The difference in percentages is attributable to the practice environment. Between the first and second half of 1996, the author was in transition between practice locations. In 1997, the new practice building environment afforded adequate time to focus on the attention to detail required to better address MB2 systems. This was important, because with the increased use of the DOM, more was seen that had to be done and more time was necessary to accomplish the additional tasks at hand. The benefits of scheduling

more clinical time were realized when the author began to evaluate the results recorded for individual years in the 8½-yr study. The results recorded for the last 2 yr, 1996 and 1997, varied significantly enough to merit discussion.

In 1996, there were 10.3% more MB2 canal systems found in U1M than in the overall (Table 4). The following year, 1997, there was another 9.0% increase of MB2 canals found in U1M (Table 5). During 1997, an increase of 9.7% also occurred in the MB2 canals found in U2M (Table 7). Also noted was a significant increase in the percentage of all teeth that could be instrumented and filled to their terminus (Tables 1, 2, 4 to 7). In summation, these results could only be explained by scheduling adequate clinical time, the advent of new technology, and more consistent utilization of the current clinical aids available to the operator.

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