Location of Canal Isthmus and Accessory Canals in the Mesiobuccal Root of Maxillary First Permanent Molars

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Abstract

Background: *Failure in surgical endodontics may be caused by many factors. Failure is commonly due to improper preparation for the root-end filling and a lack of seal of the resected root end. The aim of this study was to investigate the morphology of resected mesiobuccal (MB) root ends of maxillary first molars and to evaluate the location of the canal isthmus and accessory canals between the MB canals.*

Methods: *From 50 selected first permanent molars, sections of the MB root at 3, 4 and 5 mm from the apex were prepared, acid-etched, washed and dried. The apical side of each section was sputter-coated with gold, examined by a scanning electron microscope and photographed.*

Results: *Overall, 18 (36%) of the 50 MB roots had one canal, whereas 32 (64%) had 2 canals. Of the roots with 2 canals, 10 (31.25%) contained either a complete isthmus or accessory canals or both between the 2 main canals. Another 10 (31.25%) showed partial isthmus formation.*

Clinical Significance: *MB roots exhibit a variety of canal configurations. On the basis of these findings, we propose a classification of the resected root surface of the MB root. Prudent judgement in preparing the canal isthmus, meticulous skill and comprehensive knowledge of root canal anatomy are essential for successful treatment.*

MeSH Key Words: *apicoectomy; dental pulp cavity/anatomy & histology; human; molar/anatomy & histology*

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In root canal therapy, nonsurgical procedures represent the treatment of choice because this form of treatment addresses the entire root canal system and hence the clinical result is predictably successful. However, as the demand to save teeth has increased, surgical procedures are being performed more frequently to rectify cases in which nonsurgical root canal therapy has been unsuccessful.

Recent advances in equipment and instruments have improved this aspect of dentistry tremendously. More surgical endodontic procedures are now routinely performed by endodontists and sometimes by general practitioners. Surgical operating microscopes with high-power illumination and magnification enhance visualization of the surgical area. With such equipment, the operator can see the intricate anatomy of the root canal system. Furthermore, 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 root-end filling material.

Numerous studies of the long-term results of surgical endodontic therapy have been published.[1] A success rate of 44.1% (for an observation period of 6 months to 8 years) was reported for 136 roots of premolar and molar teeth.[2] In another study complete healing was observed in 65% of 424 recall cases.[3] Another group of authors reported that 72% of 46 molar apicoectomies were successful.[4] Similar results were reported for apicoectomy of 25 molars[5] and 70 molars.[6] In contrast, a retrospective study reviewing the results of 4 practitioners suggested a failure rate approaching 50%.[7]

It has been suggested that most surgical failures were due to a lack of seal of the resected root.[8] This lack of seal could

be caused by failure to properly prepare the isthmus area of the posterior teeth. A 33.1% incidence of canal isthmus in the mesiobuccal (MB) root of the maxillary first permanent molar has been reported.[9] Weller and others[10] detected a complete or partial canal isthmus at about 4 mm from the root apex of the MB root in all of the 50 maxillary permanent molars that they examined. In that study transverse serial sections were stained with methylene blue dye and viewed with a surgical operating microscope at 32x magnification.

We believe that the root canal system of the MB root of the maxillary first permanent molars is complex and that viewing the sections with a surgical operating microscope at 32x magnification will not necessarily reveal all of the fine anatomic details of the apical root canal. The purpose of this study was to investigate the morphology of the MB root ends of resected maxillary first permanent molars and to evaluate the location of the canal isthmus and accessory canals between the 2 MB canals. We used scanning electron microscopy at high magnification so as to visualize the canal isthmus and accessory canals at the level of the dentinal tubules.

Materials and Methods

Fifty human maxillary left and right first permanent molars were collected from general dentists and oral surgeons, then stored in a thymol solution. The sex, age and race of the patients from whom these teeth had been obtained were unknown.

A 0.2-mm ultra-thin diamond disk (Horico Diaflex, Pfingst and Company, Inc., South Plainfield, New Jersey) was used to section the MB root of the molars at 3, 4 and 5 mm from the root apex, perpendicular to the long axis of the root. These positions closely resembled the level of sectioning in endodontic surgery. The 3 sections from each tooth were acid-etched (Ultra-etch, Ultradent Products Inc., South Jordan, Utah) for 1 minute to remove the smear layer and washed in distilled water. All 3 sections of a single tooth were then placed in a small vial and dehydrated in a series of 5 ethanol solutions (50% to 100%) for 10 minutes each. The specimens were then subjected to critical-point drying (critical-point dryer, model number CPD-100, Seevac, Inc., Winter Springs, Florida). After drying, the root sections were mounted on a labelled stub and sputter-coated with gold (sputter coater model S/50 B, Edwards, Crawley, England). Only the apical sides were coated and evaluated. All sections were scanned with a scanning electron microscope (model S-2500, Hitachi, Tokyo, Japan) and photographed to allow determination of the number of root canals present and the presence or absence of an isthmus. The data were tabulated and the canal configurations classified.

Table 1* **Number of canals in the mesiobuccal root of maxillary first permanent molars**

No. of canals	Number of cases	%
1	18	36
2	32	64
Total	50	100

Table 2* **Frequency of various canal configurations in the mesiobuccal roots of maxillary first permanent molars**

Canal configuration	Number of cases	%
One canal	18	36
Two separated canals	12	24
Two separated canals with one or more accessory canals between them	4	8
Two canals, one showing partial isthmus formation	10	20
Two canals joined by an isthmus	4	8
Two canals joined by an isthmus, with one or more accessory canals within the isthmus	2	4
Total	50	100

Results

The results are presented in Tables 1 and 2.[11] One canal was present in 18 (36%) of the roots examined, and 2 canals were found in 32 (64%) of the roots (Table 1). Different canal configurations were found in different mesiobuccal roots. However, we found that the sections at the 3-, 4- and 5-mm levels in the same root often showed similar canal configurations. Consequently, the amount of root sectioning in the surgical procedure is irrelevant. Accessory canals, which appeared as smaller openings, were located in the area of the main canals. In teeth with 2 main canals, one was usually larger than the other, and a partial or complete isthmus might connect or intercommunicate between the canals at the particular level of sectioning. There were 6 configurations of canals in the mesiobuccal roots examined in this study (Figs. 1 to 6, Table 2). In the 32 teeth with 2 canals, the following configurations were observed:

- two separated canals (Fig. 2) in 12 (37.5%) of the teeth;
- two separated canals with one or more accessory canals between them (Figs. 3 and 9) in 4 (12.5%) of the teeth;
- two canals, one of which showed partial isthmus formation (Figs. 4 and 10) in 10 (31.25%) of the teeth;

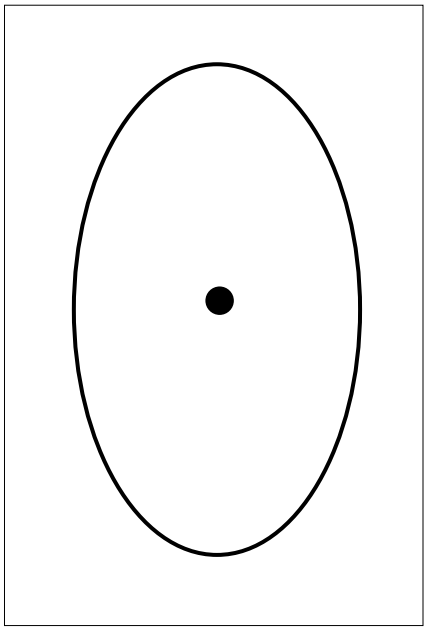

Figure 1: *One canal.**

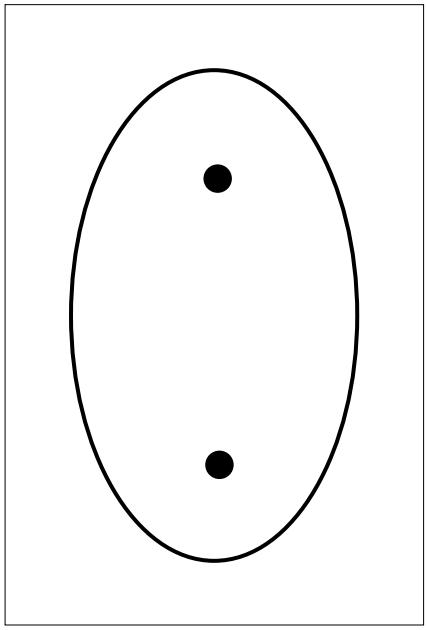

Figure 2: *Two separated canals.**

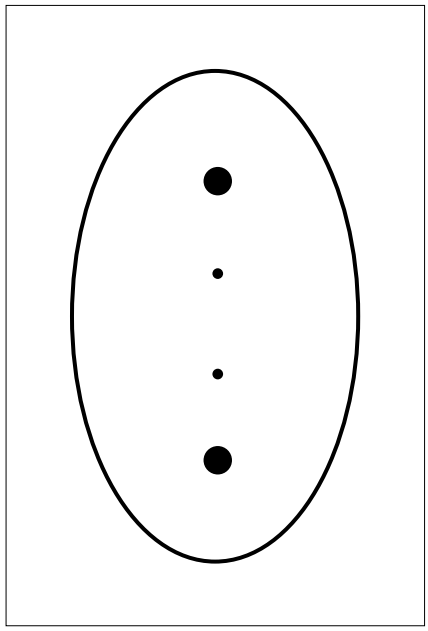

Figure 3: *Two separated canals with one or more accessory canals between them.**

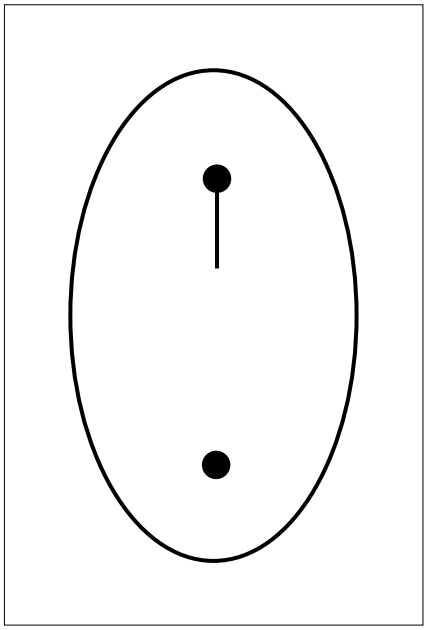

Figure 4: *Two canals, one showing partial isthmus formation.**

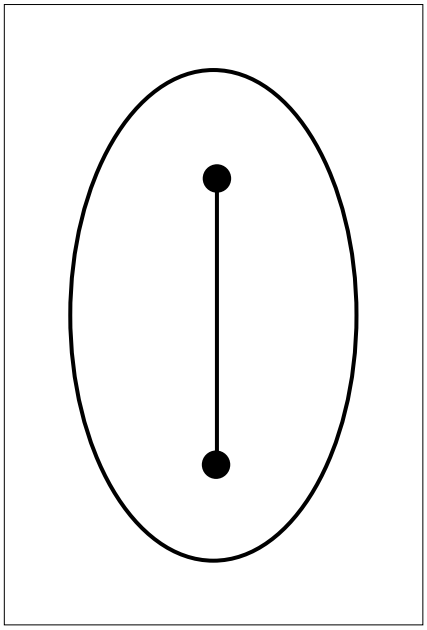

Figure 5: *Two canals joined by an isthmus.**

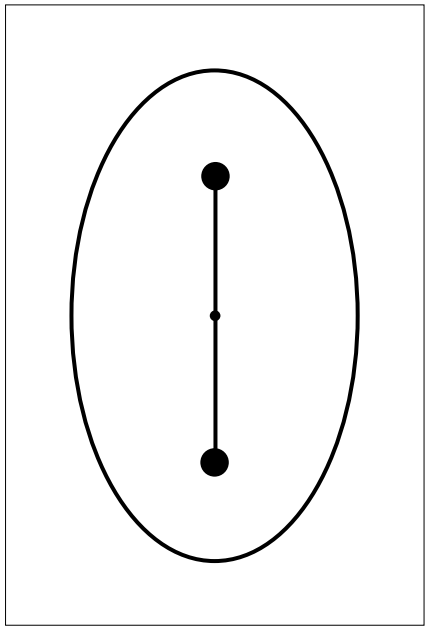

Figure 6: *Two canals joined by an isthmus, with one or more accessory canals within the isthmus.**

- two canals joined by an isthmus (Figs. 5 and 11) in 4 (12.5%) of the teeth;
- two canals joined by an isthmus, with one or more accessory canals within the isthmus (Figs. 6 to 8) in 2 (6.25%) of the teeth.

Discussion

In this study, the frequency of a complete isthmus between 2 canals in sections 3 to 5 mm from the apex was 18.75%. This is lower than the 30.1% frequency reported by Cambruzzi and Marshall,[9] but higher than the results of Weller and others,[10] who reported a complete isthmus between 2 canals in sections 3 to 5 mm from the apex in 12.0% to 14.3% of teeth examined. We found that 6.25% of the MB roots had one or more accessory canals within the isthmus joining the mesiobuccal-1 (MB_1) and mesiobuccal-2 (MB_2) canals (Figs. 7 and 8). The presence of this accessory canal should not be ignored. At high magnification, dentinal tubules were visible in the accessory canal (Fig. 8). In this study, 12.5% of the MB roots had

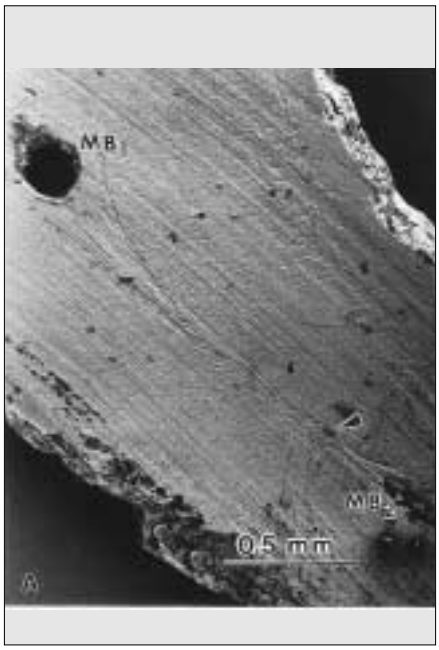

Figure 7: *Scanning electron microscopy (SEM) of a representative sample of a section with 2 main canals joined by an isthmus and an accessory canal (arrowhead) within the isthmus.**

Figure 8: *Higher magnification of the accessory canal shown in* ***Fig. 7*** *shows its dentinal tubules.**

Figure 9: *SEM of a representative sample of a section with 2 main canals and one accessory canal (arrowhead) between them.**

Figure 10: *SEM of a representative sample of a section with partial isthmus formation (arrowhead), and the MB_1 plus an accessory canal in the shape of a comma.**

one or more accessory canals between MB_1 and MB_2 that were not joined by an isthmus (Fig. 9).

The objective of surgical endodontic procedures is to place an effective root-end filling at the terminus of the resected root. Any opening on the resected root surface acts as a portal of exit or foramen. The root canal system may contain necrotic debris, tissue remnants or organic substrates that might support the growth of microorganisms. Judicious cleaning and shaping of the accessory canal and a definitive seal is desirable although not predictably attainable. Failure to seal the opening of any accessory canal will lead to eventual failure of both surgical and nonsurgical endodontic treatment. The preparation of the resected root surface to receive a root-end filling must incorporate the isthmus, as well as the opening of any accessory canal between the MB_1 and MB_2 canals.

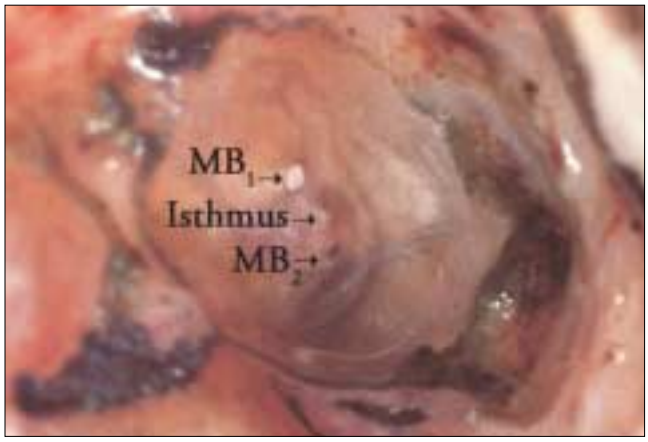

Figure 11: *Surgical microscopy with methylene blue staining shows that the bevelled mesiobuccal root has MB_1 and MB_2 canals with a complete isthmus. (Courtesy of Dr. Eric Kwan.)*

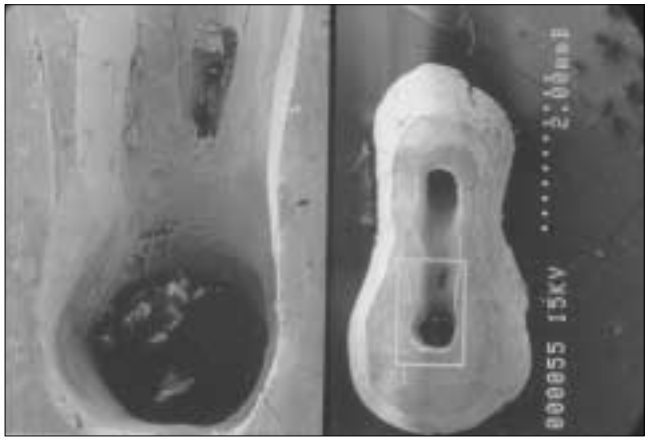

Figure 12: *Root end preparation joining the MB_1 and MB_2 canals along the isthmus; the accessory canal is included.*

The concept of partial isthmus formation is difficult to articulate. In 10 (31.25%) of the 32 teeth with 2 canals, one of the canals extended toward the other (Fig. 10). 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. However, in our examination of sections at levels 3 to 5 mm from the root apex, we found that the partial isthmuses remained as partial isthmuses. This leads us to believe that not every partial isthmus will become a complete isthmus elsewhere in the MB root.

On the basis of these findings, we propose the following classification of the resected surface of the MB root of maxillary first permanent molars:

- Type I: One main canal; if an accessory canal is present, a suffix is added to indicate the number; thus types I-A, I-B and I-C signify a main canal with 1, 2 or 3 accessory canals, respectively.
- Type II: Two main canals, MB_1 and MB_2; if any accessory canal is present, a suffix is added to indicate the number, as for type I, above (e.g., type II-D signifies 2 canals with 4 accessory canals).
- Type III: Two main canals with a partial isthmus; if any accessory canal is present, a suffix is added to indicate the number, as for type I, above.
- Type IV: Two main canals joined by a complete isthmus; if any accessory canal is present, a suffix is added to indicate the number, as for type I, above.

This classification is universal and specifies both the configuration of the MB canal and the number of accessory canals present.

The variation in success rate of endodontic surgery may be due to factors such as radiographic interpretation, untreated root canal systems, operator skill, assessment criteria, length of observation period, complexity of the surgical procedure, and use of high-power illumination and magnification. One of the keys to success is knowing the anatomic details of the apical root canal. It is not uncommon to discover at surgery that the portals of exit of the root canal system were not sealed by the nonsurgical procedure. Methylene blue or crystal violet can be used to disclose unfilled root canal space, such as an isthmus between the 2 canals in the MB root (Fig. 11). During surgery, the amount of the root and the angle of the root to be resected would change the 2-dimensional configuration of the canal and the relationship between the MB_1 and MB_2 canals. In the root-end preparation, the MB_1 and MB_2 canals should be joined, and this would include the possible isthmus and the accessory canals between the 2 main canals (Fig. 12). The isthmus must be sealed by root-end filling to ensure predictable periapical healing.

It is well accepted that scanning electron microscopy is best for studying the surface topography of the teeth. This method can also be used to examine in fine detail the root sections of common surgical sites. Our findings revealed the complexity of the cross-sectional anatomy of the MB roots of the maxillary first permanent molars. Indeed, no 2 root canal systems are exactly alike. In contrast, surgical operating microscopes cannot be used to study root sections at such high magnification.

To prevent vexing complications for both the clinician and the patient, it behooves the clinician to be familiar with all possible variants of root canal anatomy of a planned surgical site. Prudent judgement is essential for joining the area between the MB_1 and MB_2 canals during preparation of the root-end cavity. Treatment outcome will be most predictable when the experienced clinician has comprehen-

sive knowledge of the root canal anatomy to guide both nonsurgical and surgical endodontic therapy and can thus render impeccable patient care. ◆

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**Tables 1 and 2 and Figures 1 to 10 are reprinted from* Micron, *Vol. 29, No. 4, Yu DC, Tam A, Chen MH. The significance of locating and filling the canal isthmus in multiple root canal systems. A scanning electron microscopy study of the mesiobuccal root of maxillary first permanent molars. 261-5, 1998, with permission from Elsevier Science.*

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