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Root canal morphology of the human mandibular first molar

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Forty-five plastic casts of the root canals of extracted human mandibular first molars were fabricated and studied. In approximately one third of the teeth, there were four root canals. When a root contained two root canals, they either remained two distinct canals with separate apical foramina, united to form a common apical foramen, or communicated with each other partially or completely by transverse anastomoses. The frequency of these ramifications has been determined.

The primary objective of root canal therapy is to fill the débrided canals with an inert filling material in order to eliminate a source of injury from residual organic material or from apical percolation into voids in the restored canals.

The most common cause of apparent failure in endodontically treated teeth is apical percolation, resulting primarily from incomplete canal obturation.¹ It is quite possible that a root canal could be incompletely obturated because the operator failed to recognize its ramifications or existence. It is imperative, therefore, that the dentist have a thorough knowledge of root canal morphology before he can successfully treat teeth endodontically.

Most of the early available literature concerning root canal morphology is found in textbooks. Mühlreiter² and Black³ were the first to elaborate on this subject. Since that time, Preiswerk,⁴ Fasoli,⁵ Fischer,⁶ Hess,⁷ Grove,⁸ Rottenbitler,⁹ Davis,¹⁰ and Mueller¹¹ have contributed to the knowledge of root canal morphology. There have also been studies of sectioned teeth by Barrett,¹² Green,¹³ and Weine and his co-workers.¹⁴

The current concept of root canal morphology of the mandibular first molar is based on the work of Hess,⁷ who made vulcanite casts to duplicate the anatomy of the pulp cavities. He considered the mandibular first and second molars to

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have identical root canal anatomy. Of the 512 first and second molars from persons between the ages of 6 and 50 years, he found 0.3 per cent with one canal, 17.7 per cent with two canals, 78.0 per cent with three canals, and 4.0 per cent with four canals. In reporting the anatomy of the mandibular first molar, many authors^{11, 13, 15, 16} have cited these frequencies determined by Hess.

Although the occurrence of four root canals in a mandibular first molar is mentioned in most endodontic and dental anatomy textbooks, it is referred to as "may have,"¹⁷ "occasionally,"¹⁸ "infrequently,"¹⁹ and often the possibility of four canals is not even mentioned.²⁰ The frequency of occurrence is not given in any of the references.

In a clinical pilot study conducted by Griffin and his co-workers,²¹ roentgenograms of all mandibular first molars treated endodontically during one decade were examined. Of the 203 clinical cases examined, fifty-six (27.5 per cent) had four root canals filled. Of these fifty-six cases, twenty-three (41.0 per cent) had separate foramina for each of the distal root canals. None of the cases had only one or two canals. These data differ considerably from the frequencies reported by Hess.

Since the mandibular first molar is the tooth most frequently treated endodontically,¹⁶ and since the literature is so inconclusive and variable, we decided to conduct a detailed investigation of the morphology of the root canals of the extracted human mandibular first molar.

MATERIALS AND METHODS

The forty-five extracted mandibular first molars used in this study were collected from the Dental Department, Naval Administration Command, Great Lakes, Illinois. The patients were male Caucasians, born in the United States, and ranged in age from 17 to 22 years.

Polyester casting resin stained with a red pigment was used to make plastic casts of the root canals of the mandibular first molars. The pulp chambers of the teeth were opened and each root canal was débrided with a $\times\times\times$ fine-barbed broach. The teeth were then placed in a 3 per cent solution of hydrogen peroxide at room temperature. As stated by Hibbard and Ireland,²² hydrogen peroxide was found to remove the contents of the root canals in approximately 3 weeks, and it had no decalcifying action on the dentine.

After 3 weeks, the teeth were washed in tap water and placed in 70 per cent isopropyl alcohol for 48 hours. They were then thoroughly air dried, and the prepared resin was placed in the pulp chamber of each tooth. A vacuum of 30 p.s.i. was applied to the root apices, and the resin was allowed to flow through the pulpal cavity of each tooth until it emerged from the apical foramina of all roots. Fig. 1 shows a drawing of the vacuum apparatus used in the fabrication of the plastic casts.

The resin was allowed to polymerize at room temperature for 24 hours, and then the teeth were decalcified in a 35 per cent solution of nitric acid for 10 days. A preliminary experiment determined that polyester casting resin is chemically inert to the action of nitric acid.

Table I. Summary of results—morphology of mandibular first molar

Sample size	Number of roots		Number of canals per tooth				Number of canals per root			
	2	3	Number of canals per tooth				M		D	
			1	2	3	4	1	2	1	2
45	44	1	0	3	29	13	3	42	32	13
Percentage of total	97.8	2.2	0	6.7	64.4	28.9	6.7	93.3	71.1	28.9

M = mesial; D = distal; W = whole root; C = coronal third of root; M* = middle third

RESULTS

Forty-five plastic casts were made of the root canals, and the following features were identified: number of roots, number of root canals per tooth and root, ramifications of the root canals of each root, roots with transverse anastomoses between root canals, and the locations of the transverse anastomoses. These data are summarized in Table I.

Two root canals were present in three (6.7 per cent) teeth, three canals in twenty-nine (64.4 per cent) teeth, and four canals in thirteen (28.9 per cent) teeth. Figs. 2, 3, and 4 show casts of teeth that had two, three, and four canals.

In 59.5 per cent of the teeth, the mesial canals remained divided throughout the length of the root. These ramifications are illustrated by Specimen C of Fig. 3 and Specimens A and B of Fig. 4. In the other 40.5 per cent of the teeth, the mesial canals were seen converging and joining in the apical third of the root and having a common foramen. This convergence of the mesial canals is shown in Specimens A and B of Fig. 3 and Specimen C of Fig. 4.

In 38.5 per cent of the distal roots with two canals, the canals remained separate, with each canal having an apical foramen. Specimens A and B of Fig. 4 exemplify this configuration. In the other 61.5 per cent of teeth with two distal canals, they united and terminated in a common apical foramen. This is illustrated by Specimen C of Fig. 4.

DISCUSSION

In order for the dentist to render a complete endodontic service, he must be familiar with root canal morphology of all the teeth. Many difficulties have been encountered in all studies conducted on root canal morphology. Roentgenographic studies show only one plane of the tooth. It is not always a true picture, therefore, of the conditions actually present in the tooth. In the sectioning methods, the minute canals and curvatures are difficult to follow, regardless of the care exercised in grinding. With serial sections, it is difficult to demonstrate morphology, and some of the anatomic features are often lost in the decalcifying process. The vulcanite casts made of the pulp cavity are not necessarily replicas, because the vulcanite may not penetrate into all the ramifications of the canals. Also, vulcanite may be forced into small defects produced during drying, processing, or vulcanizing. This is also the difficulty encountered in the staining and transilluminating studies.

An attempt was made in this investigation to eliminate or reduce many of the defects of previous investigations. The teeth used in this project were not

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root	Two canals, separate foramina		Two canals, common foramen		Roots with two canals, transverse anastomoses	Location of transverse anastomoses			
	M	D	M	D		W	C	M*	A
13	25	5	17	8	33	5	2	6	20
28.9	59.5	38.5	40.5	61.5	60	15.2	6.1	18.1	60.6

third of root; A = apical third of root.

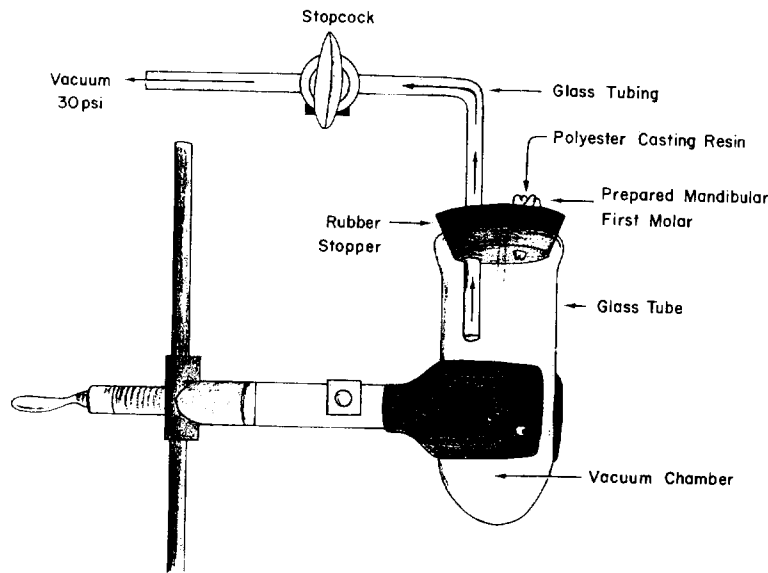


Fig. 1. Drawing of the vacuum apparatus used in the fabrication of the plastic casts.

allowed to become dry from the time of extraction until the plastic casts were fabricated. Since plastic casts were used, it was possible to view the root canal morphology in every plane of the teeth in order to tabulate and evaluate the data. Because a vacuum system was used in this investigation, the polyester casting resin was not introduced into any artificial ramifications that could have been created by pressure, drying, or processing. The one difficulty encountered in conducting a morphologic study of such minute root canals was that some of the mesial components were fragile and had to be handled with extreme care.

In comparing the results of this investigation with those obtained by Hess,⁷ we found many differences. Hess reported that 17.7 per cent of the molars had two root canals. We noted only 6.7 per cent with two canals. Hess found 78.0 per cent with three canals, and the results of our investigation showed only 64.4 per cent of the sample with three canals. The greatest difference in the two investigations is in regard to the molars with four canals. Our investigation revealed 28.9 per cent of the molars with four canals, whereas Hess reported four canals in only 4.0 per cent of the teeth studied. These discrepancies must be due, in part, to the fact that Hess considered the mandibular first and second molars to have identical anatomy and combined them in his study.

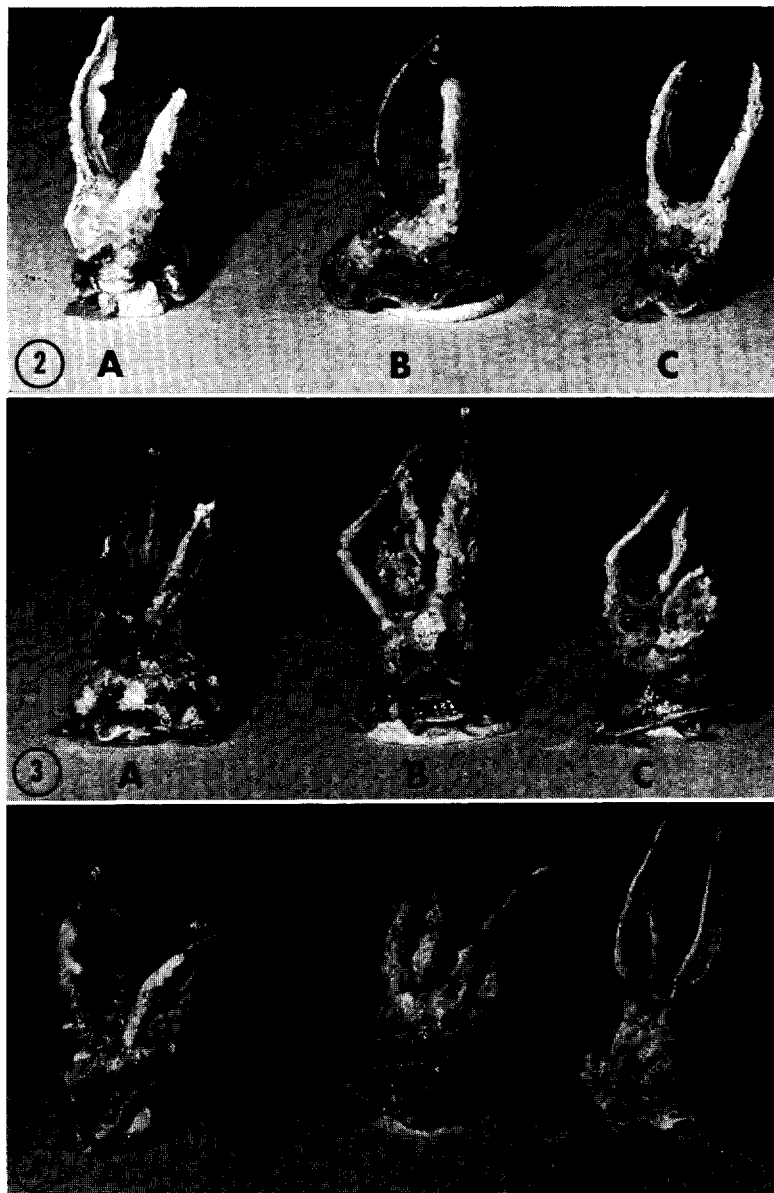


Fig. 2. Specimens of the mandibular first molar with two root canals. (The mesial root is to the left and the distal root to the right.)

Fig. 3. Specimens of the mandibular first molar with three root canals. (The mesial root is to the left and the distal root to the right.)

Fig. 4. Specimens of the mandibular first molar with four root canals. (The mesial root is to the left and the distal root to the right.)

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It is interesting to note that the results of this investigation agreed very closely with the clinical pilot study,²¹ which revealed that 27.5 per cent of the cases had four root canals filled. Also, in the pilot study, 41.0 per cent of the teeth had separate foramina for each of the distal root canals. This investigation reported 38.5 per cent of the distal roots with two canals remaining as separate canals and separate foramina.

There has never been an investigation dealing with the frequency with which the mesial or distal canals unite in a common foramen before leaving the tooth. According to Grossman,¹⁸ mesial or distal canals may remain divided throughout their length, terminating in two separate apical foramina; may unite, terminating in a common apical foramen; or may communicate with each other partially or completely by means of transverse anastomoses.

This investigation revealed that 59.5 per cent of the mesial and 38.5 per cent of the distal canals remained separate along the entire length of the root, with separate foramina at the apex. In 40.5 per cent of the mesial and 61.5 per cent of the distal canals, they joined in a common canal at the apical third, with a common foramen.

According to Hess,⁷ there is a gradual appearance after 14 years of age of a dentine partition in the mesial root which divides it into two canals. Actually, in this study we found that 60.0 per cent of the roots with two canals still had some form of transverse communication. The majority of these anastomoses were limited to the apical third of the root. This observation was not too surprising since the sample was collected from persons 17 to 22 years of age.

SUMMARY

The purpose of this investigation was to study the morphology of the root canals of the mandibular first molar.

Forty-five plastic casts of the root canals of extracted human mandibular first molars were fabricated and studied. Three teeth (6.7 per cent) had two root canals, twenty-nine (64.4 per cent) had three root canals, and thirteen (28.9 per cent) had four root canals. The number of canals per root was also determined.

When a root contained two root canals, they either remained two distinct canals with separate apical foramina, united and formed a common apical foramen, or communicated with each other partially or completely by transverse anastomoses. The frequency of occurrence of these ramifications has been determined.

CONCLUSIONS

The dentist must always look for a second canal in the distal root of a mandibular first molar. Such a canal occurs quite frequently, and if one is missed, it could cause failure of endodontic treatment. If the traditional triangular outline were changed to a more rectangular one, it would permit better visualization and exploration of a possible fourth canal in the distal root.

The frequency with which canals unite and form a common foramen should

be noted and considered when obturating. The knowledge that such a high percentage of teeth contains transverse anastomoses is essential for complete removal of the entire root canal contents.

Morphologic knowledge is indispensable and improves the operator's ability to locate and trace a root canal to its termination, thereby increasing the degree of successful treatment.

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