Scanning electron microscopic investigation of incidence, location, and size of accessory foramina in primary and permanent molars

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Objective: The purpose of this study was to determine and compare the incidence, location, and size of accessory foramina in the furcation region of permanent and primary molars.

Method and materials: A random sample of 100 extracted human permanent maxillary and mandibular first and second molars (25 teeth of each type) and a random sample of 100 extracted human primary maxillary and mandibular molars (50 teeth of each type) were used. The crowns and roots of each tooth were removed at a point 1.5 mm apical to the external furcation region, and a second cut was made at a point 1 mm apical to the cementoenamel junction. The specimens were examined using scanning electron microscopy at magnifications ranging from X10 to x 1,250. The incidence, location, and size of accessory foramina were documented and statistically analyzed.

Results: Of the 100 permanent molars examined, 79% had accessory foramina with diameters ranging from 10 µm to 200 nm. Accessory foramina were present in 94% of the primary molars, with diameters varying from 10 µm to 360 µm. The incidence of accessory foramina was significantly higher in primary than in permanent molars.

Conclusion: The presence of accessory foramina with large diameters may imply that an inflammatory process can spread from pulpal to periodontal tissues and vice versa. (Quintessence Int 2004;35:699-705)

Key words: accessory root canal, endodontic-periodontic lesion, furcation, pulpal-periodontal interaction, pulp chamber floor, SEM

CLINICAL RELEVANCE: High incidence of accessory foramina may imply a direct communication between the pulp and periodontal tissues, and this direct relationship should be taken into consideration during both endodontic and periodontal treatment.

The intimate anatomic relation of the pulp to periodontal tissue via accessory canals has been studied by many investigators.¹-¹² On the pulp chamber floor of molars, in the bifurcation or trifurcation area, and on the lateral root surface, accessory canals can be found, but the occurrence of these canals is not obligate. These canals are usually extremely narrow, permitting only small-diameter arterioles to pass.¹³ In pathologic situations, interactions between the pulp and periodontal tissue can occur via toxic products, with resultant concomitant pulpal-periodontal breakdown.¹⁴-¹⁷ Pulpal-periodontal interactions have been observed clinically in the furcation region of maxillary and mandibular permanent and primary molars following pulpal injury. An accessory canal is a potential pathway that could lead to periodontal disease in the furcation area originating from necrotic pulps.¹⁸,¹⁹ Moreover, a deep periodontal pocket may expose the opening of an accessory canal and, thus, allow microorganisms or their metabolic products to gain access to the pulp.²⁰ It has been demonstrated that even caries-free teeth without signs of periapical pathology but with signs of periodontal disease showed pulpal inflammation.²¹ In such cases, alveolar bone loss in the furcation regions of molars can be induced by pulp inflammations and necrotic or cariously involved pulps.²²

A variety of different techniques has been used to demonstrate anatomically these fine accessory canals in the root canal system. A light microscopic study by
Everett et al. demonstrated a high incidence of accessory canals in a total of 328 extracted permanent mandibular molars. Burch and Hulen examined 95 maxillary and 100 mandibular permanent molars. This study indicated a 76% frequency of accessory canals in the furcation area of these teeth. According to Koenigs et al., the size of accessory canals varied from 4 to 250 μm, and the incidence of accessory canals was higher in maxillary than in mandibular permanent teeth. Vertucci and Anthony found that 76% of permanent maxillary first molars, 64% of mandibular second molars, 84% of maxillary first molars, and 84% of mandibular second molars had accessory foramina in the furcation area. The size of these foramina canals varied from 4 to 720 μm, and the number ranged from 0 to 20 per tooth.

Lowman et al. showed, by drawing a radiopaque dye through the root canal system under vacuum, that the incidence of accessory canals in the coronal and middle thirds of root surfaces was 55% in maxillary and 63% in mandibular molars. Gutmann introduced safranin dye into 102 extracted permanent molars that were placed in a vacuum. Accessory canals were seen in 28.4% of the total sample in the furcation region. A passive dye ingress study on extracted permanent molars using 0.5% basic fuchsin demonstrated a 57% frequency of patent accessory canals in the furcation area of permanent molars.

In primary molars, pathologic bone changes following pulpal inflammation are not likely to be found at the apices, but in the inter-radicular furcation region. In order to examine the close inter-relationship between the pulp and periodontal ligament, some investigations have been conducted to study the canals that connect the pulp chamber floor and the furcation area in primary molars. Paras et al. examined 20 extracted primary molars using scanning electron microscopy. According to their results, 20% of the specimens showed accessory canals on the pulp chamber floor and 50% in the furcation area. Wrbas et al. conducted a study to investigate the existence of patent accessory canals in the furcation areas of 20 human primary second molars. Accessory foramina were found in 77.5% of the molars in the furcation area and in 45% on the pulp chamber floor. Both for the maxillary and mandibular molars, these authors observed a 50% frequency of patent accessory canals.

Although the existence of accessory foramina in the furcation area of permanent teeth has been well demonstrated, little is known on the location and size of accessory foramina in furcation areas of primary teeth. Moreover, no attempts have been made to compare the incidence and size of accessory foramina in permanent teeth with those in primary teeth. Therefore, the purpose of this study was to determine and compare the incidence, location, and size of accessory foramina in the furcation region of permanent and primary molars.

**METHOD AND MATERIALS**

A random sample of 100 extracted human permanent maxillary and mandibular first and second molars without any signs of resorption were used in this investigation (25 teeth of each type). Furthermore, a random sample of 100 extracted human primary maxillary and mandibular molars (50 teeth of each type) was used. Identification of the teeth was based on crown and root morphology. The pulp status and reason for extraction were not recorded. Criteria used for selection were the presence of an intact crown and root structure, teeth having fused roots, evidence of extraction damage, or either caries or restoration extending apically to the cementoenamel junction (CEJ) were excluded from the sample. Immediately upon extraction, the teeth were placed in physiologic saline solution and maintained in that solution until tooth preparation began.

The crowns and roots of each tooth were removed with a low-speed saw (model 1600, Leitz) under running tap water at a point 1.5 mm apical to the external furcation region, and a second cut was made at a point 1 mm apical to the CEJ. Pulp tissue was removed from the specimens using an endodontic broach and 3-minute immersion in 5.25% sodium hypochlorite solution. The specimens were rinsed in running water for 5 minutes and placed in 100% acetone for 48 hours. This solution was changed every 12 hours. Finally, the specimens were dried in an oven for 12 hours at 60°C. All specimens were numbered, and to ensure electrical conductivity, a surface of the specimen not involved in the investigation was painted with a metallic air-drying paint and fixed on a special aluminum specimen disk (Provag). A 90-nm gold coating was placed on the specimens with a sputter coater (Balzers Union). Subsequently, the specimens were examined using a scanning electron microscope (REM Philips 500X, Philips) at magnifications ranging from ×10 to ×1,250.

The number of every visible accessory foramen on the pulp chamber floor and their diameters were recorded and photographed. Subsequently, the specimens were carefully removed from the specimen disk and again placed on the aluminum specimen disk in such a way that the furcation surfaces and lateral root surfaces could be viewed. Again, the number of accessory foramina and their diameters were recorded and photographed. An accessory foramen was an opening that was at least twice the size of adjacent dentinal tubules and that was open into the dentin or cementum.
The following features were recorded: number, size, and location of accessory foramina present on the pulp chamber floor; furcation surface; and lateral root surface. A chi-square test was used to determine whether there were significant differences between the incidence of accessory foramina in permanent and primary teeth and between the frequency of accessory foramina concerning their location. Differences in the size of the accessory foramina were analyzed using the Mann-Whitney U test, because the data were not distributed normally according to the Kolmogorov-Smirnov test.

RESULTS

The number, location, and size of accessory foramina present on the pulp chamber floor, furcation surface, and lateral root surface are summarized in Tables 1 and 2.

Of the 100 extracted permanent teeth, 79% had accessory foramina that varied from 10 µm to 200 µm (Fig 1). No statistically significant differences were found between the frequency of accessory foramina in maxillary and mandibular molars (P = 1.0). Foramina on both the furcation surface and the lateral root surface were found significantly more often than on the pulp chamber floor (P < .001). Concerning the size of the accessory foramina, no statistically significant differences were observed between maxillary and mandibular molars or the different locations of the foramina (P > .05). The incidence of accessory foramina and also their size in maxillary or mandibular and first or second molars were statistically not significantly different (P > .05).

Of the 100 extracted primary teeth, 94% had accessory foramina that varied from 10 to 360 µm (Fig 2). No statistically significant differences were found between the frequency of accessory foramina in maxillary and mandibular molars (P = 1.0). Foramina on both the furcation surface and the lateral root surface were found significantly more often than on the pulp chamber floor (P < .01). Concerning the size of the accessory foramina, no statistically significant differences were observed between either maxillary and mandibular molars and the different locations of the foramina (P > .05).

Overall, the incidence (χ² = 8.392, P < .01) and size of accessory foramina (U test; P < .05) were statistically different between permanent and primary molars. While the latter had about 3.5 accessory foramina per tooth, the permanent molars showed on average less than 2.5 foramina per tooth (Tables 1 and 2).

DISCUSSION

The etiology of accessory canal formation has been described by Seltzer and Bender. These accessory foramina are presumed to be caused by a localized failure in the formation of Hertwigs sheath, with a consequent lack of odontoblast differentiation and dentin formation at this point. This results in a small accessory canal connecting the periodontal ligament with the root canal. The gap in the Hertwigs sheath is probably produced by the persistence of abnormally placed blood vessels reaching the pulp. Seltzer and Bender reported that besides blood vessels in patent accessory canals, collagen fibers, pulp, and connective tissue also can be found.

In this study, all observed patent foramina did not contain nerves, vessels, or connective tissue when viewed under the scanning electron microscope (Figs 1b and 2d). This finding agrees with previous reports and is probably the result of the tissue-dissolving effect of sodium hypochlorite. No tooth was scaled or curetted in order to eliminate the possibility of opening furcal accessory foramina, since it is well known that some occluded foramina can be made patent by root planing.

A variety of methods has been used to investigate the presence and incidence of accessory foramina. Radiographic, light microscopic, and scanning electron microscopic studies have been conducted. Whereas light microscopic studies reveal only the number of accessory canals or foramina, information on the location and size of accessory canals originates from SEM investigations. Moreover, several experimental methods have been used to demonstrate the patency of these accessory canals.

Topographic SEM studies of the presence of accessory foramina, such as this investigation, provide detailed examination of the different areas (pulp chamber floor, furcation area, and lateral root surface) because of the high magnification (Figs 1 and 2). It has to be kept in mind, however, that SEM investigation reveals only accessory foramina. The nature of a canal (true, blind, looping, and enclosed) cannot be evaluated. Nevertheless, the findings of previous studies indicate that the majority of accessory foramina were found to represent patent accessory canals.

Of the 100 examined permanent teeth, 79% showed accessory foramina. A 26% frequency of accessory foramina was found on the pulp chamber floor; a 63% incidence on the furcation surface; and a 58% frequency on the lateral root surface. These findings are in good agreement with the light microscopic study by Burch and Hulen, in which accessory foramina on the furcation surface were found in 76% of maxillary and mandibular molars. Maxillary molars presented
### Incidence, number, size, and location of accessory foramina in permanent molars

| Tooth Type                  | Total Cases | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean |
|-----------------------------|-------------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|
| Maxillary first molars      | 250         | 2.1 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  |
| Maxillary second molars     | 250         | 1.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  |
| Mandibular first molars     | 250         | 0.3 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  |
| Mandibular second molars    | 250         | 0.3 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  |

**Note:**

- **n**: Number of cases
- **Max**: Maximum size
- **Min**: Minimum size
- **Mean**: Mean size
- **%**: Percentage

### Incidence, number, size, and location of accessory foramina in primary molars

| Tooth Type                  | Total Cases | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean |
|-----------------------------|-------------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|
| Primary molars              | 250         | 2.1 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  | 0.0 | 0.0 | 1.2  |
| Maxillary                  | 250         | 1.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  | 0.0 | 0.0 | 1.0  |
| Mandibular                 | 250         | 0.3 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  | 0.0 | 0.0 | 0.3  |

**Note:**

- **n**: Number of cases
- **Max**: Maximum size
- **Min**: Minimum size
- **Mean**: Mean size
- **%**: Percentage
Fig 1  Scanning electron micrographs of accessory foramina in permanent molars. (a) Multiple accessory foramina on the furcation surface of a maxillary second molar (original magnification ×20); and (b) accessory foramen on the furcation surface of a maxillary first molar (original magnification ×320).

Fig 2  Scanning electron micrographs of accessory foramina in primary molars. (a) Multiple accessory foramina on the pulp chamber floor of a mandibular molar (original magnification ×20); (b) multiple accessory foramina on the pulp chamber floor of a mandibular molar (original magnification ×80); (c) accessory foramen on the furcation surface of a mandibular molar (original magnification ×20); and (d) two accessory foramina on the lateral root surface of a maxillary molar (original magnification ×80).
an average of 2.51 foramina per furcation and mandibular molars, 2.14 foramina, while in the present study, the maxillary molars showed an average of 3.3 foramina and the mandibular molars 1.9 foramina per furcation (Table 1). Niemann et al. reported that the likelihood that a patent accessory canal exists in the furcal area of permanent molars can be expressed within the confidence interval of 57.4% to 76.6%. The observed 63% incidence of accessory foramina on the furcation surface (Table 1) fits well within the limits of their confidence interval. Furthermore, the finding of Niemann et al. that the likelihood of maxillary or mandibular molars exhibiting a patent accessory canal was not statistically significant, agrees with the present results. Also, with regard to the size of the accessory foramina, the results of this study (10 to 200 μm; Table 1) are comparable with other reports. Koenigs et al. noted that the size of accessory foramina varied from 4 to 250 μm, and according to Vertucci and Anthony, the size varied from 4 to 720 μm.

Concerning the results in primary teeth, this study demonstrated accessory foramina in 94% of the maxillary and mandibular molars (Table 2). A 40% frequency of accessory foramina was found on the pulp chamber floor, a 77% incidence on the furcation surface, and a 63% frequency on the lateral root surface. Thus, the incidence found in this study corroborated the results found by Wrbas et al. They recorded the incidence of accessory foramina to be 77.5% on the furcation surface of primary molars and 45.0% on the pulp chamber floor. In contrast, these results are in strong disagreement with the findings of Ringelstein and Seow who found an incidence of 42.7%. Also, the values found by Paras et al. (50% on the furcation surface, 20% on the pulp chamber floor) and by Reddy and Babu (38.3%) did not agree with the present results.

According to the findings of this investigation, the incidence of accessory foramina was significantly higher in primary molars than in permanent (P < .01); also, the diameters of accessory foramina were significantly greater in primary than in permanent molars (P < .05). While the primary molars had about 3.5 accessory foramina per tooth, the permanent teeth showed on average less than 2.5 foramina per tooth (see Tables 1 and 2). This is a new finding since a comparison between the incidence of accessory foramina or accessory canals in primary and permanent molars has not been published yet.

The clinical significance of these findings has been reported previously. In this study of abscess formation in connection with primary molars, it has been shown that in at least 29% of primary molars, the site of radiographic change and clinical abscess formation may be accounted for by accessory canals. Thus, an inflammatory process can spread rapidly from pulpal to periodontal tissues and vice versa.

From the endodontic standpoint, failure to seal adequately to pulp chamber floor (Fig 2a) following endodontic treatment may result in leakage and communication with the furcation area through unfilled accessory canals. Even though the communication between pulp and periodontal tissues was not confirmed in this study, a very special effort to seal the pulp chamber floor subsequent to obturation of the main root canals in all molars is necessary. Several methods have been advocated for the treatment of the pulp chamber floor in order to seal accessory canals: warm gutta percha with vertical condensation; compressing zinc oxide eugenol on the pulp chamber floor; or application of modern adhesive resin systems.

Due to the high incidence of accessory foramina in primary teeth, these facts may be especially relevant during endodontic treatment of primary teeth. It is known that various kinds of disturbances in hard tissue formation can occur as a result of trauma to the tooth germ. Thus, primary teeth associated with periapical lesions and a close location to the tooth germ of the successive permanent teeth may cause white or yellow-brown discoloration of enamel or enamel hypoplasia (like Turner's hypoplasia) on the successive permanent tooth. This direct relationship between pulp and periodontal tissues should also be taken into consideration when using antimicrobial agents in endodontic treatment. For example, when the pulp chamber and the instrumented root canals were flooded with a fluid intracanal medicament, tissue-toxic agents such as camphorated paramonochlorphenol or formaldehyde can diffuse through accessory canals and may cause widespread destruction of vital inter-radicular tissue.

Clinical management of cases exhibiting signs of pulp-induced periodontal lesions in the furcation region of molars may require only endodontic therapy to eliminate the causative factors. Hence, the present findings and previously reported results strongly emphasize the necessity for a thorough evaluation of the status of pulp tissue in all cases of extensive periodontal disease.

From the periodontic standpoint, it has to be kept in mind that periodontal pockets and bone loss can cause exposure of accessory canals located on the furcation surface (Fig 1a) or on the lateral root surface (Fig 2d). Furthermore, accessory canals covered by cementum can be reopened by excessive root planing. These accessory canals or accessory foramina might be contaminated and filled with necrotic tissue and plaque, which may tend to perpetuate periodontal furcation lesions, making successful therapy difficult.
CONCLUSIONS

Within the limitations of this SEM study, because no attempts have been made to investigate the patency of accessory canals, the following conclusions and recommendations for the clinical management can be made:

1. Accessory canals might be responsible for interradicular bone alterations of primary and permanent molars in cases of pulp inflammation.
2. Endodontic therapy should be carried out first on all pulp-induced lesions or combined endodontic-periodontic lesions for which a definitive diagnosis cannot be established.
3. In some cases, complete periodontal therapy for a molar furcation area may also require endodontic therapy.
4. The establishment of the pulpal status is of prime importance in determining the proper sequence of treatment in cases of combined lesions.

REFERENCES