

Frequency, Size and Location of Apical and Lateral Foramina in Anterior Permanent Teeth

(Frekuensi, Saiz dan Lokasi Foramen Apeks dan Lateral pada Gigi Anterior)

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ABSTRACT

The aim of the study was to determine the frequency, size and location of apical and lateral foramina on anterior teeth. A total of 100 anterior teeth consisting of maxillary and mandibular incisors and canines were fixed in 10% formalin. Periodontal tissue remnants were mechanically removed and teeth were stained in 2% aqueous silver nitrate. The teeth were dried and examined using a Leica MZ 7.5 zoom stereomicroscope. The size of apical and lateral foramina and their distance from the anatomical apex of the tooth were measured directly using a calibrated eyepiece scale. Accessory foramina more than 1.8 mm from the apex were regarded as lateral foramina. Eighteen percent of teeth possessed more than one apical foramen. Seven teeth (three maxillary centrals, three maxillary canines, one mandibular lateral) had 11 lateral foramina each. The mean diameter of the lateral foramina was 0.14 mm (SD = 0.08) and their mean distance from the apex was 4.49 mm (SD = 2.63, range 1.9-10.5 mm). Multiple foramina were most common on maxillary canines and least common on maxillary laterals. The mean diameter of apical foramina for all teeth possessing a single foramen was 0.35 mm (SD = 0.10) and the mean apical foramen diameter for all teeth with multiple apical foramina was 0.22 mm (SD = 0.08). Most anterior teeth possess one apical foramen and no lateral foramina; about 20% possessed more than one apical foramen and about 10% possessed one or more lateral foramina. These findings should be considered when root-treating anterior teeth.

Keywords: Apical foramen; canine; incisor; root

ABSTRAK

Matlamat kajian adalah untuk menentukan frekuensi, saiz, dan lokasi foramen apeks dan foramen lateral pada gigi anterior. Satu ratus gigi anterior yang terdiri daripada gigi insisor maksila dan mandibel serta kanin telah direndam dalam 10% formalin. Sisa-sisa tisu periodontium dibuang dan gigi-gigi kemudiannya diwarnakan menggunakan larutan akueus argentum nitrat 2%. Gigi-gigi tersebut dikeringkan dan diperiksa di bawah stereomikroskop Leica MZ 7.5 zoom. Saiz foramen apeks dan lateral berserta jarak dari apeks anatomi diukur menggunakan skala kanta mata yang telah ditentu ukur. Foramen aksesori yang melebihi 1.8 mm dari apeks dianggap sebagai foramen lateral. Didapati 18% gigi mempunyai lebih daripada satu foramen apeks. Tujuh gigi (tiga gigi insisor sentral maksila, tiga kanin maksila dan satu gigi insisor lateral mandibel) mempunyai 11 foramen lateral. Min diameter foramen lateral adalah 0.14 mm (SD = 0.08) dan jarak min dari apeks adalah 4.49 mm (SD = 2.63, julat 1.9-10.5 mm). Lebih daripada satu foramen paling kerap dijumpai pada gigi kanin maksila dan paling jarang pada insisor lateral maksila. Min diameter untuk foramen apeks bagi semua gigi dengan satu foramen adalah 0.35 mm (SD = 0.10); min diameter bagi foramen apeks bagi semua gigi dengan berbilang foramen adalah 0.22 mm (SD = 0.08). Kesimpulannya, kebanyakan gigi anterior mempunyai lebih daripada satu foramen apeks dan tiada foramen lateral. Sebanyak 20% mempunyai lebih dari satu foramen apeks dan 10% mempunyai satu atau lebih daripada satu foramen lateral. Maklumat ini perlu dipertimbangkan ketika menjalankan rawatan akar gigi anterior.

Kata kunci: Akar; foramen apeks; insisor; kanin

INTRODUCTION

Knowledge of apical anatomy is crucial in performing endodontic treatment. There are inconsistencies in the reported incidence of multiple foramina in single-rooted teeth. This could be due to the variations in investigative techniques, non-uniform terminology and the lack of agreement in distinguishing between apical and lateral foramina. Some of the techniques used include sectioning

of teeth (Chapman 1969), infiltration of the root canal system with dyes (Kartal & Yanikoğlu 1992), scanning electron microscopy (Guttierez & Aguayo 1995), radiographic technique (Scarfe et al. 1995) and dental computerised tomography (Robinson et al. 2002).

The incidence and location of lateral foramina has been much less studied than those of apical foramina. The most recent study related to this subject was carried

out by Adorno et al. (2010), whereby the distribution and incidence of accessory canals was assessed in Japanese maxillary anterior teeth. In this article, we described a simple technique of examining the detailed surface features of the roots of human teeth and we have applied the method to investigate apical and lateral foramina in extracted anterior teeth collected from Malaysians, a population that has been rarely studied with respect to root morphology.

MATERIALS AND METHODS

One hundred permanent anterior teeth, comprising maxillary and mandibular central and lateral incisors and canines, were obtained from dental clinics in peninsular Malaysia. The study sample included a minimum of 10 specimens of each tooth type. All teeth were fully formed, as examined under the operating microscope. Teeth which were immature, had undergone resorption or damaged were excluded from the study.

After extraction, the teeth were stored in 70% aqueous ethanol. Remnants of periodontal ligament were removed. The teeth were stained in 2% aqueous silver nitrate and dried before examination with a Leica® MZ 7.5 stereomicroscope equipped with a Leica® MPS 30 semi-automatic film camera. The dimensions of each foramen and its distance from the apex of the root were measured directly using a calibrated eyepiece graticule. In foramina that were not circular, the mean of the maximum and minimum diameters were recorded. The distance of the foramen to the root apex was measured along the long axis of the root from the tip of the apex to the point that was judged to be the centre of the foramen. Foramina found at a distance of 1.8 mm or less from the root apex were

considered as apical foramina. Those found more than 1.8 mm from the root apex were regarded as lateral foramina (Figure 1).

RESULTS

Of the one hundred anterior permanent teeth examined, 82 had a single apical foramen and the remaining 18 had two or more apical foramina (Table 1). The maximum number of apical foramina found on one tooth was four. The modal value for number of apical foramina on anterior teeth was one, but in teeth with multiple apical foramina, the modal value was two. In incisors and canines possessing a single apical foramen, the mean diameter of the foramen and its distance from the apex for each tooth type is given in Table 2. For all 82 teeth with a single apical foramen, the mean diameter was 0.35 mm (SD = 0.1) and the mean distance from the apex was 0.35 mm (SD = 0.29). The mean diameter of multiple apical foramina was 0.22 mm (SD = 0.084) and their mean distance from the apex was 0.53 mm (SD = 0.45).

The mean diameter of lateral foramina was 0.14 mm (SD 0.08 mm) and their mean distance from the apex was 4.49 mm (SD 2.65 mm). The distance of the lateral foramina from the apex ranged from 1.9 to 10.5 mm. Multiple foramina, either apical or lateral, were the most common on maxillary canines (in 9 out of 21 teeth) and the least common on maxillary lateral incisors (in 2 out of 19 teeth).

DISCUSSION

In this study, 82% of the anterior permanent teeth had a single apical foramen and about 90% did not have a lateral

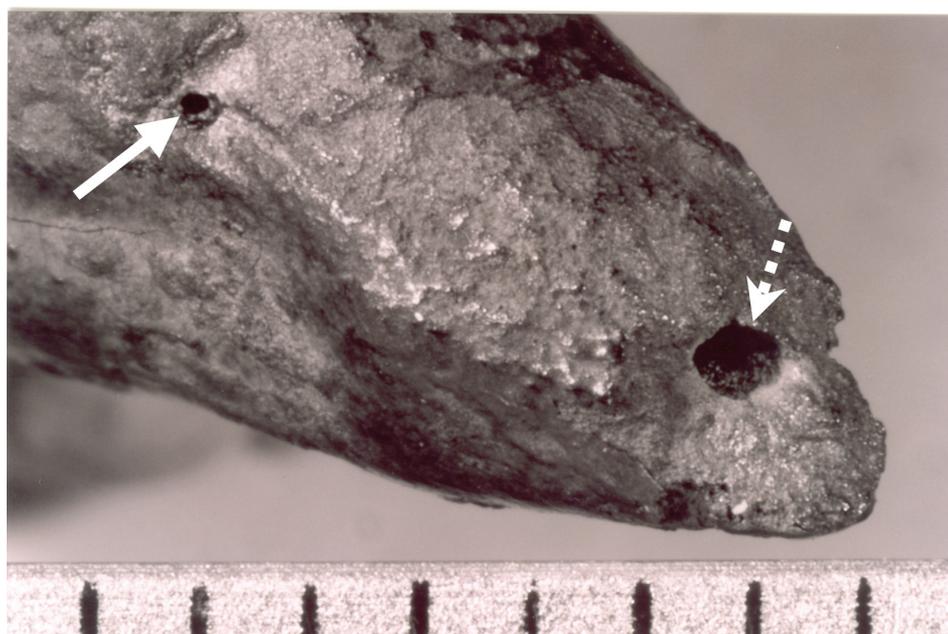


FIGURE 1. Magnified view of a maxillary central incisor showing a lateral foramen (solid arrow) and apical foramen (dotted arrow). Each scale division = 1.0 mm

TABLE 1. Number and type of teeth with multiple apical foramina, lateral foramina and with both multiple apical and/or lateral foramina

Tooth type	Upper central	Lower central	Upper lateral	Lower lateral	Upper canine	Lower canine
Number of teeth	15	17	19	16	21	12
Teeth with multiple apical foramina	0	3	2	4	7	2
Teeth with lateral foramina	4	0	0	1	3	0
Teeth with multiple apical and/or lateral foramina	4	3	2	5	9	2

TABLE 2. Mean diameter and distance from root apex of apical foramen in teeth with single apical foramen

Tooth type	Upper central	Lower central	Upper lateral	Lower lateral	Upper canine	Lower canine
Number of teeth	15	14	17	12	14	10
Mean diameter of foramen (SD)	0.41 (0.10)	0.33 (0.12)	0.32 (0.08)	0.30 (0.07)	0.41 (0.08)	0.32 (0.06)
Mean distance from apex (SD)	0.35 (0.38)	0.37 (0.21)	0.28 (0.17)	0.21 (0.15)	0.58 (0.50)	0.40 (0.26)

foramina. Rarely, an anterior tooth may have multiple apical and multiple lateral foramina. Although the influence of multiple root canals and foramina on the prognosis of endodontic therapy is still debated, it may be that their occurrence could explain the unexpected failure of root-treated anterior teeth.

Our simple technique of staining the roots with silver nitrate displayed surface features with a remarkable degree of detail and facilitated photography (Figure 1). In combination with a stereomicroscope, it is possible to visualise features at 50 μm or less. Compared with scanning electron microscopy, this technique is an inexpensive method to examine large numbers of specimens. The entire root can be viewed and photographed from any aspect.

There is no generally-accepted definition of a lateral canal. De Deus (1975) classified lateral canals as those directed laterally from the root canal. However, our study deals with the root surface so we can only define a lateral canal by its associated foramen position relative to the root apex. There is no agreement in the literature regarding a specific point that demarcates the apical from the lateral region of a root. For example, Gutierrez and Aguayo (1995) included foramina as far as 4.31 mm from the apex as apical foramina. On the other extreme, Kasahara et al. (1990) found that 95% of apical foramina in maxillary central incisors were located within 1.0 mm of the apex.

A distance of 1.8 mm from the root apex distinguished apical from lateral foramina, largely because in our specimens of anterior teeth, it was very unusual for a

single apical foramen to be more than that distance from the apex. Due to the variation in techniques of study and also in defining apical and lateral foramina, it was difficult to compare our results with previous studies. Green (1956) used a stereomicroscope to examine the apical region of anterior teeth and found multiple apical canals in 10-12 % of his specimens, a lower proportion than that found in our study (18%) and perhaps reflecting the fact that Green did not stain the tooth surface. Chapman (1969) using sections of roots, found that 73% of 120 anterior permanent teeth had a single apical foramen, a figure that is comparable with the 82% found in our study. Of the 27% of teeth in Chapman's study with multiple apical foramina, the majority had 2 foramina and the greatest number of apical foramina in a single tooth was 5 (in an upper canine). These results support our contention that anterior teeth with more than 2 foramina were rarely found.

The mean diameter of all apical foramina found in the present study (0.31 mm) and their mean distance from the apex (0.41 mm) compared with the mean diameter found by Chapman (0.28 mm) and mean distance from the apex of 0.36 mm. Chapman found lateral canals in 45% of his teeth, a surprisingly high incidence especially since he examined only the terminal 3 mm of the root whereas in the present study we found lateral foramina in only 7% despite examining the whole surface of the root. However, not all of Chapman's lateral canals emerged at the surface of the root, some having been blocked by calcific or soft tissue deposits (Chapman 1969).

Altman et al. (1970) in a histological study of the apical region of maxillary central incisors found evidence of multiple apical canals in 15 out of a total of 20 specimens: the majority of teeth with accessory apical canals had between 1 and 4 accessory canals but one specimen had a total of 20 separate foramina. Altman et al. (1970) cut thin sections of the apical region of his specimens but apparently did not decalcify the teeth prior to sectioning. This could have caused some artefactual splits to develop in the dentine while cutting and subsequently an overestimation of the number of accessory canals.

Hess et al. (1983) used the electron microscopy to examine the apical region of 27 permanent teeth and found that the main foramen varied in diameter from 0.1 to 0.52 mm, a range that is similar to the dimensions of single apical foramina in the present study. These authors reported that additional apical foramina ranged in diameter from 0.06 to 0.08 mm. This is somewhat less than the dimensions of multiple apical foramina found in the present study. Kasahara et al. (1990), using a dye injection technique, found that 7% of maxillary central incisors possessed multiple apical foramina, an incidence less than half that was found in our study. However, these authors report that 49% of their specimens showed lateral canals, a much larger proportion than the 7% found in our study.

Gutierrez and Aguayo (1995), using low power scanning electron microscopy, found a single foramen in 58% of incisors and canines and multiple apical foramina in the remaining 42%. These authors could not establish a pattern of apical foramina that was typical for a particular tooth type. Sert et al. (2004), in a study of mandibular anterior teeth in a Turkish population, found lateral canals in 7% of central incisors, 13% of lateral incisors and 15% of mandibular canines.

CONCLUSION

Staining with silver nitrate allowed good visualisation of the fine details of root morphology, including apical and lateral foramina. The majority of permanent incisors and canines had a single apical foramen but around 18% have two or more apical foramina. In a small proportion of anterior permanent teeth, (7% in the present study) there are lateral foramina which may be situated as far as 10.5 mm from the apex. At the surface of a root, lateral foramina average 0.14 mm, multiple apical foramina 0.22 mm and single foramina 0.35 mm in diameter. These findings should be considered when carrying out endodontic treatment of anterior teeth.

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REFERENCES

- Adorno, C.G., Yoshioka, T. & Suda, H. 2010. Incidence of accessory canals in Japanese anterior maxillary teeth following root canal filling ex vivo. *International Endodontic Journal* 43: 370-376.
- Altman, M., Guttuso, J., Seidberg, B.H. & Langeland, K. 1970. Apical root canal anatomy of human maxillary central incisors. *Oral Surgery Oral Medicine Oral Pathology* 30: 694-699.
- Chapman, C.E. 1969. A microscopic study of the apical region of human anterior teeth. *Journal of the British Endodontic Society* 3: 52-58.
- De Deus, Q.D. 1975. Frequency, location and direction of the lateral, secondary and accessory canals. *Journal of Endodontics* 1: 361-366.
- Green, D. 1956. A stereomicroscopic study of the root apices of 400 maxillary and mandibular anterior teeth. *Oral Surgery Oral Medicine Oral Pathology* 9: 1224-1231.
- Gutierrez, J.H. & Aguayo, P. 1995. Apical foraminal openings in human teeth. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 79: 769-777.
- Hess, J.C., Culierias, M.J. & Lamiable, N. 1983. A scanning electron microscopic investigation of principal and accessory foramina on the root surfaces of human teeth: Thoughts about endodontic pathology and therapeutics. *Journal of Endodontics* 9: 275-281.
- Kartal, N. & Yanikoğlu, F.C. 1992. Root canal morphology of mandibular incisors. *Journal of Endodontics* 18: 562-564.
- Kasahara, E., Yasuda, E., Yamamoto, A. & Anzai, M. 1990. Root canal system of the maxillary central incisor. *Journal of Endodontics* 16: 158-161.
- Robinson, S., Czerny, C., Gahleitner, A., Bernhart, T. & Kainberger, F.M. 2002. Dental CT evaluation of mandibular first premolar root configurations and canal variations. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 93: 328-332.
- Scarfe, W.C., Fana, C.R. & Farman, A.G. 1995. Radiographic detection of accessory/lateral canals: Use of RadioVisioGraphy and Hypaque. *Journal of Endodontics* 21: 185-190.
- Sert, S., Aslanalp, V. & Tanalp, J. 2004. Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. *International Endodontic Journal* 37: 494-499.
- Walker, R.T. 1987. Root form and canal anatomy of maxillary first premolars in a southern Chinese population. *Endodontics and Dental Traumatology* 3: 130-134.

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