Morphologic Analysis of the Root Apex in Human Teeth

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Abstract

Introduction: To determine the morphologic shape and position of the root apex and the major foramen in maxillary and mandibular teeth. **Methods:** A total of 845 maxillary and mandibular human teeth root specimens were evaluated. Each root specimen was measured at each root apex by using a calibrated microscope at a magnification of 20×. The anatomic parameters evaluated included the position of the root apex and the major foramen (in the center, buccal, lingual, mesial, or distal) and shapes of peripheral contours of the major foramen (rounded, oval, asymmetric, and semilunar) and root apex (rounded, flat, beveled, and elliptical). All data were summarized, and means, frequencies, and percentages were calculated for each group of specimens (incisors, canines, premolars, and molars). **Results:** The most frequent root apex morphology in maxillary and mandibular teeth was the round shape (35.1%). The most frequent shape of the apical foramen was round (52.9%) or oval (25.2%). The major location of both the root apex (39.7%) and the major foramen (58.4%) was in the center of the root. **Conclusion:** The most frequent root apex morphology and apical foramen in the maxillary and mandibular teeth was the round followed by the oval shape. The most prevalent location of the root apex and the major foramen was in the center followed by the distal position. *(J Endod 2010;36:664–667)*

Key Words

Anatomic root apex, dental anatomy, morphology

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0099-2399/$0 - see front matter

doi:10.1016/j.joen.2010.01.014

For successful endodontic treatment, knowledge of the internal and external root canal anatomy is critical (1–3). Unfortunately, two-dimensional radiographic images do not reveal all anatomic characteristics (4, 5). Most canals do not communicate with the periodontal tissue precisely at the root apex, and the apical foramen often does not have a round shape (6). Morphologic analyses show that canals are oval shaped or irregular in the apical third and present their largest diameter at the buccolingual aspect (7–9).

Apical foramina can be asymmetrical under physiologic and pathologic conditions, such as tooth adaptation to functional activity (10–12). Constant remodeling of the root apex by external root resorption and cementum apposition appear to be the most common causes of deviation of the major foramen (13, 14).

With regard to fillings, some studies confirmed that many of the canal surfaces (especially in the apical region) are not touched during canal preparation because of oval or irregular configurations (8, 15, 16). In addition, a buccal location of the foramen has the potential to cause an incorrect clinical measurement of the canal. Radiographically, an apical foramen located buccally or lingually is often superimposed over the root structure, making it difficult to view the exit point of the instrument (4).

Although there is a close relationship between the apical foramen and the root apex, they frequently do not coincide (7). Some authors reported that the foramen openings never coincided with the long axis of the root, defining apical deviation as the extension of a small portion of the foramen from the center of the long axis (17). Deviations ranging from 34% to 92% have been reported (10, 11, 13, 18–23). The aim of this study was to determine the morphologic shapes and positions of the root apex and major foramen in maxillary and mandibular teeth.

Materials and Methods

In this study, 845 nonrestored teeth of the maxillary (n = 453) and mandibular (n = 392) arch (central and lateral incisors, canines, premolars, and molars) with completely formed apices were used. These teeth were obtained from the School of Dentistry at our institution. The dental specimens were collected and analyzed in accordance to the guidelines set forth by our institution's Ethics Committee. The total number of the studied roots was 1,331, and the distributions of the different groups of teeth are summarized in Table 1.

The specimens were manually cleaned from the calculus and periodontal tissues and then stored in saline. We used teeth without any root alterations that could interfere in the identification of the major foramen of each root (ie, apical fractures, root resorption, or hypercementosis). The major foramen was defined as the opening of the largest diameter found at the root apex.

The teeth were dried with gauze compress and cotton, and the apical area was stained with graphite that was carefully applied with a pencil to facilitate the identification of the major foramen of each root. The opening of the largest diameter found at the root apex identified the major apical foramen. Individually labeled bottles were used to keep the teeth separated, and each tooth group was given a number code. The specimens selected were mounted on a microscope slide to prevent their movement and to allow the evaluation to be made parallel to the long axis of the teeth for the calculation of anatomic parameters.

Examinations of the apices were performed with an optical microscope (R. Fuess GmbH, Steglitz, Germany) at a magnification of 20×. A single examiner who was trained

TABLE 1. Morphology of the Root Apex

	Maxillary					Mandibular				
Tooth	Rounded (%)	Flat (%)	Beveled	Elliptical	*n*	Rounded	Flat	Beveled	Elliptical	*n*
Incisors	43 (33.6)	33 (25.8)	27 (21.1)	25 (19.5)	128	36 (32.1)	24 (21.4)	16 (14.3)	36 (32.1)	112
Canines	28 (23.3)	25 (20.8)	17 (14.2)	50 (41.7)	120	20 (18.9)	18 (17)	16 (15.1)	52 (49.1)	106
Premolars	91 (45)	55 (27.2)	25 (12.4)	31 (15.3)	202	60 (57.7)	14 (13.5)	9 (8.7)	21 (20.2)	104
Molars	67 (30.2)	53 (23.9)	29 (13.1)	73 (32.9)	222	53 (38.1)	19 (13.7)	9 (6.5)	57 (41)	139

TABLE 2. Morphology of the Major Foramen

	Maxillary				Mandibular			
Tooth	Rounded (%)	Oval (%)	Asymmetric (%)	Semilunar (%)	Round (%)	Oval (%)	Asymmetric (%)	Semilunar (%)
Incisors	58 (45.3)	38 (29.7)	20 (15.6)	12 (9.4)	54 (48.2)	29 (25.9)	17 (15.2)	12 (10.7)
Canines	52 (43.3)	31 (25.8)	24 (20)	13 (10.8)	61 (57.5)	20 (18.9)	13 (12.3)	12 (11.3)
Premolars	93 (46)	68 (33.7)	27 (13.4)	14 (6.9)	53 (51)	22 (21.2)	18 (17.3)	11 (10.6)
Molars	150 (67.6)	43 (19.4)	17 (7.7)	12 (5.4)	78 (56.1)	35 (25.2)	18 (12.9)	8 (5.8)

and calibrated for the study performed the evaluations. The examiner conducted a preliminary assessment of 10% of samples randomly, and after 20 days, the same samples were re-evaluated in a masked fashion. The examiner agreement was >0.75 according to the Kappa test.

The anatomic parameters evaluated were the shapes of the peripheral contours of major apical foramen (rounded, oval, asymmetric, and semilunar) and the root apex (rounded, flat, beveled, and elliptical). The location was recorded and classified as center, buccal, lingual, mesial, or distal surface for both the root apex and the major apical foramen. It was considered as off center when a large portion of the major apical foramen (≥50%) was located toward the other surfaces.

Additionally, the surface morphology of one randomly selected specimen from each group was qualitatively evaluated with the scanning electron microscope (Carl Zeiss DSM 940A; Carl Zeiss, Oberkochen, Germany). The selected samples were prepared by sectioning the tooth crown, and the sections were set on metal stubs and then gold metalized. For the microscopic analysis, the specific parameters of 20 kV, 27 to 28 mm, and magnification ranging from 12 to 100× were used. All data were summarized with means, frequencies, and percentages for each group (incisors, canines, premolars, and molars) using the software SPSS 8.0 (SPSS Inc, Chicago, IL).

Results

The distribution of the morphology and location of the root apex and the major foramen are summarized in Tables 1 to 4. The most common morphology of the root apex in incisives, canines, and premolars group was the round shape followed by the elliptical shape in mandibular and maxillary molars. The most common shape of the major foramen in all groups was round (52.9%) followed by oval (25.2%).

The location of the major foramen was in the center of the root apex in 58.4% of specimens and deviated from the anatomic apex in 41.6%. The frequency of deviation was higher in the maxillary (22.8%) versus the mandibular (18.7%) teeth. The most frequent locations were buccal and mesial surfaces followed by distal and lingual/palatal (Table 2). The root apex was most commonly located in the center in all groups followed by distal and buccal locations (Table 3).

Discussion

Successful endodontic treatments require the knowledge of the normal root canal morphology and its variations (1–3, 5, 16). In this study, 1,133 roots from adult teeth were examined. The observations of the anatomic topography of the root apex and the major foramen in the present study are in agreement with previous findings. Major findings from this sample included demonstration of the eccentric positions of the major foramen in 41.6 %, and this deviation favored the buccal or mesial locations in the anterior teeth (Fig. 1). In molars, we observed buccal deviations, and in premolars, we observed mesial/distal deviations.

Although there is a close relationship between the locations of the apical foramen and the root apex, the frequency of differing locations of such structures is high. According to some studies, the deviation of the apical foramen ranged from 34% to 92% (7, 10, 11, 13, 18–23). In the present study, the frequency of the apical foramen deviation was 41.6%. Other authors, however, observed a frequency of 45% for the apical deviation (20), and another study (24) has described that in approximately 69% of the anterior teeth, the major foramen did not open directly to the apex. An anatomic study (13) determined microscopically that the frequency of the deviation of the main foramen was 76%, and others reported an even higher percentage of major foramina deviating from the anatomic apices with a mean of 92.4% (19).

The differences between our results and another study that observed that the foramen openings never coincided with the principal axial axis of the root or those of others that showed higher values can be attributed to the methodology (17). These other studies considered the case of a small portion of the foramen area extending to the center of the long axis as an apical deviation. In our study, because of the different shapes and peripheral contours of the apical foramen, it was considered as a deviation only when a significant portion (>50%) of the major foramen extended to the center of the long axis.

The second most frequent location for an eccentrically located apical foramen was towards the buccal aspect. Clinically, this anatomic position of the root apex may cause an incorrect measurement of the canal, with an error of about 2 or 3 mm and may still appear to be correct. At this point, the radiographic dissociation is of crucial importance. This technique will project the canal curvature onto a different plane (25).

With respect to the location of the root apex, the central (39.7%) and distal (34.5%) positions were the most commonly observed in all classes of teeth. The morphology of the root apex was categorized as round, flat, beveled, and elliptical. The most frequent root apex morphology in maxillary and mandibular teeth was the round shape for incisives and premolars (Fig. 1). In canines and molars, it was found that the sharp configuration predominated. Our results showed that

TABLE 3. Location of the Eccentrically Major Foramen

	Maxillary					Mandibular				
Tooth	Centralized (%)	Buccal (%)	Lingual (%)	Mesial (%)	Distal (%)	Centralized (%)	Buccal (%)	Lingual (%)	Mesial (%)	Distal (%)
Incisors	55 (43)	27 (21.1)	8 (6.3)	13 (10.2)	25 (19.5)	50 (44.6)	17 (15.2)	8 (7.1)	25 (22.3)	12 (10.7)
Canines	59 (49.2)	20 (16.7)	10 (8.3)	17 (14.2)	14 (11.7)	48 (45.3)	14 (13.2)	13 (12.3)	21 (19.8)	10 (9.4)
Premolars	103 (51)	20 (9.9)	13 (6.4)	21 (10.4)	45 (22.3)	53 (51)	13 (12.5)	9 (8.7)	10 (9.6)	19 (18.3)
Molars	186 (83.8)	10 (4.5)	6 (2.7)	9 (4.1)	11 (5)	108 (77.7)	11 (7.9)	5 (3.6)	8 (5.8)	7 (5)

TABLE 4. Location of the Root Apex

	Maxillary					Mandibular				
Tooth	Centralized (%)	Buccal (%)	Lingual (%)	Mesial (%)	Distal (%)	Centralized (%)	Buccal (%)	Lingual (%)	Mesial (%)	Distal (%)
Incisors	40 (31.3)	30 (23.4)	8 (6.3)	16 (12.5)	34 (26.6)	48 (42.9)	21 (18.8)	6 (5.4)	20 (17.9)	17 (15.2)
Canines	53 (44.2)	9 (7.5)	6 (5)	9 (7.5)	43 (35.8)	49 (46.2)	2 (1.9)	3 (2.8)	15 (14.2)	37 (34.9)
Premolars	86 (42.6)	25 (12.4)	22 (10.9)	5 (2.5)	64 (31.7)	34 (32.7)	13 (12.5)	8 (7.7)	4 (3.8)	45 (43.3)
Molars	88 (39.6)	20 (9)	5 (2.3)	20 (9)	89 (40.1)	52 (37.4)	6 (4.3)	4 (2.9)	15 (10.%)	62 (44.6)

a great number of mandibular roots had the sharp morphology, similar to others findings that found sharp shapes (34.5%) to be the most common followed by the round shape (30.5%) in anterior teeth (22).

The shapes of apical foramen were categorized as round, oval and semilunar, but variations were possible, resulting in asymmetrical shapes. The majority of specimens showed a round shape (52.9%) of the major foramen, but variations of the peripheral contours were observed (Fig. 1). The oval shape appeared as the second most common in all specimens (25.2%). Of the four main contours of the apical major foramen, the semilunar type ranged from 4.5% to 3.8% in maxillary/mandibular groups. The asymmetrical peripheries ranged from 5.8% to 7.7%.

Although most of the apex foramen were round (52.9%) or oval (25.2%) in shape, another study described the shapes of peripheral contours of the apical foramen as semilunar, serrated, hourglass, or asymmetric (26). The author found round types to make up 58% to 78% followed by oval and asymmetrical shapes.

These slight variations could be caused by the methodology used to calculate the morphology, the different ages of specimens, the small number of groups investigated, or the influence of occlusion and other factors that could mask or modify the results (13). The permanent remodeling of the root apex through cementum apposition and resorption probably could interfere and modify the results of the anatomic evaluation.

Instrumentation or filling should not extend beyond the apical foramen (8). This is very important when the location of the major apical foramen or root apex is buccal or lingual because it may result in overinstrumentation. The clinical determination of this limit is based on the operator's tactile sensitivity and the subjective interpretation of the bidimensional radiographic image (27). Small but quite important variations of apical micromorphology, which may not be detected radiographically, require the use of auxiliary methods like electronic methods, an operating microscope, and cone-beam computed tomography scanning (1).

Conclusions

The predominant morphology of the root apex in incisors and premolars was the round shape both in the maxillary and mandibular teeth. In canines and molars, the predominant configuration was the pointed shape. The morphology of the apical foramen showed a predominance of the rounded shape followed by the oval shape. The prevalent location of the root apex and the foramen was the central position followed by the distal position.

Figure 1. An scanning electron micrograph of the different root apices showing different deviations of the major foramen (*left*). The typical round shape of the root apex (*center*) and the major foramen (*right*).

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