

Variations in Canal Morphology, Shapes, and Positions of Major Foramen in Maxillary and Mandibular Teeth

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Abstract

Context and Aim: A plethora of studies have revealed that there is a lack of general consensus in the precise anatomic detailing of the canals and the major foramen in both the maxillary and mandibular teeth while emphasizing the significance of the same for a successful endodontic treatment. The aim of the present study was to determine the variations in canal morphology, shapes, and positions of major foramen in maxillary and mandibular teeth. **Materials and Methods:** In the present study, 420 extracted human maxillary and mandibular teeth with completely formed apices were included. The specimens were cleaned for surface debris including remnants of periodontal tissue and were stored in saline. Examination of the apices was performed with the help of stereomicroscope for their exact shapes and configurations and precise anatomic location. Comparison of different parameters within the group was done using Chi-square test while $P < 0.05$ was considered statistically significant. **Results:** The results of the present study indicated that apical foramen in mandibular teeth showed higher degree of deviation with a prevalence of 70.2% while flat shape of apical foramen was observed only in maxillary teeth. Furthermore, maximum deviation in maxillary teeth was recorded in the canines with a prevalence of 90% while, in mandibular teeth, maximum deviation was recorded with mandibular second premolars with a prevalence of 79.12%. **Conclusions:** The results of the present study revealed that deviation of apical foramen from the root apex was seen in 68.2% of the specimens. Furthermore, deviation was greater in the mandibular than the maxillary teeth.

Keywords: Canal morphology, major foramen, maxillary and mandibular teeth, morphologic shapes and positions

INTRODUCTION

A precise knowledge of the internal and external canal anatomy and the positions of major foramen is critical for a successful endodontic treatment. Unfortunately, plain film radiography fails to reveal all anatomic detailing in most of the situations being a two-dimensional representation of three-dimensional anatomic structures with complex anatomies. Furthermore, most of the canals do not have a well-defined, predictable course and do not communicate with the periapical and periodontal tissues precisely at their anatomic apex. The apical foramen too often does not have a round configuration as is presumed and discovered with the help of conventional radiology.^[1,2]

Numerous studies on canal morphology have revealed intense variations in canal morphologies, with the canals being oval or irregular in the apical third of their anatomic course and presenting their greatest diameter in the buccolingual dimension.^[1,2] Furthermore, the foramina may change their shapes and location based on the functional influences including varying tongue and occlusal pressures and mesial drift on the teeth. Such changes are often reflected in the form of resorption of cementum on the wall of the foramen which

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is farthest from the pressure while a simultaneous cemental apposition is seen on the wall that is the nearest. The net result of all these changes is deviation of the foramen away from its anatomic apex. The morphology of the root apex is also influenced by the number and the anatomical location of the blood vessels present at the time of the formation of the root apex. The foramina can be asymmetrical too under the influence of the varying physiological and pathological conditions existing during the formative stages of the root apex.^[3]

Furthermore, the possibilities of vascular branching are so varied at the apex that prediction of the number of the developing foramina is almost uncertain.^[3] Few studies have also confirmed that many a times, canals are not even prepared owing to their complex, inapproachable configurations. Such variations in the anatomy of the canals and the apices often lead to an increased possibility of errors in carrying out the correct clinical measurements. Radiographically, such variations in the anatomy of the canals and the apices including a foramen located buccally or lingually which often gets superimposed over the underlying structure of the root make canal negotiation an extremely tiring task with sometimes, these unnegotiated canals being one of the most significant reasons for endodontic failures and flares.^[4]

Although, in most of the clinical situations, the apical foramen is often seen as the terminal point of the root apex, there are high chances of variations wherein the two may be morphologically differently located.^[1,2] A plethora of studies have also reported that the foramen openings never coincided with the long axis of the roots defining apical deviation as the extension of a small portion of the foramen from the center of its long axis. ElAyouti *et al.* also reported such irregularities in the exact working length determination leading to overestimation of the working length of canals in 51% of the treated cases.^[5] Therefore, an exclusive dependence on dental radiographs for exact working length determination often leads to erroneous results and subsequent complications of over- and/or under-instrumentation of the canals leading to endodontic failures. Numerous studies conducted in this regard have also concluded with extensive variations in the precise anatomic detailing of the canals and the major foramen in both the maxillary and mandibular teeth while emphasizing the significance of the same for a successful endodontic treatment. The aim of the present study was to determine the variations in canal morphology, shapes, and positions of major foramen in maxillary and mandibular teeth.

MATERIALS AND METHODS

In the present study, 420 extracted human maxillary and mandibular teeth (210 – maxillary and 210 – mandibular) The study protocol was approved by the Institutional Ethics Committee via letter approval no. SDDC/IEC/07-41-2018. with completely formed apices including the central and lateral incisors, canines, first and second premolars, and first

and second molars from both the maxillary and mandibular arches were included. The specimens were manually cleaned for the surface debris including remnants of the periodontal tissue and were stored in saline. Teeth with apical fracture, root resorption, and hypercementosis were excluded from the study. The teeth were dried with gauze compress and cotton, and the apical areas were stained with graphite to facilitate the identification of the major foramen of each root. The opening of the largest diameter found at the root apex was noted as the major apical foramen while individually labeled containers were used to keep the teeth separate. Each group of teeth was given a number code. The specimens selected were mounted on a stereomicroscope slide with a magnification of $\times 10$ 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. Examination of the apices was performed for their exact shapes and configurations and precise anatomic location. It was considered off-center when a large portion of the major apical foramen ($\geq 50\%$) was located toward other surfaces.

Statistical analysis used

Statistical analysis was done using IBM SPSS statistics version 17 (Chicago, IL, USA). Comparison of different parameters within the group was done using Chi-square test while $P < 0.05$ was considered statistically significant.

RESULTS

In the present study, a total of 696 apical foramina were evaluated out of the 420 extracted human maxillary and mandibular teeth (210– maxillary and 210– mandibular) included. The results obtained in the present study revealed that the frequency of deviation was 68.4% in evaluated teeth while the most common location of the apical foramen was central with 31.6% of the teeth followed by distal with a prevalence of 18.2%. Mesial deviation of the apical foramen was the next most common deviation noticed (17.4%) followed by labial/buccal (17%), then lingual (10.1%), and palatal (5.7%) deviations. The most common shape found in all evaluated apical foramen was round with a prevalence of 65.1% followed by oval with a prevalence of 31.0%. Semilunar shape of apical foramen was noticed in 0.6% of the teeth examined while an equal number of teeth showed flat apical foramen. Furthermore, 2.7% of the teeth examined revealed uneven apical foramina. The location of the apical foramen for maxillary group and mandibular group is shown in Table 1. Apical foramen in mandibular teeth showed higher degree of deviation with a prevalence of 70.2%. Table 2 represents the shape of the apical foramen for the two groups. Flat shape of apical foramen was observed only in maxillary teeth. The locations of the apical foramen for each type of maxillary teeth are shown in Table 3. Maximum deviation in maxillary teeth was recorded in the canines with a prevalence of 90% while the least was seen in case of maxillary central incisors with 63.3% prevalence. The locations of apical foramen for each type of mandibular teeth are shown in Table 4. Maximum deviation in mandibular

teeth was recorded with mandibular second premolars with a prevalence of 79.12% while the least was with mandibular canines with 61.3% prevalence. The shapes of apical foramen for each type of maxillary teeth are shown in Table 5. The most common shape of apical foramen for maxillary central incisors was oval with 56.7% prevalence while flat shape of apical foramen was only observed in maxillary second molars with 4.5% prevalence. Table 6 represents the shapes of apical foramen for each type of mandibular teeth. The most common shape of apical foramen for mandibular central incisors was oval with 53.3% prevalence while the prevalence of flat shape apical foramen in mandibular teeth was found to be 0.0%.

DISCUSSION

As a general consent, apical constriction is used as an anatomic reference point by most of the clinicians as the apical terminus of the canals for canal shaping and cleaning purposes. Since locating the apical constriction is difficult in most of the situations clinically, radiographic apex is considered to be a more reliable reference point, though this consensus again has met with a lot of controversy since variations in root morphology and size and shape distortion along with superimpositions seen on plain film radiography with variation in the angulations used for exposure may cause the location of the radiographic apex to vary from its anatomic apex.^[1,2,6] A study conducted by Meder-Cowherd *et al.* revealed that apical constriction was not present in a significant percentage of the roots studied while yet another study conducted by Wu *et al.* concluded that the major apical foramen was a useful landmark for canal shaping and cleaning purposes.^[6,7] It was because of these findings and the supporting evidences in the existing literature in this regard that in the present study, focus was kept on apical foramen rather than apical constriction.

The results of the present study showed deviation of the apical foramen from the anatomic root apex in 68.2% of the teeth

selected for the study. Likewise, Sayão Maia *et al.* found 60% of the specimens with deviation of the apical foramen.^[8] In two different studies conducted by Martos *et al.*, though, the authors found lower prevalence of around 45% in the samples examined.^[1,2] The wide variations in the results might be attributed to the differences in the sample size included and methodologies used to assess such anatomic differences.

In the present study, the most frequent direction of deviation of the apical foramen from the anatomic root apex was found to be distal in accordance with the results of the study conducted by Sayão Maia *et al.*^[8] It is particularly important to know the direction of the curvature of each root, especially curvature toward the lingual or the buccal aspects of the root since the conventional radiographs often are unable to detect these deviations and project a similar image of a straight canal for either of the case. Such occurrences often lead to serious errors by the clinicians during preparation of such canals for endodontic treatments. By knowing the high prevalence of such variations, the clinicians can avoid the chances of failed negotiations by carefully observing the direction of the instruments while exploring the root canals often leading to inadvertent perforation of the canals during instrumentation.

The second most frequent direction of deviation of the apical foramen from their anatomic root apex in the present study was found to be buccal or labial with 17% prevalence. The said observation was again found to be in accordance with previous studies conducted by Martos *et al.*^[1,2] In the present study, the deviation in lingual/palatal direction was found to be around 15.8%. Furthermore, the frequency of deviation in lingual/palatal direction was found to be maximum (40%) in case of central incisors while the frequency of deviation in buccal direction was found to be maximum (23.3%) in the lateral incisors in case of maxillary teeth. In mandibular teeth, central incisors showed the highest degree of the labial deviation of the apical foramen (43.4%) while lateral incisors showed the

Table 1: Location of apical foramen for maxillary and mandibular specimens

Location of apical foramen	Maxillary	%	Mandibular	%	
Distal	61	16.20	66	20.60	Chi-square=8.2460, P=0.0830
Labial/Buccal	54	14.30	64	20.10	
Mesial	65	17.20	56	17.50	
Lingual/Palatal	62	16.40	38	11.90	
Center	125	33.20	95	29.80	
Deviation		66.80		70.20	

Table 2: Shape of apical foramen for maxillary and mandibular specimens

Shape of apical foramen	Maxillary	%	Mandibular	%	
Round	235	62.30	28	68.30	Chi-square=74.1960 P=0.0001*
Oval	122	32.00	94	29.50	
Flat	4	1.10	0	0.00	
Uneven	15	3.90	4	1.30	
Semilunar	1	0.30	3	0.90	

*P<0.05 - Statistically significant

Table 3: Location of apical foramen for individual maxillary root specimens

	Distal %	Labial/buccal %	Mesial (%)	Lingual (%)	Center (%)	Palatal (%)	Total
First premolar	6	15.79	8	21.05	7	18.42	38
Second premolar	2	3.33	11	18.33	10	16.67	60
First molar	21	21.21	9	9.09	20	20.20	99
Second molar	19	21.11	17	18.89	10	11.11	90
Canine	7	23.33	2	6.67	12	40.00	30
Central incisor	2	6.67	2	6.67	3	10.00	30
Lateral incisor	4	13.33	7	23.33	2	6.67	30
Total	61	16.18	54	14.32	65	17.24	377

**P*<0.05 - Statistically significantChi-square=121.2105,
P=0.0001*

highest degree of lingual deviation (21.2%). The labial/buccal deviation of apical foramen was found to be the maximum in mandibular teeth while the lingual/palatal deviation of apical foramen was maximum in case of maxillary teeth. Clinically, this labial/buccal and lingual/palatal deviation of the apical foramen may cause an incorrect measurement of the canal with an error of about 2–3 mm of the working length with increased chances of underpreparation and high chances of endodontic failures due to infected pulp tissue remaining in the canals.^[1,2]

In the present study, 68.5% of the posterior teeth showed deviation of their apical foramen. Rahimi *et al.*, though, found deviation in 83% of the examined maxillary incisors in their study.^[9] Souza *et al.* likewise found 75% of the apical foramina deviating from their anatomic root apex.^[10] In the present study, the frequency of deviation of the apical foramen in maxillary central incisors was found to be 73.3% which was in close accordance with the said study.

In the present study, the frequency of deviation of the apical foramen in the maxillary central incisors was found to be 70% as against 66.67% in the laterals and up to 90% in the maxillary canines. Similarly, the frequency of deviation in the upper and lower central and lateral incisors and canines together in the present study was found to be 70.2%.

The frequency of deviation of apical foramen in mandibular second premolars in the present study was found to be 78.1% in close accordance with the study conducted by Rahimi *et al.* who found that the apical foramen was deviating in 78.1% of the teeth examined in their study.^[9] Likewise, the frequency of deviation of apical foramen in the present study for mandibular premolars together was found to be 72.8% in close accordance with the study conducted by Safi *et al.* who found similar deviation in a range of 80%–90%.^[11] In the present study, the frequency of apical foramen deviating from root apex in molars was found to be 68.7% as against the finding of the study conducted by Asna-Ashari *et al.* who found the said deviation in 52% of the samples studied.^[12] Sayão Maia *et al.*, on the other hand, found the percentage of deviation to be 60.1%.^[8]

The other significant parameter examined in the present study included the shape of apical foramen studied wherein the most common shape of apical foramen in the present study was found to be round followed by oval configuration. The findings of the present study were found to be in close accordance with the studies conducted by Martos *et al.*^[1,2] Numerous studies including the ones conducted by Marroquín *et al.* and Jeong *et al.* have also shown oval to be the most common shape of the apical foramen in the studied samples in their studies.^[13,14]

In the present study, 57% of the central and lateral incisors and canines showed round apical foramen. Martos *et al.*, though, found 52.9% of the apical foramina with round shape in their study.^[1,2] In case of posteriors, Marroquín *et al.* found 71% of the apical foramina in the maxillary while 53% of the apical foramina in the mandibular molars having an oval configuration.^[13] Likewise, Jeong *et al.* found oval apical

Table 4: Location of apical foramen for individual mandibular root specimens

	Distal	%	Labial/Buccal	%	Mesial	%	Lingual	%	Center	%	Total
First premolar	11	27.50	6	15.00	10	25.00	0	0.00	13	32.50	40
Second premolar	7	21.88	8	25.00	4	12.50	6	18.75	7	21.88	32
First molar	29	29.00	12	12.00	17	17.00	14	14.00	28	28.00	100
Second molar	11	20.75	8	15.09	14	26.42	4	7.55	16	30.19	53
Canine	0	0.00	10	32.26	4	12.90	5	16.13	12	38.71	31
Central incisor	5	16.67	13	43.33	2	6.67	2	6.67	8	26.67	30
Lateral incisor	3	9.09	7	21.21	5	15.15	7	21.21	11	33.33	33
Total	66	20.69	64	20.06	56	17.55	38	11.91	95	29.78	319

*P<0.05 - Statistically significant

foramen in 69.9% of the samples included in their study.^[14] The results of the present study, though, revealed only 27% of the apical foramina among the posteriors with oval shape with 36.7% prevalence in case of maxillary and 25.8% in case of mandibular molars.

Olson *et al.* found the most common shape of apical foramen to be uneven in their study with a prevalence rate of 70% in contrast with the results of the present study as the most common shape of apical foramen in the present study in case of maxillary central incisors was found to be oval with 56.7% prevalence while uneven shape was found only in 3.4% of the teeth examined.^[15] The variation in the results could be attributed again to the differences in the sample size studied, differences in the methodologies used to evaluate the morphology, the different age groups of the patients the specimens belonged to, and the influence of occlusion and other factors that could modify the results significantly.

Over- or under-instrumentation of the canals is often an important cause of endodontic failures. This is even more significant in case of buccally/lingually deviated apical foramen because it might often lead to over instrumentation, the chances for which are avoided based on the operator's clinical skills and an accurate interpretation of radiographic images, though, with increasing advances in the diagnostic adjuncts available these days, the clinicians are often switching to the recent technological advances including electronic apex locators, operating microscopes, and cone-beam computed tomography.^[1,16,17]

CONCLUSIONS

The results of the present study revealed the most common location of apical foramen in center followed by distal while the deviation of apical foramen from the root apex was seen in 68.2% of the specimens. The most common direction of deviation was found to be distal followed by mesial while the second most common direction of deviation among posteriors was buccal. Furthermore, deviation was greater in the mandibular than the maxillary teeth. In maxillary teeth, deviation of apical foramen was greater in the central and lateral incisors and canines than posteriors while, in mandibular teeth, deviation of apical foramen was found to be more common in the posterior than in the anterior teeth. Maxillary canines showed maximum deviation of apical foramen while, on the contrary, mandibular canines showed the least deviation in the observed specimens. The most common shape of apical foramen was round followed by oval while oval shape of apical foramen was the most frequent finding with the central incisors.

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Table 5: Shape of apical foramen for individual maxillary root specimens

	Round	%	Oval	%	Flat	%	Uneven	%	Semilunar	%	Total	Chi-square=60.2722, P=0.0001*
First premolar	32	84.21	4	10.53	0	0.00	2	5.26	0	0.00	38	
Second premolar	38	63.33	14	23.33	0	0.00	7	11.67	1	1.67	60	
First molar	56	56.57	43	43.43	0	0.00	0	0.00	0	0.00	99	
Second molar	59	90.77	2	3.08	4	6.15	0	0.00	0	0.00	65	
Canine	22	73.33	6	20.00	0	0.00	2	6.67	0	0.00	30	
Central incisor	12	40.00	17	56.67	0	0.00	1	3.33	0	0.00	30	
Lateral incisor	19	57.58	11	33.33	0	0.00	3	9.09	0	0.00	33	
Total	238	67.04	97	27.32	4	1.13	15	4.23	1	0.28	355	

*P<0.05 - Statistically significant

Table 6: Shape of apical foramen for individual mandibular root specimens

	Round	%	Oval	%	Flat	%	Uneven	%	Semilunar	%	Total	Total	Chi-square=75.6913, P=0.0001*
First premolar	2	13.33	13	86.67	0	0.00	0	0.00	0	0.00	15	15	
Second premolar	24	75.00	8	25.00	0	0.00	0	0.00	0	0.00	32	32	
First molar	2	6.67	27	90.00	0	0.00	1	3.33	0	0.00	30	30	
Second molar	40	75.47	13	24.53	0	0.00	0	0.00	0	0.00	53	53	
Canine	2	22.22	5	55.56	0	0.00	1	11.11	1	11.11	9	9	
Central incisor	14	46.67	16	53.33	0	0.00	0	0.00	0	0.00	30	30	
Lateral incisor	17	51.52	12	36.36	0	0.00	2	6.06	2	6.06	33	33	
Total	101	50.00	94	46.53	0	0.00	4	1.98	3	1.49	202	202	

*P<0.05 - Statistically significant

Conflicts of interest

There are no conflicts of interest.

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