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Anatomic Characteristics of the Apex of the Tooth Root in Georgian Population Using Scanning Electron Microscopy (SEM)

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ABSTRACT

BACKGROUND

The knowledge of topography and morphology of the anatomical landmarks located in the apical third of the root is crucial for successful endodontic treatment. The apical third of the root is the narrowest part of the root which should be processed with the minimally invasive method to create an ideal space for obturation.

OBJECTIVES

The apical third of the roots has not been conducted in Georgia, therefore there is no map of the apical third variations of the tooth canals of the Georgian population. Our study aimed to investigate the single-rooted teeth's anatomical foramen form, number, and topography in the Georgian population with a scanning electron microscope.

METHODS

For the study, we have selected 102 single-rooted teeth extracted from the upper and lower jaws of humans. For the preparation of extracted teeth, we used a protocol based on the general rules of tooth preparation available in the literature. The morphological study of the samples was performed with a JOEL company scanning electron microscope (GSM 6510LV), which is equipped with an English company Oxford Instrument energy dispersive micro-X-ray spectral analyzer, X-Max.

RESULTS

The most common shape of the anatomical foramen in the population of Georgia was round (54.90%) and oval (39.21%). It was found that only one anatomical hole in the upper central incisors was noted in the entire population. In the teeth of all the other groups we studied, we described one or more anatomical foramen. It was also interesting to study deviations of anatomical foramens. The research showed, that most often the anatomical foramen was at the peak of the root apex and had the distal position from it. The degree of deviation in the teeth of the upper and lower jaw was 50.98% of total.

CONCLUSIONS

54.90% of the anatomical tooth root foramen of the population of Georgia have a round shape, 39.21% have an oval shape, and the other shapes are found only in 5.88%. 1 anatomical foramen at the apex of the tooth root in 79.41% of cases, and 2 holes or more in 20.58%. The central opening of the apical foramen was described in 50 teeth (49.02%).

KEYWORDS

Anatomical foramen; apex; deviation; maxillary and mandibular teeth; root; SEM (Scanning Electron Microscope).

BACKGROUND

The knowledge of topography and morphology of the anatomical landmarks located in the apical third of the root is crucial for successful endodontic treatment. The apical third of the root is the narrowest part of the root which should be processed with the minimally invasive method to create an ideal space for obturation.[1,2]

Nowadays, the dental market has a wide selection of equipment, accessories, and treatments. Targeted radiography and computed tomography, are almost mandatory for planning the endodontic treatment and treatment outcome registration, allowing for a better understanding of the root apical architecture.[3]

It is not the news, that the horizontal dimension of the root canal system is more complicated to study than the vertical dimension (root length, initial working length of the canal) It is due to the presence of additional canals and anatomical foramens.[4] Without using the traditional clinical-radiological methods of examination, it is practically impossible to determine in which area of the root surface and in which direction such canals have to be open.[5-7] But for

successful endodontic treatment, it is important to determine the distance between physiological narrowing, anatomical foramen, and anatomical apex. Anatomical foramen frequently is taking asymmetric form (due to different pathological processes) and may not be located at the peak of the anatomical apex of the tooth root. Either the diameter of the foramen is not stabile and due to stages of apposition and maturation frequently experiences age-related aberrations.[8]

The diversity of the apical part of the canal is determined by the presence of numerous additional canals, by resorption and reparation of foci, attached, inserted, and free calcifications of pulp and irregular dentin. The above-mentioned reasons are the basis of the so-called "refractory" periodontitis, which is difficult to manage and often does not comply with endodontic treatment.[9-12]

The apical third of the roots has been studied by different authors at different times with different methods.[13,14] The obtained data were more or less variable from each other and were authentic only for specific populations.[15]

A similar study has not been conducted in Georgia, therefore there is no map of the apical third variations of the tooth canals of the Georgian population.

Our study aimed to investigate the single-rooted teeth's anatomical foramen form, number, and topography in the Georgian population with a Scanning Electron Microscope.

METHODS

For the study, we have selected 102 single-rooted teeth extracted from the upper and lower jaws of humans. From the upper jaw: 19 - central, 8 - lateral incisor; 8 - molar, 10 - second premolar. From the lower jaw: 20 - central incisor; 17 - lateral incisor, 9 - molar, 11 - first premolar (Tab.1).

The teeth samples for the study were prepared by us at the UNIDENT dental clinic and Teaching-Research Center and the TSMU dental clinic named after Apolon Urushadze (Fig.1). The study of teeth with a scanning electron microscope was performed at the Strategic Research Center of the Technical University of Georgia.

TABLE 1. The distribution of the human teeth according to their groups

	Extraxted teeth (n=102)	
	Upper jaw (n=45)	**Lower jaw (n=57)**
Central incisors	19	20
Lateral inscisors	8	17
Canina	8	9
1st premolar	0	11
2nd premolar	10	0

FIGURE 1. The distribution of (A) the human teeth according to their groups and (B) sample pack, and storage

The extracted teeth were carried out according to the order of the Minister of Internally Displaced Persons from the Occupied Territories, Labor, Health and Social Affairs of Georgia (dated June 23, 2020, N01-282/o (Prevention of infection when handling extracted human teeth, tissue biopsies around the tooth, and operative material. https://www.moh.gov.ge).

For the preparation of extracted teeth, we used a protocol based on the general rules of tooth preparation available in the literature. At first, the teeth were washed and placed in a disinfectant solution (ANIOSYME DD1 BIOLAND) for 1 hour. Then the teeth were cleaned from the surrounding tissues with ultrasound and a brush. Clean teeth were rinsed under running water and placed in a 5% NaOCL solution for 24 hours (for the final elimination of organic debris around the root) for storage. he teeth removed from the antiseptic solution were washed again in running water and placed in 90% ethyl alcohol for dehydration. We left in a such way prepared teeth in the air for 72 hours. The morphological study of the samples was performed with a JOEL company scanning electron microscope (GSM 6510LV), which is equipped with an English company Oxford Instrument energy dispersive micro-X-ray spectral analyzer, X-Max. Electron imaging of the surface was produced in secondary electrons using an accelerating voltage of 20 kV. Since the research object (tooth) is impermeable, its surface was covered with a thin

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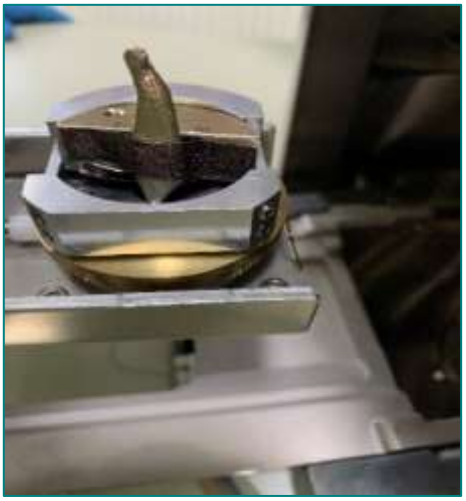
layer of gold (<10 nm) to obtain a sharp image. For this purpose, the JEC-3000FC vacuum coating device of the Japanese company JOEL was used (Fig.2). The sample was attached to a cylindrical aluminum table using a special graphite adhesive tape (Fig.3). After creating a vacuum of 3 Pa pressure, a gold plasma cloud was formed as a result of "bombarding" the gold foil with high voltage ions, which ensured that the surface of the sample was covered with an amorphous layer of gold. (Fig.4) After turning off the vacuum, the cylindrical table was placed with the sample in a special microscope holder and attached to the goniometric stage of the microscope. After obtaining an appropriate vacuum in the microscope column, the sample was ready for morphological study.

FIGURE 2. Vacuum coating

FIGURE 3. The sample is placed on a cylindrical table

FIGURE 4. A sample covered with a thin layer of gold



RESULTS

As mentioned, we studied the apical part of 102 teeth. The most common shape of the anatomical foramen in the population of Georgia was round (54.90%) and oval (39.21%). In 5.88% we described fissured-like, helmet-like, and other forms. Flat-shaped apical foramens (which have been encountered in some literature sources) have not been observed. A round foramen was observed in 60% of the upper teeth, and an oval foramen in 40%. In the case of mandibular teeth, the percentage ratio was distributed as follows: 50.87% had round-shaped foramens, 38.59% had oval foramens, and 10.52% had other shapes. (Tab.2)

TABLE 2. Distribution of apical foramen shapes in extracted human teeth

	Upper jaw				Lower jaw			
Teeth	**Number**	**Round**	**Oval**	**Other**	**Number**	**Round**	**Oval**	**Other**
Central incisors	19	12 63.1%	7 36.8%	0	20	6 30%	14 70%	0
Lateral inscisors	8	0	8 100%	0	17	12 70.6%	5 29.4%	0
Canina	8	8 100%	0	0	9	5 55.6%	0	4 44.4%
1nd premolars	0	0	0	0	11	6 54.5%	3 27.3%	2 18.2%
2nd premolars	10	7 70%	3 30%	0	0	0	0	0
Total	45	27 60%	18 40%	0	57	29 50.9%	22 38.6%	6 10.5%

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The next task of our research was to study the number of apical foramens. It was found that only one anatomical hole in the upper central incisors was noted in the entire population (Tab.3).

In the teeth of all the other groups we studied, we described one or more anatomical foramen, although the number of cases of one foramen was higher (79.41%), two anatomical foramens made up 16.66% of cases, and more than two - 3.92%.

The number of anatomical foramens in the teeth of the upper and lower jaw was distributed as follows: in the teeth of the upper jaw, there was one anatomical hole in 77.77%, two in 17.77%, and more than two in 4.44%. On the lower jaw: one anatomical hole - 80.70%, two anatomical holes in 15.78%, and more than two in 3.50% (Tab.3).

TABLE 3. Distribution of the number of anatomical holes in extracted human teeth

	Upper jaw				Lower jaw			
Teeth	n	1	2	>2	n	1	2	>2
Central incisors	19	19 (100%)	0	0	20	18 (90%)	2 (10%)	0
Lateral inscisors	8	6 (75%)	2 (25%)	0	17	15 (88.2%)	2 (11.8%)	0
Canina	8	4 (50%)	4 (50%)	0	9	7 (77.8%)	2 (22.2%)	0
1nd premolars	0	0	0	0	11	6 (54.4%)	3 (27.3%)	2 (18.3%)
2nd premolars	10	6 (60%)	2 (20%)	2 (20%)	0	0	0	0
Total	45	35 (77.8%)	8 (17.8%)	2 (4.4%)	57	46 (80.7%)	9 (15.8%)	2 (3.5%)

It was also interesting to study deviations of anatomical foramens. The research showed, that most often the anatomical foramen was at the peak of the root apex and havd the distal position from it. The degree of deviation in the teeth of the upper and lower jaw was 50.98% in total. The percentage of deviation probability was higher in the lower jaw (54.38%) than in the upper jaw (46.66%) (Tab.4).

TABLE 4. Redistribution of apical foramen localization in extracted human teeth

	Upper jaw			Lower jaw		
Teeth	n	Central	Deviation	n	Central	Deviation
Central incisors	19	15 (78.9%)	4 (21.2%)	20	5 (25%)	15 (75%)
Lateral inscisors	8	5 (62.5%)	3 (37.5%)	17	12 (70.6%)	5 (29.4%)
Canina	8	4 (50%)	4 (50%)	9	0	9 (100%)
1nd premolars	0	0	0	11	9 (81.8%)	2 (18.2%)
2nd premolars	10	0	10 (100%)	0	0	0
Total	45	24 (53.3%)	21 (46.7%)	57	26 (45.6%)	31 (54.4%)

DISCUSSION

The results obtained during the study of the shape, number, and topography of the anatomical foramen with a scanning electron microscope allowed us to analyze several interesting issues and draw the preliminary conclusions (Fig.5).

The following physiological foramen shape frequencies were founded, most often the anatomical foramen in the teeth studied had round (54.90%) and oval (39.21%) shapes, and in some samples, helmet-like and crack-like (5.88%) shapes were reviewed.

Our study results are relevant to existing studies and researchs. For example, after M. Z. Manva-ს studies (2020-2021) in 68% of back teach-round foramen were reviewed.[16,17] In the data of X. Pi and co-authors (1996), the round foramen was 94%.[18] A study by J. Martos (2010) showed 52.9% in favor of a round foramen.[19,20] In the studies of B. Swathika and co-authors (2021) also dominated the round shape of the anatomical foramen - 62%.[13] In the same study, B. Swathika described for the first time the flat shape of the anatomical foramen in the maxillary teeth.

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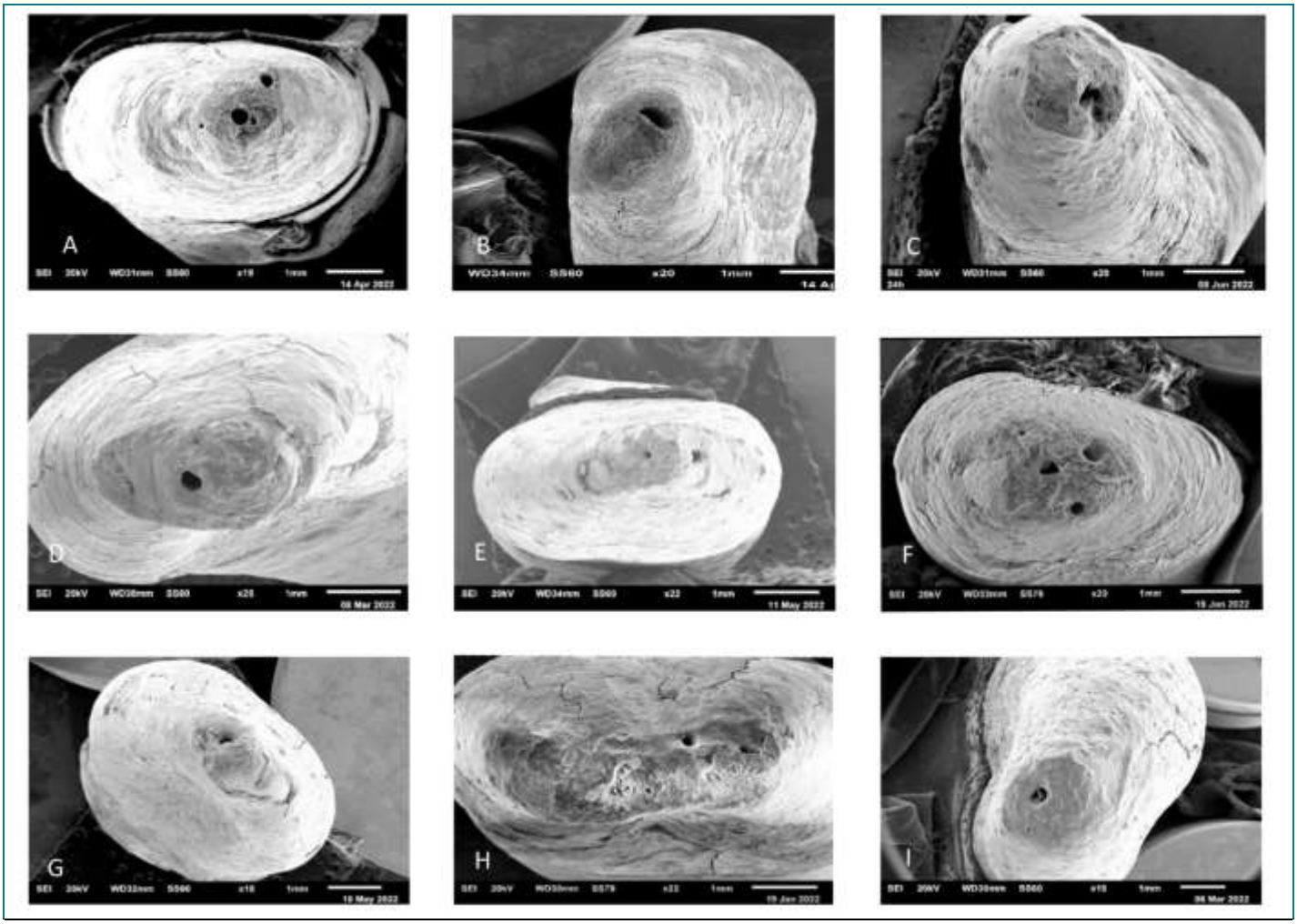
FIGURE 5. Shapes and topography of the anatomical foramen with a Scanning Electron Microscopy (SEM)



A. Sample 4.4 - Round apical foramen; B. Sample 3.3 - Oval apical foramen; C. Sample 1.2 - Crack like shape of apical foramen; D. Sample 4.2 - One anatomical foramen; E. Sample 3.1 - two anatomical foramen; F. Sample 3.4 - >2 anatomical foramen; G, H, and I. Sample 4.3, sample 4.1, and sample 1,3 - deviation.

However, there are different data: in the results of the study of S. Arora and S. Tevar (2009), the oval shape of foramen prevailed (69.9%),[4] The results provided by B.B Marroquin and co-authors (2004) were also dominated by the oval shape of the foramen (71%),[21] as well as in the study conducted by H. Jeong and co-authors - 69.9% (2009).[22] Number of the authors do not share the idea of division of the anatomical foramen into round and oval shapes and consider the border between these two shapes to be very conditional.[23] From a clinical point of view, a round apical foramen is easier to "manage" than an oval one. The instruments and obturation materials provided for mechanical canal treatment are more suitable for round anatomic openings than for oval ones. The following observations were made: the study for the number of apical foramina; which is mentioned in the research results, revealed one anatomical foramen only in the upper central incisors (100%), in all other cases the number of foramens was 2 or more. We found a different ratio of a foramen in upper second premolars, namely one foramen in 60% of cases, two ones - in 20%, and more than two - in 20% of cases. In the lower first premolars, one foramen was seen in 54.54%, two foramens in 27.27%, and more than two foramens in 18.18% of cases.

D. Abdullah and co-authors studied the shape, size, and location of the anatomical hole in upper permanent front teeth (2013),[24] According to this study, 18% of upper front teeth had additional cavities. J.H. According to the data of Gutierrez and P. Aguayo (1995), additional holes were observed in 42% of upper frontal teeth.[5,25] The study of I.S. Watanabe (1990) was also interesting, where the author described additional anatomical holes in the upper central incisors.[26] The same information was found in the studies of S. Rahim (2009), where the author describes the presence of lateral canals and additional holes in the upper central incisors (9%).[9]

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According to the same study, additional cavities were noted in 13% of lower first premolars. Additional cavities were observed in 17.8% of lower first premolars in the study of L. Awawdeh (2008).[15] In a study conducted by A. Morfis et al. (1994), a high rate of additional canals was detected in the upper second premolars (48.3%) and in the medial root of the upper (41.7%) and lower (50%) first molars.[27]

The research results of A. Morfis (1994) -74%, L. Awawdeh (2019) -64% and T.-Y. Lu's (2006) 66% were different, they observed only one anatomical hole in the lower first premolar.[28-30] The results of the study of single-rooted lower premolars conducted by K. Oliveira (2015) seem surprising. The author described one apical hole in 64%, two in 22%, three in 7%, four in 3%, and five in 1% .[14]

The presence of additional anatomical holes makes the outcome of endodontic treatment unpredictable. Their mechanical-chemical treatment is often difficult and sometimes impossible, which in turn has a negative impact on the treatment result.

This issue becomes acute when the "opening" of the apical hole(s) is done not at the apex of the root, but by removing it from it. This phenomenon of deviation often complicates the determination of the working length of the canal. The determination of radiological length facilitates the process of periapical penetration of Endo instruments and increases the risk of toxic effects of irrigation solutions on periapex tissues.

In our study, deviation of the anatomical hole was noted at 50.98%. The rate of deviation in the teeth of the upper jaw is 46.66%, and in the case of the teeth of the lower jaw, it is 54.38%.

The obtained data are more or less correlated with M.Z. Manva (2021) - 68%,[17] Y. Kuttler (1995) - 68-80%,[31] V. Blaskovic-Subat (1992) - 76%,[32] J. Martos (2009) - 60%[19] and with the results of S. Arora and S. Tewari (2009) - 48-83%.[4] B. Swathika (2021) observed the highest frequency of deviation in upper molars (90%) and lower second premolars (79%).[13] In our case, the highest deviation was detected in the lower molar (100%) and upper second premolar (100%).

Based on the obtained results, the following conclusions can be drawn:

- 54.90% of the anatomical tooth root foramens the Georgian population have a round shape, 39.21% have an oval shape, and the other shapes are found only in 5.88%;
- Round-shaped anatomical foramens were detected most often in the upper jaw in 100%, and oval-shaped foramens in the upper lateral incisors in 100%;
- We described 1 anatomical foramen at the apex of the tooth root in 79.41% of cases, and 2 holes or more in 20.58%;
- The central opening of the apical foramen (at the peak of the root apex) of the examined teeth was described in 50 teeth (49.02%) deviations of the apical foramen were also detected with a similar frequency (52 teeth, 50.98%).

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