Endodontics

A STEREOMICROSCOPIC STUDY OF THE ROOT APICES OF 400 MAXILLARY AND MANDIBULAR ANTERIOR TEETH

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The object of this study is to increase our knowledge in the field of endodontics through critical examination of tooth apices and to organize the findings in a definite statistical form.

This study of 400 anterior teeth is a continuation of my previous research dealing with the root apices of 100 mandibular molars. It was extended to anterior teeth as a result of the great interest exhibited in the original investigation. A study of the apical areas of teeth is of major importance, inasmuch as it involves the gateway of the circulatory and nervous systems of teeth.

The use of the stereomicroscope allowed precise visualization of the many variations in the morphology of the apex and foramina.

As in the previous study, the Bausch and Lomb senior model BKT-5, a stereoscopic wide-field microscope, was used; illumination was provided by a Nicholas illuminator. This instrument, adjustable for various positions, gives a most intense spotlight effect. Its easily adjustable condenser system efficiently concentrates brilliant intense light on a small area, or evenly distributes it over large fields of view. A blue daylight filter, the nearest approximation to daylight, was used. The intensity of light is adjusted by a transformer.

Measurements were made with a calibrated micrometer disk, inserted into a specific receptacle in the eyepiece. These calibrations were viewed superimposed on the magnified specimen. A millimeter ruler was placed on the stage. The number of calibrations in the eyepiece superimposed on 1 mm. of the ruler was noted. For example, if there were twenty divisions on the eyepiece to 1 mm. on the stage ruler, we recognized that each division was equal to 1/20 or 0.05 mm. on the specimen.


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At the 20-power magnification, the clear view of depth was found to be greater than that at 30-power magnification; the greater the power, the less the depth of focus.

The 400 specimens were collected at random from the offices of general practitioners and oral surgeons and from dental clinics. These were obtained from patients of all ages because of the impracticability of segregating teeth from definite age groups. It was presumed that the ages of the patients ranged from above 40, since anterior teeth are rarely removed in younger persons. This being the case, we were to expect narrower canals and apical foramina due to secondary dentine and cementum formation as compared to those found in the anterior teeth of younger persons.

The teeth used were:

50 Maxillary central incisors  
50 Maxillary lateral incisors  
50 Maxillary cuspids  
200 Mandibular central and lateral incisors  
50 Mandibular cuspids.

Inasmuch as the mandibular central and lateral incisors were anatomically similar and it was not possible to identify each as a separate unit, they were grouped under one classification.

Determination of Number of Canals

In making calculations with regard to the number of teeth having accessory foramina, it was necessary to establish whether or not each foramen represented a major canal. It was essential, therefore, to study each root to ascertain whether there were one or two canals present. Examination disclosed that all maxillary anterior teeth had single canals. The mandibular teeth presented a more complicated morphology. It is of interest to note that previous investigators indicated that 40 per cent of mandibular anterior teeth had double canals, and unofficial reports of many present-day clinicians claimed that only 10 per cent had them. Because of this difference of opinion, 200 mandibular central and lateral incisors were used, rather than a smaller number, so that a more certain average could be reached. In the techniques used in this study, it was found that of the 200 specimens examined 40, or 20 per cent, had double canals.

In examining the cut ends of roots, a fibrotic substance was frequently removed from a corridor connecting what originally appeared to be two separate canals (Fig. 1). The result was a single ribbon-shaped canal.

Stereoscopic Examination of Apices

The specimens were cemented upright on microscope slides, five to a slide, as this was most efficient for examination and study of the apical area and foramina. Of the forty teeth mentioned that had double canals, twenty-six had two foramina but fourteen had only one foramen. This posed the
question of why these specimens designated as having two canals visible at
the cut end had only one foramen. An attempt was made, therefore, to find
a solution to this problem.

The results of this examination disclosed that, out of the fourteen speci-
mens with one foramen, eight had one canal open to the apex (major canal)
but the second canal (minor canal) was calcified and impenetrable; the re-
mainning six showed a coalescence of the two canals (confluent canals) into
one apical foramen (Fig. 2).

Fig. 1.—Photograph of tissue removed from corridor connecting what originally appeared to be
two distinct canals.

In instances of extremely narrow canals, some as small as 50 microns
measured at the cut end, it was only with great difficulty that the apical
foramina could be negotiated and often it was impossible. This is understand-
able when one realizes that the smallest practical reamer used measures 2
microns at its tip and flares out to a thickness of 125 microns in diameter
at a point 1 mm. from the tip. Under these conditions, when attempting to
follow a canal it is possible to propel an instrument apically by leverage and
cause it to reach areas other than the canal proper.

In one case, which was omitted from this study (Fig. 3) because it had
no canals or a foramen, the root canal was completely calcified and both ends
were impenetrable, even though radiolucency was noted in the canal area,
creating the illusion that a canal was present. Thus, one may reach a dead
end when exploring a canal and, after much difficulty, realize that the canal is
completely calcified. This fact is of utmost significance in studying roent-
genograms for endodontic diagnosis.
Fig. 2.—Roentgenograms of mandibular incisor roots, originally 12 mm. in length, having two canals and one apical foramen. After cutting the roots to shorter lengths, various types of coalescence of canals were observed in A, B, and C; D reveals one calcified impenetrable canal and one canal to emerge as a single foramen.

Fig. 3.—Completely impenetrable canals. A and C are buccolingual views and B and D are mesiodistal views of a mandibular incisor. Roentgenograms revealing radiolucency gave the impression that a canal was present. After cutting the roots shorter, C and D, it was impossible to penetrate the cut end thus, indicating complete calcification of canal areas.
Topography of Apical Area

In general, there were three types of apex configurations: infundibular, tapered, and deflected (Fig. 4). More accessory foramina were noted on the infundibular type than on either of the others.

![Fig. 4.—Three general types of apex formation: A, Infundibular; B, tapered; C, deflected.](image)

In most instances, the surfaces of the apical areas were smooth. Some were rough or irregular and others gave the appearance of erosion in varying degrees. In some cases, the whole apex seemed to have been eroded to form a crater. This may or may not have been due to periapical pathosis. The apical foramina were usually found in an eccentric position. The edges of the peripheries appeared somewhat beveled, giving the effect of a slight funnel shape.

![Fig. 5.—Shapes of peripheral contours of apical foramina. A, Round; B, oval; C, asymmetrical; D, semilunar; E, hourglass; F, serrated.](image)

Observations were made from the foraminal surface, internally, where possible, to a depth of 1 to 2 mm. The majority of specimens showed a gradual narrowing from the surface diameter of the foraminal opening to about one-half its diameter at a depth of 1 mm. The interior walls of the opening were occasionally rough and irregular. Some showed a variation in shape in addition to pronounced funneling to a depth of 1 mm. or more. Others evidenced serrated edges at the peripheries. The foramina were categorized as round, oval, and asymmetrical, but variations of these were intermingled, resulting in a multiplicity of shapes (Fig. 5).

It is notable that, on cutting sagittal sections of roots, it was difficult at times to discern the difference between cementum and dentine at the apex. On close observation, what appeared to be cementum was sclerosed or transparent dentine. When held up to a light, calcified dentine appeared more
translucent than uncalcified dentine. This translucency appeared most often at the periphery. In most cases, the cementum was about 0.25 mm. thick and the thickness increased, as the apex was approached, to as much as 1 mm. but rarely more.

With the exception of foramina opening directly on the apex, rarely did an instrument enter the canal in a continuous line with the central axis of the root. The instrument generally entered the curve in the foramen at angles varying from 10 to 60 degrees to the central axis of the root, the average angle being about 20 degrees. In some cases of curved roots, the instrument entered the bend at the foramen at an angle of 80 degrees.

Fig. 6.—Shapes of the internal area of a foraminal opening. 1, Slightly funnel-shaped; 2, pronounced funnel-shaped; 3, irregular-shaped. A, Cementum; B, transparent dentine.

Fig. 7.—Inserted instrument shows the angle of the foramina to the central axis of the root. Note the distances of the major foramina from the apices.

Accessory Foramina

In general, the accessory foramina appeared to be about one-half or one-third the diameter of the major foramina, but in some cases they were the same. Accessory foramina measured approximately 30 microns. One way of confirming an accessory canal was to insert a reamer in the major canal and
to view it from the accessory canal. In some cases, it was possible to fit a human hair (10 to 50 microns) into an accessory foramen and view it from the major canal. In other cases, it was difficult to judge whether or not an accessory canal led to a major canal or terminated subapically. In one case the accessory canal looped in and out of the apex without entering the major canal.

**Summary**

General observations of Tables I and II:

**Percentages of Accessory Canals.**—Of the 400 teeth examined, the percentage with one or more accessory foramina ranged between 10 per cent and 12 per cent. This average was found in the maxillary as well as the mandibular anterior teeth. Most of these had only one accessory foramen.

<table>
<thead>
<tr>
<th>Table I</th>
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<tbody>
<tr>
<td><strong>MAJOR FORAMINA</strong></td>
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<tr>
<td><strong>TEETH</strong></td>
</tr>
<tr>
<td>Maxillary central incisors</td>
</tr>
<tr>
<td>Maxillary lateral incisors</td>
</tr>
<tr>
<td>Maxillary cuspids</td>
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<tr>
<td>Mandibular central and lateral incisors</td>
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<td>Mandibular cuspids</td>
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**Diameters of Foramina.**—The average diameter of the major foramina of 150 maxillary teeth was 0.4 mm.

The average diameter of the major foramina of 250 mandibular teeth was 0.3 mm.

The average diameter of the accessory foramina of all the 400 teeth was 0.2 mm.

**Distances of Foramina From Their Apex.**—The average distance of all major foramina (excluding the mandibular incisors) from their apex was 0.3 mm.

The average distance of the major foramina of the mandibular incisors from their apex was 0.2 mm.

The average distance of all accessory foramina from the apex ranged from 1.0 to 2.2 mm.
Table II

<table>
<thead>
<tr>
<th>Teeth</th>
<th>No. Teeth</th>
<th>Diameter (mm.)</th>
<th>Distance from Apex (mm.)</th>
<th>Total (% of Teeth)</th>
<th>One Foramen (% of Teeth)</th>
<th>Two Foramen (% of Teeth)</th>
<th>Three or More Foramina (% of Teeth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary central incisors</td>
<td>50</td>
<td>0.2</td>
<td>1.6</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Maxillary lateral incisors</td>
<td>50</td>
<td>0.2</td>
<td>2.2</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Maxillary cuspids</td>
<td>50</td>
<td>0.2</td>
<td>1.4</td>
<td>12</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Mandibular central and lateral incisors</td>
<td>200</td>
<td>0.2</td>
<td>0.4</td>
<td>12</td>
<td>9.5</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>Mandibular cuspids</td>
<td>50</td>
<td>0.2</td>
<td>1.0</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Contours.—Of the three main contours of the apical foramina, the round type ranged from 58 to 78 per cent, the balance up to 100 per cent were oval and asymmetrical. Serrated peripheries ranged from 14 to 21 per cent, and pronounced funnelling ranged from 18 to 46 per cent.

Foramina observed directly on the apex ranged from 22 to 46 per cent.

Number of Canals Present.—Of 150 maxillary anterior teeth examined, all roots contained single canals. Of the 200 mandibular incisors examined, forty contained two major canals. Of these forty, twenty-six had two of foramina exiting from the apex and the remainder had one major foramen. Of the fourteen exiting in one foramen, eight had one calcified canal and six had coalescing canals.

Conclusion

This material may serve as a stimulus to others to continue examining greater numbers of teeth, thereby developing a closer approach to the statistical mean as a result of their investigations. It is hoped that this and previous morphologic studies will be of value in diagnosis and treatment.

The author is greatly indebted for the helpful discussions and criticisms rendered him in stereomicroscopic examination and collection of data by Mr. Arnold Reisman of I.B.M.; Dr. Bernard Metrick, past-president of the Endodontia Study Club of Brooklyn; and Hector Santemma, research assistant. Appreciation and thanks are also expressed to the Watson Scientific Laboratories of the International Business Machine Company and the Bausch and Lomb Company for supplying the stereomicroscope and the necessary equipment and to Richard I. Derby of General Mills Company for processing the stereomicrophotographs for projection in three dimensions.

References