Root Canal System of the Maxillary Canine

By

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Summary: To better assess the efficacy of mechanical preparation of root canals, transparent specimens of 250 extracted maxillary canines were investigated for canal configuration, thickness and curvature of the root canal, condition of any accessory canals, and location of the apical foramen. Fewer than 40% of the specimens showed accessory canals that were mechanically impossible to clean. The majority of the lateral branches were small, greater than a #15 file, and none of the branches were larger than a #20 file. Although apical foramina located away from the apex were observed in 30% of the maxillary teeth, 96% of all apical foramina were within 0.5 mm of the apex. Data on the thickness of the root and main canal in the apical portion and curvature of the root canal suggest that, for adequate apical preparation, a #60 file must be able to reach the apical constriction.

Introduction

One of the most important factors in endodontic therapy is the mechanical preparation of the root canal. Despite the high success rates seen for appropriate endodontic procedures1–2), a suitable method for cleaning complex root canals such as those with lateral branches or apical ramifications has not yet been established. Furthermore, cleaning narrow flattened canals or roots with a high degree of curvature is extremely ineffective3–4).

Despite a great number of studies that have investigated the anatomy of root canals5–6), research specifically oriented toward developing a suitable endodontic therapy has been insufficient. For example, if accurate data on the size of the apex of root canals could be obtained, it might provide reliable standards for the amount of instrumentation normally required in this region. In an attempt to provide such data, Kerekes and Tronstad7–9) measured the diameter of root canals by taking sections of anterior, premolar, and molar teeth at 1, 2, 3, 4, and 5 mm from the apex. On the basis of these data, they then estimated the smallest size of instruments that would ensure, with 90% probability for each tooth type, adequate preparation of the circular-shaped canals at the various distances from the apex. Owing to the small sample size (20 specimens of each tooth type), the reliability of their findings is compromised. Furthermore, because their measurements were obtained from the cross sections of root canals, the effects of the curvature of the root canals on measurements were not accounted for in their analysis.

The condition of the accessory canals such as lateral branches is another area that requires further investigation. Although studies have shown a high incidence of furcation, particularly in the apical portion of the root10–11), the influence of furcation size on the failure of endodontic therapy has not been investigated. Furthermore, data on the incidence of apical ramifications are extremely scarce.

In the present study, we macroscopically investigated specimens of extracted canines to determine canal configuration, thickness and curvature of the root canals, condition of any accessory canals, and location of the apical foramina. The purpose of the present study was to provide clinical data on canal configuration in an attempt...
to more accurately assess the efficiency of mechanical instrumentation, thus providing better guidelines for the preparation of root canals in endodontic therapy.

Materials and Methods

A total of 250 extracted maxillary canines with no visible abnormalities were examined. Following manual surface cleaning, the teeth were placed in a 10% sodium hypochlorite solution in an ultrasonic cleaner to remove residual organic matter and surface debris. Radiographs of each tooth were taken from the labiolingual direction, and then dye (India ink) was administered by the vacuum injection method. The stained teeth were decalcified using 10% nitric acid for 48 h and then were washed and dried. Transparent specimens were created by submerging the dried teeth in methylsalicylate. The specimens were then assessed according to the following categories by the naked eye.

Main Root Canal

The thickness of the main root canal, regardless of direction, was measured by determining the largest diameter at locations 0.5, 1, 2, 3, 4, and 5 mm away from the apical foramen toward the crown using the tip of the files as a reference. Measurements were classified into 5 groups with respect to the size of the file: less than #20, from #20 to less than #40, from #40 to less than #60, from #60 to less than #80, and over #80.

The curvature of the main canal was measured as the angle between the axis of the canal (as it extends away from the pulp cavity) and a line for the foramen at the point where the canal may be discerned to diverge away from the axis. The curvature was classed in 10-degree increments (0 to 9, 10 to 19, 20 to 29, 30 or greater). The direction of curvature was classified as toward the labial, lingual, mesial, or distal surface.

Apical Foramen

The straight line distance of the foramen from the apex was measured and classified according to 0.5-mm intervals. Teeth in which the apical foramen was eccentrically positioned were examined for the orientation of the orifice, using the same criteria described for lateral branch orifices. In cases of apical ramification, when a branch could be judged as the one that a probe would most likely follow, its orifice was defined as the apical foramen, and its distance from the apex and orientation were treated in the above manner.

Accessory Canals

The number of accessory canals (apical ramification and lateral branches) was noted for each specimen. Each lateral branch was divided for this purpose into sixths, consecutively numbered from the apical (1/6) to the cervical (6/6) portions (Fig. 1). The orientation of each opening was classified according to criteria set by Yoshiuchi et al. With the use of a hypothetical cross section of a root with a lateral branch, the center of the labial surface is defined as 12 o’clock and the center of the lingual surface as 6 o’clock. The labial (buccal) surface (B) is defined as the span between 11 and 1 o’clock, the mesiolabial (BM, or distolabial, BD) between 1 and 2 o’clock, the mesial (M, or distal, D) between 2 and 4 o’clock, and so on. The orientation of each lateral branch orifice was classified according to these divisions (Fig. 2). Furthermore, the thickness of the lateral branches was

Fig. 1. Levels of lateral branch orifice.

Fig. 2. Orientation of lateral branch orifice.
measured macroscopically and categorized into 7 groups with respect to the size of the files: less than #10, approximately #10, approximately #15, approximately #20, approximately #25, approximately #30, and over #30 (Fig. 3).

**Results**

**Main Root Canal**

Table 1 shows the thickness of main root canals. At the 0.5 mm, 1 mm, 2 mm, and 8 mm levels, a peak can be seen from #20 to less than #40, and 85.6% at the 0.5 mm level, 80.0% at the 1 mm level, and 66.8% at the 2 mm level were less than #40.

Table 2 shows the degree and direction of curvature of the main root canals. Most specimens were straight or almost straight (< 10 degrees), and only 1.6% of the specimens had a degree of curvature greater than 20 degrees. Analysis of the direction of curvature showed that the canals were oriented toward all directions.
Of the 250 teeth with a distinct apical foramen, 174 (69.6%) had the foramen located at the center of the root apex. Of the remainder, the foramen was judged to be approximately 0.5 mm away from the apex in 67 teeth (26.8%), and at approximately 1.0 mm in 9 (3.6%). Thus, a total of 96.4% of all foramina were located approximately 0.5 mm or less from the apex and 100% were approximately 1.0 mm or less away. Data on the orientation of the eccentrically located foramina are given in Table 3.

**Accessory Canals**

Of the 250 teeth that were assessed, 158 (63.2%) had simply a single main canal (Table 4). Apical ramifications were observed in 30 teeth; of these 24 had only two branches and 6 had three branches. Lateral branches were observed in 67 teeth; of these 43 had only one lateral branch, 14 had two branches, 7 had three, and 3 had four or more (Fig. 4). Table 5 shows a summary of the thickness of the lateral branches. Thicker lateral branches tended to have fewer branches, and none of the branches were larger than a #20 file.

97.1% of lateral branches were located in the apical third (1/6, 2/6), and there were no predominant tendencies with respect to the orientation of the lateral branch orifice (Table 6).

**Discussion**

Pulpectomy and canal debridement have usually been performed only on the main root canal. It has been reported that, despite the existence of untreated accessory canals, good clinical results were obtained on maxillary canines, as well as on other teeth, when these procedures were done properly

12–14

In this study, almost 40% of the maxillary canines examined had accessory canals that may be impossible to clean. Because most of the lateral branches were extremely small—more than 70% were the size of a #10 file or less—it is likely that they will heal naturally after proper debridement and obturation of the main canal is performed.

In regard to the possibility of adequate mechanical enlargement of the main canal, we could observe, in the case of maxillary canines, that the root canal generally has a simple cylindrical shape. Moreover, the incidence of curvature severe enough to inhibit mechanical preparation is extremely low. Accordingly, it is possible to es-

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**Table 3.** Orientation of eccentrically located apical foramen (Maxillary canine)

<table>
<thead>
<tr>
<th>Eccentricity (mm)</th>
<th>Orientation</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 mm</td>
<td>B</td>
<td>29</td>
</tr>
<tr>
<td>1.5 mm</td>
<td>BM</td>
<td>20</td>
</tr>
<tr>
<td>1.0 mm</td>
<td>BD</td>
<td>3</td>
</tr>
<tr>
<td>0.5 mm</td>
<td>L</td>
<td>5</td>
</tr>
<tr>
<td>0 mm</td>
<td>LM</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>LD</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>%</td>
<td></td>
<td>38.2</td>
</tr>
<tr>
<td>Eccentrically average (mm)</td>
<td></td>
<td>9.7</td>
</tr>
<tr>
<td>Maximum (mm)</td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Table 4.** Classification of root canal system (Maxillary canine)

<table>
<thead>
<tr>
<th>Type of canal</th>
<th>No.</th>
<th>Simple main root canal No. (%)</th>
<th>Apical ramification only No. (%)</th>
<th>Lateral branch(es) only No. (%)</th>
<th>Both apical ramification and lateral branch(es) No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>246</td>
<td>154 (62.6)</td>
<td>25 (10.2)</td>
<td>62 (25.2)</td>
<td>5 (2.0)</td>
</tr>
<tr>
<td>Type II</td>
<td>4</td>
<td>4 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total (%)</td>
<td>250</td>
<td>158 (63.2)</td>
<td>25 (10.0)</td>
<td>62 (24.8)</td>
<td>5 (2.0)</td>
</tr>
</tbody>
</table>

**Table 5.** Thickness lateral branch (Maxillary canine)

<table>
<thead>
<tr>
<th>Thickness</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than #10 reamer</td>
<td>73</td>
<td>70.2</td>
</tr>
<tr>
<td>From #10 to less than #15</td>
<td>21</td>
<td>20.2</td>
</tr>
<tr>
<td>From #15 to less than #20</td>
<td>10</td>
<td>9.6</td>
</tr>
<tr>
<td>Larger than #20 reamer</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
<td></td>
</tr>
</tbody>
</table>
timate the final size required for the apical portion on the basis of measurements of the apical part of the root canal. Data on the thickness of the canal over the first 5 mm from the foramen indicate that preparation is normally adequate when the canal is enlarged to a #60 file within 1 mm of the foramen.

References