The influence of the apical limit of root canal preparation on apical foramen transportation (laboratory study)

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ABSTRACT

Objective: This study was conducted to evaluate the effect of apical terminus location of the root canal preparation on apical transportation in vitro.

Materials and Method: Thirty extracted human maxillary first molars with mature apices were used. The mesiobuccal root of each tooth was mounted in a square piece of silicone leaving foramen on top. The specimens were randomly divided into 3 groups according to the apical limit of root canal preparation (flushed with apical foramen, 0.5 and 1 mm away from the apical foramen). Initial and final photographs of apical foramen were taken before and after instrumentation using a stereomicroscope. The images of each specimen (pre and post) were superimposed to determine transportation.

Results: Results demonstrated that termination of the root canal preparation flushed at the apical foramen showed the highest transportation with statistically significant difference in comparison to the other two groups.

Conclusion: No statistically significant difference was found comparing termination of the root canal preparation 0.5 mm or 1mm away from the apical foramen.

Keywords: apical foramen, apical preparation limit, apical transportation.

INTRODUCTION

The apical limit of root canal instrumentation and obturation has always been a matter of great controversy. Despite the large number of published studies on this subject, a consensus has not yet been reached. A question exists regarding the ideal limit of a root canal preparation and filling, since the apical foramen is not always located at the anatomic apex of tooth\(^1\). This deviation of the foramen from the anatomic apex cannot be easily detected by radiographic examination, particularly when the openings occur on the buccal or lingual root surfaces\(^2,3\). With this in mind, greater consideration should be given in determining the actual length of the root canal. Ideal working length determination will lead to proper cleaning and shaping and proper obturation. With proper placement of filling material, there is less chance of inflammatory reactions and post-operative pain\(^1,2,3\). The ideal apical reference point in the canal is the apical stop which is related to the apical constriction (minor apical diameter) which is proved to be 0.5 to 1 mm away from the external foramen or major diameter on the root surface (radiographic apex)\(^1\). On the other hand, the radiographic apex has been fostered by many clinicians; where they utilize this site to terminate the canal preparation. Their point of view is to ensure that the apical portion of the canal has been cleaned and filled sufficiently; they are not even satisfied unless some excess material is pushed through the apical foramen\(^4-7\). No research was found evaluating the effect of apical limit of root canal preparation and apical foramen transportation.

MATERIALS AND METHODS

Preparation of the specimens

After having patients’ consents, thirty extracted human maxillary first molars with mature apices were collected for the study. Teeth were left in 2.6 % Sodium
Hypochlorite (NaOCl) for 2 hours to disinfect teeth. Root surfaces were further scaled with a periodontal curette and the teeth were stored in 10% buffered formalin phosphate solution. Decoronation was done for the mesiobuccal roots at the cementoenamel junction to obtain root specimens of identical length. Facial and lateral radiographs were taken to ensure that the teeth had single canals. Visual examination with a 4 x magnifying lens ensured the existence of a completely formed apex. A small access preparation was made at the opening of the canal orifice using round diamond bur. Pulp tissue remnants were removed with barbed broach (Maillefer, Switzerland). Each root canal was explored to confirm its patency using a size 10 stainless steel. K file as a pathfinder to assure apical patency. The position of the apical foramen was determined by means of a stereomicroscope at 40 X magnification (Carl Zeiss, Germany). Each root specimen was mounted in a square piece of high consistency, condensation-curing silicone (Speedex, Coltène Whaledent, Switzerland), leaving the foramen on the top. A hole was made at the lower surface of the silicone to have a direct coronal access to the root canal. Special marks were done on the side of the silicone to ensure almost the exact repositioning of the specimens. (Figure 1)

Classification of the root specimens
The specimens were randomly divided into 3 groups according to the apical termination of the preparation. The working length was calculated by inserting a 10 st. st. K file (Maillefer, Switzerland) down to the apex until it was just visible at the apical foramen using a 4 x magnifying lens to be flushed with the apical foramen (Group I). For Group II working length; the same procedure was done as in-group I and then 0.5 mm was subtracted. For Group III, the same procedure as in-group I was done and then 1 mm was subtracted to determine the working length.

Root canal preparation
All root canals were instrumented as described in Table 1, the root canals were flared using Gates Glidden # 2, 3 to obtain a glide path. The root canals were then instrumented using Hero Shaper Nickel Titanium (NiTi) rotary instruments (Micromega, France) in a crown down way (Table 1). The root canals were prepared apically to size # 30 (taper 0.04). Irrigation was performed using 2ml of 2.25% sodium hypochlorite NaOCl solution between each file. All the instruments were used with a light in and out pecking motion. Rc-prep paste (Premier, USA) was always used with the Ni Ti rotary instruments as a lubricant to avoid their separation. At the end of the cleaning and shaping 17 % EDTA (Meta, Korea) was left in the root canal(s) for 1 min. It was then followed by a 5-ml rinse with 2.25% NaOCl.

Apical foramen imaging
A stereomicroscope connected with digital camera was used to take photographic images for each specimen. An initial photograph of the apical foramen was taken before instrumentation. After root canal preparation, the specimens were repositioned on the microscope and images were taken under the same conditions. The images of each specimen (pre and post) were superimposed according to the peripheral shape of the apical foramen using the Photoshop program (Adobe
Photoshop 7.0 me). Transportation was determined by comparing the drawings of the outline of the apical foramen obtained of each specimen. The mean centering ratio was calculated by the formula X1–X2/Y (where X1 represents the maximum extent of apical foramen in one direction, X2 is the movement in the opposite direction, and Y is the diameter of the final apical foramen\(^9\)). According to this formula, the centering ratio approaches zero as X1 and X2 become closer. Zero is an indication of perfect foramen centering and no apical foramen transportation. (Figure 2)

As the data is nonparametric, the statistical analysis of the data obtained in the present study was carried out using Mann-Whitney Test for two independent samples from a continuous field was used.

**RESULTS**

Apical transportation was found to occur with variable degrees (Table 2 and Figures (3-6)). The mean and standard deviation values of the maximum displacement of the apical foramen(X1) for all were shown in Table (3), (4) .The statistical analysis of these values revealed statistically significant difference between mean rank of group I and group II as well as group I and group III (\(p<0.05\)). There was no statistically significant difference between mean rank of group II and group III.

<table>
<thead>
<tr>
<th>Step</th>
<th>Instrument</th>
<th>Part of the canal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Size 10 K-file</td>
<td>Estimated working length (W.L)</td>
</tr>
<tr>
<td>2</td>
<td>Preflaring with Nos. 2,, 3 Gates Glidden</td>
<td>Coronal third</td>
</tr>
<tr>
<td>3</td>
<td>Heroshaper No. 20 6%</td>
<td>Coronal third to middle third</td>
</tr>
<tr>
<td>4</td>
<td>Heroshaper No. 20 4%</td>
<td>Middle third to apical third</td>
</tr>
<tr>
<td>5</td>
<td>Heroshaper No. 25 4%</td>
<td>W.L</td>
</tr>
<tr>
<td>6</td>
<td>Heroshaper No. 30 4%</td>
<td>W.L</td>
</tr>
</tbody>
</table>

**Table 2: centering ratio by group**

<table>
<thead>
<tr>
<th>Cases</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.13</td>
<td>0.19</td>
<td>0.09</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>0.12</td>
<td>0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>0.1</td>
<td>0.0</td>
<td>0.08</td>
</tr>
<tr>
<td>5</td>
<td>0.26</td>
<td>0.02</td>
<td>0.06</td>
</tr>
<tr>
<td>6</td>
<td>0.14</td>
<td>0.18</td>
<td>0.06</td>
</tr>
<tr>
<td>7</td>
<td>0.24</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>8</td>
<td>0.12</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>9</td>
<td>0.01</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>10</td>
<td>0.39</td>
<td>0.12</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Table 1: Crown-down sequence used to prepare the root canals**

As the data is nonparametric, the statistical analysis of the data obtained in the present study was carried out using Mann-Whitney Test for two independent samples from a continuous field was used.

**Statistical analysis of the data**
Figure 3: Centering ratio by group

Figure 4: A Stereo photomicrograph of the apical foramen of a sample of Group III (1mm away from apical foramen) after superimposition (original magnification 40 X)

Figure 5: A Stereo photomicrograph of the apical foramen of a sample of Group II (0.5mm away from the foramen) after superimposition (original magnification 40X)

Figure 6: A Stereo photomicrograph of the apical foramen of a sample of Group I (0.0 mm) after superimposition (original magnification 40 X)

Table 3: Comparison between mean ranks of the centering ratios by group

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Rank</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>13.40</td>
<td>0.028*</td>
</tr>
<tr>
<td>II</td>
<td>7.60</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>6.50</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Mean and median of centering ratios by group

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (±SD)</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.1810 (±0.1131)</td>
<td>0.1350</td>
</tr>
<tr>
<td>II</td>
<td>0.0910 (±0.0603)</td>
<td>0.0800</td>
</tr>
<tr>
<td>III</td>
<td>0.0640 (±0.0207)</td>
<td>0.0650</td>
</tr>
</tbody>
</table>

DISCUSSION

It is widely accepted that root canal preparation and filling should terminate in the area where histologically the pulp tissue ends. Therefore, a thorough knowledge of the root canal anatomy especially at the apex area and the ability to determine accurately the root length is necessary for successful endodontic therapy. If the termination is too short or too long, the outcome is negatively influenced.

Many authors have demonstrated that...
the main foramen could be located at a distance ranging from 0.20 to 3.00 mm or more from the anatomical apex\textsuperscript{2,12-19}. The clinical significance was that many root canals could be inadvertently prepared beyond the apical foramen\textsuperscript{20}. Deviation of the main foramen from the anatomical apex was reported. It was demonstrated that it never coincided with the main axis of the root\textsuperscript{13,16,21-23}. Dummer et al (1984) stated that it was impossible to establish apical constriction actual position during root canal therapy\textsuperscript{22}. Therefore, potential extrusion of cleaning products beyond the apical terminus in the surrounding tissues is unavoidable which might result in delayed healing or even treatment failure because of a foreign body reaction\textsuperscript{24}. By contrast, some researchers recommended termination of all the endodontic therapy at the apical foramen in order to fill the apical ramifications and lateral canals. They explained that by the higher success rate they observed. They added that overfilling did not produce the worset results. They even added that extrusion of sealer caused no discomfort and in fact it enhanced the success of the treatment\textsuperscript{25-33}. Souza (2006) advocated that endodontic treatment should extend to the full canal length and should not be limited to a point located 1 mm short of the apical foramen\textsuperscript{34}. Moreover, it makes sense that precise working length prevents transportation of the apical foramen. The Glossary of Endodontic Terms of the American Association of Endodontists defines transportation as “the removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation”\textsuperscript{35}. Transportation may cause harboring of debris and residual microorganisms related to insufficient cleaning of the root canals. Furthermore, it destroys the integrity of the root and reduces its fracture resistance, which may adversely affect the treatment outcome\textsuperscript{36}. This study was concerned about apical foramen transportation after root canal preparation 0.0, 0.5 and 1 mm of the apical foramen. The apical foramen was stereomicroscoped before and later after preparation. Then, the images were superimposed to estimate the transportation using the mean centered ratio (X1-X2/Y). Data showed apical foramen transportation with different levels. Most of the techniques used in root canal preparation were reported to have the tendency of producing transportation\textsuperscript{37-40}. Our results revealed that termination of the root canal preparation flushed at the apical foramen showed the highest transportation with statistically significant difference in comparison to the other two groups. There were no previous studies assessing the relation between apical transportation and apical termination. We can correlate the failure of some cases where the apical root canal preparation was flushed at the apical foramen to transportation\textsuperscript{20-24}. No statistically significant difference was found comparing termination of the root canal preparation 0.5 mm or 1mm away from the apical foramen. Apical foramen cleaning is not a determinant of periapical lesion repair\textsuperscript{41}. In 2000, Souza stated, “foramen cleaning is just another step toward proper cleansing and preparation of the root canal, and, therefore, is not solely responsible for the success or failure of endodontic treatment”\textsuperscript{42}. However, authors claimed that foramen cleaning is essential to create better conditions for tissue repair, as in cases of pulp necrosis where bacteria are found beyond the dentinal canal\textsuperscript{25-28}. It was justified by the minimum amount of remaining bacteria located beyond the cementodentinal junction which was not enough to keep the periapical reaction\textsuperscript{43}. In a previous study, it was shown that root canal preparation 0.5 mm away from the apical foramen will guarantee the efficiency of cleaning and shaping the root canal\textsuperscript{44}.

**CONCLUSION**

Findings suggest that termination of the root canal preparation 0.5 mm away
of the apical foramen will produce little transportation in comparison to the 0.0 mm flushed with the apical foramen. There was no significant difference between termination of the root canal preparation 0.5 mm and 1 mm away from the apical foramen. So, apical preparation termination 0.5 mm away from the apical foramen will produce better successful results in root canal treatment.

REFERENCES

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