Original Article

Effect of Immediate and Delayed Post Space Preparation on Apical Leakage Using Three Root Canal Obturation Techniques After Rotary Instrumentation

Gin Chen,1,2,3 Yu-Chao Chang1*

Background/Purpose: For teeth that have undergone root canal therapy, post fabrication and subsequent crown restoration are often required to increase strength. It is necessary to remove a portion of gutta-percha during post space preparation that may cause displacement of the root canal fillings and affect their sealing ability. This study evaluated the effects of different post space preparation time intervals and root canal obturation techniques on the apical sealing ability of filled root canals.

Methods: One hundred single-canal teeth were incrementally crown-down enlarged to an apical diameter of 0.40 mm with 0.06 taper by K3 rotary instrumentation, combined with 5.25% NaOCl irrigation. The teeth were randomized into four groups: 30 obturated by lateral compaction technique (Group 1); 30 by vertical compaction technique (Group 2); 30 by injectable thermoplasticized gutta-percha technique (Group 3); and 10 controls with no obturation (Group 4). All specimens were stored in 100% humidity at 37°C. Immediately and 3 days and 7 days after obturation, post space was made utilizing heated pluggers, and leaving a 5.0-mm gutta-percha filling. The teeth were immersed in 2.0% methylene blue solution for 72 hours, and finally cut longitudinally in half. Dye leakage was examined under a stereomicroscope. The results were recorded and statistically analyzed.

Results: The mean distance of dye leakage after post space preparation at three different time intervals in Group 1 were greater than those in Groups 2 and 3. One-way analysis of variance indicated that the apical seal or adaptation of vertical compaction technique and injectable thermoplasticized gutta-percha technique were not easy to break during post space preparation.

Conclusion: Teeth treated by vertical compaction and injectable thermoplasticized gutta-percha techniques showed less leakage than those treated by lateral compaction. The least amount of dye leakage existed when the post space preparation was made on day 7 after root canal obturation.

Key Words: apical seal, injectable thermoplasticized gutta-percha technique, lateral compaction technique, post space preparation, vertical compaction technique

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1Graduate School of Dentistry, College of Oral Medicine, Chun Shan Medical University, 2Division of Endodontics and Periodontics, Department of Dentistry, Taichung Veterans General Hospital, Taichung, 3College of Dentistry, National Yang-Ming Medical University, Taipei, Taiwan.

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*Correspondence to: Professor Yu-Chao Chang, Department of Dentistry, Chun Shan Medical University, 110 Section 1, JiaGuo North Road, Taichung City 402, Taiwan.
E-mail: cyc@csmu.edu.tw
Post-endodontic teeth often rely on crown restorations or other suitable restorative materials for the rehabilitation of their original functions, such as phonetics and mastication. Before crown fabrication, intracanal posts are frequently needed to enhance dentinal strength and retention of crowns. Restoration of endodontically treated teeth must partially remove gutta-percha from the coronal section of the obturated root canals before post preparation begins, and this procedure can affect the apical seal.\(^1\) Metzger et al have demonstrated that the sealing of the root canal fillings is proportional to the length of the remaining filling.\(^2\) Most of the studies have agreed that retention of 5 mm of obturating material in the apical region is considered a safe margin.\(^2\)–\(^5\) Increased post length is desirable for boosting resistance against occlusal rest, but caution must be taken with the quantity of gutta-percha removed, so that the quality of the sealing ability does not deteriorate and does not give rise to reinfection or affect the success rate of the completed root canal therapy. Unfortunately, sealers often disintegrate or vacate upon removal of gutta-percha, which affects the apical seal and causes failure of the endodontic treatment as a result of reinfection.\(^6,7\)

Of the many different methods of removing gutta-percha cited in the past, the thermal method is generally accepted as the safest, most controlled and effective way of removing the specific length or amount of gutta-percha required.\(^8,9\) Although Hiltner et al are skeptical that different methods of gutta-percha removal contribute significantly to apical leakage, the thermal, chemical, and mechanical methods do have their distinctive differences.\(^10\) For example, the difficulty in manipulation of chemical solvents, tackiness of removed sealants, or even the toxicity and oncogenicity of solvents all pose potential problems in the chemical solvent method. Excess removal of gutta-percha is also a frequent issue encountered with the mechanical method. From an endodontics point of view, the use of these two methods is not highly recommended. Haddix et al have revealed that the thermal method has better outcome (less leakage) in comparison to the others.\(^11\) McCombe and Smith have used Roth’s 801 and AH26 sealers (Dentsply, Konstanz, Germany) to compare whether post placement before or after sealer setting made a difference to the post stability, and no difference was noted.\(^12\) However, Fan et al have suggested that delayed post space preparation results in more leakage when using AH26 and pulp canal sealers (Kerr, Romulus, MI, USA).\(^13\) Despite the availability of detailed research and in-depth discussions regarding the methods and techniques used for gutta-percha removal, consensus about the time interval of post preparation or obturation material removal has yet to emerge, and it has yet to be shown how this affects the sealing ability of the remnant material.

Accordingly, the objective of the present study was to assess the different root canal obturation techniques and the time interval of post space preparation to preserve the apical seal after root canal treatment. The results highlight the most suitable timing and method for post space preparation, which will help to reduce endodontic failure and improve the success rate of the prosthodontic procedures.

**Materials and Methods**

**Teeth**

A total of 100 single-canal teeth with a mature, intact apex were extracted for reasons such as advanced periodontitis or orthodontic treatment. They were collected and preserved in 10% buffered formalin solution at 37°C until use. Before experimental procedures, all samples were soaked in 5.25% NaOCl solution for 8 hours to remove all surface organic debris, and then rinsed with water and stored in physiological saline.

**Root canal preparation**

The crowns of the teeth were first cut at the cement–enamel junction using a lower-speed carborundum disk under water cooling. The working length was established by gradually introducing a 10# K-file (apical diameter of 0.10 mm; Kerr, Romulus, MI, USA) that extended through the
apex, until it was visible at the apical foramen and deducting 1.0 mm from the actual tooth length. The root canal was cleansed and shaped, using K3 rotary nickel–titanium following the incremental crown-down preparation sequences of 0.12/25, 0.10/25, 0.08/25, 0.06/25 and continuous enlargement to apical size #40 (0.06/40, diameter of 0.40 mm). The root canals were irrigated with 5 mL 5.25% NaOCl at each change of file. When the preparation was completed, the root canal was finally irrigated with 10 mL 5.25% NaOCl and 3 mL 17% trisodium ethylenediaminetetraacetic acid solution. A #10 file was finally inserted into the canal and verified the integrity of the apical constriction.

**Root canal obturation**

After root canal preparation was completed, the root canals were dried with sterile absorbent paper points and randomized into three experimental groups (n = 30) and one control group (n = 10).

Group 1 (30 teeth). All samples were dried by aspiration and absorbent paper points, try-in a size #40 gutta-percha master cone, and the corrected size was verified by a frictional fit or tug back sensation. An even layer of CaOH-containing root canal sealer, Sealapex (Kerr), was coated to the canal walls, and lateral compaction with finger spreaders was utilized to pack master gutta-percha cone and accessory gutta-percha cone homogeneity. After the completion of root canal obturation, 30 samples were randomly divided into three subgroups (n = 10). The post space was prepared immediately and 3 days and 7 days after obturation. The root canal fillings at the coronal area were removed using heated plugger and leaving 5-mm gutta-percha filling at the apices. Once adequate amounts of gutta-percha were removed, canal orifices were corked with dry cotton pellets and access cavities were sealed with ZnO eugenol cement.

Group 2 (30 teeth). The samples were treated similarly to group 1; only root canals were obturated using injectable thermoplasticized warm gutta-percha technique (Obtura techniques) and condensed with hand pluggers.

Group 3 (30 teeth). The samples were treated similarly to group 1; only root canals were obturated using injectable thermoplasticized warm gutta-percha technique (Obtura techniques) and condensed with hand pluggers.

Group 4 (10 teeth). Five teeth were treated similarly to group 1; only root canal fillings were not removed. The other five teeth were left without root canal fillings.

**Apical dye penetration**

As soon as all specimens were obturated and post-space prepared, the coronal portion of the root was sealed with IRM temporary filling material. The roots were coated with two layers of fast-acting cyanoacrylate ester adhesive (Super Bonder-Locktite, KY, USA) and nail polish, covering the whole specimens, including the access restoration, but not the apical 2.0 mm of the root. The specimens were soaked in a 100% humidity water bath at 37°C for 72 hours. Subsequently, all the specimens were thermal cycled in a 55°C water bath and immersed in 2% methylene blue dye for 72 hours. Finally, they were washed in running tap water to remove excess dye material.

**Final assessment and statistical analysis**

All the specimens were sectioned longitudinally using a sharp chisel along the buccolingual direction after grooving with a fissure diamond bur. All the sections were examined and photographed at 20× magnification next to a millimeter ruler for reference, using a Nikon automatic camera fixed to the stereomicroscope.

Dye leakage was measured as the linear penetration of the stain. All the sections were examined and recorded by two experienced endodontists. The mean value was collected as the resultant data. The leakage was considered the dependent variable in the analyses. The SPSS one-way analysis of variance test was used for statistical analysis to assess the three root canal compaction techniques, the different time intervals of post space preparation, and their statistical significance for the assessment of their benefits and shortcomings. A p value of 0.05 was regarded as significant.
Results

After all the tooth specimen procedures were completed, including root canal enlargement, obturation, gutta-percha filling removal for post-space preparation, dye penetration test, and vertical split, the teeth were examined under a stereomicroscope to determine the depth of dye penetration. The means and standard deviations of the dye leakage after post space preparation after root canal obturation with three different techniques are listed in the Table.

Statistical analysis indicates that, regardless of the root canal obturation techniques chosen—either lateral or vertical compaction—there was no significance difference in dye penetration immediately and 3 days after obturation. There was one exception on day 7, when the dye penetration results indicated that the vertical compaction and injectable thermoplasticized gutta-percha techniques had better results than lateral compaction.

On the other hand, if either lateral or vertical compaction technique is selected and compared, the effect of gutta-percha removal time interval of three different occasions (immediate after obturation, the day 3 and the day 7), significance results are obtained. With the vertical compaction method, there was less leakage on day 7 after obturation compared with immediately and 3 days after, although no significance differences were observed in the lateral compaction group.

Two conclusions can be drawn from our observations: (1) at any given time, the apical sealing ability of the lateral compaction method was inferior to that of the two vertical techniques; and (2) in comparing the lateral and vertical compaction obturation techniques, dye penetration of the vertical compaction and injectable thermoplasticized gutta-percha techniques showed significantly less leakage than the lateral compaction technique.

Discussion

To avoid root canal contamination during post fabrication and installation, or indirectly affecting the stability or retention of subsequent prosthetic crowns, adequate amounts of root canal filling material (gutta-percha) must be removed during post space preparation. The sealability of the remaining obturation material is often influenced by several factors, such as the setting time of the root canal sealer, the method of filling material removal, the equipment utilized, and the length of the remaining filling. In many clinical situations, a smaller remnant must be left to increase post retention. Zmener has reported that there should be at least 4.0 mm of filling material remaining, so as not to affect the apical sealing ability. Many previous studies have stated that 5.0 mm of obturation material is considered a safe margin, thereby compromising the apical seal. Some authors (e.g. Haddix et al) consider 3.0 mm to be the minimum remnant to preserve the seal, although Abramovitz et al have reported that a reduction of fillings to 3.0 mm produces an unpredictable seal. They have demonstrated that a remnant filling of 5 mm is clearly inferior to the intact filling. Mattison et al believe that a minimum of 5.0 mm is more suitable, and Nixon et al have argued that at least 6.0 mm is required to prevent a negative impact on the apical sealing ability. There is a general consensus that the length of the remnant filling is inversely proportional to the probability of apical

Table. One-way analysis of variance and mean and standard deviation of dye penetration observed on the canal walls ($n=10$)

<table>
<thead>
<tr>
<th></th>
<th>Lateral compaction</th>
<th>Vertical compaction</th>
<th>Thermoplasticized warm gutta-percha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>2.40 ± 0.93</td>
<td>1.74 ± 0.77</td>
<td>1.81 ± 0.86</td>
</tr>
<tr>
<td>Day 3</td>
<td>1.76 ± 0.76</td>
<td>1.68 ± 0.89</td>
<td>1.32 ± 0.75</td>
</tr>
<tr>
<td>Day 7</td>
<td>1.45 ± 0.60</td>
<td>0.78 ± 0.31</td>
<td>0.68 ± 0.28</td>
</tr>
</tbody>
</table>

Leakage values are measured in mm. p values < 0.05.
leakage, and it is best to retain at least 5.0 mm of filling material in the canal; thus, the present study left 5.0 mm as the baseline remnant filling material.

Matloff et al have concluded that dye penetration is the most sensitive method in the leakage study.\(^{15}\) Several studies using dye penetration methods have reported minimal differences in apical leakage with immediate or delayed post space preparation using different methods of filling material removal.\(^3,8,10\) Meanwhile, the most widely used methodology to assess dye leakage is longitudinal sectioning of samples; the advantage of this technique is that the dye penetration and total leakage of the sample can be measured from a single section.

There is no consensus about the time interval of post preparation, with some authors proposing immediate preparation,\(^6,7\) but others recommending different time intervals.\(^16\) Solano et al have found significantly less leakage when the post space is prepared at the time of obturation, rather than 7 days after obturation.\(^7\) In the present study, leakage was significantly greater after immediate post preparation compared with 3 days and 7 days after obturation. Statistical analysis demonstrated that the vertical compaction method shows less dye leakage when the gutta-percha was removed 7 days after obturation compared with immediately and 3 days after. This was probably because the sealers had not set, and the flow of the materials could fill any gaps, voids or disturbances caused by the preparation, before setting was complete. According to the study of Madison et al,\(^8\) the setting time of the CaOH-containing root canal sealer in the present study is 3 days, and the compounds may continue evaporation for up to 7 days. Therefore, we selected three time intervals of immediately and 3 days and 7 days after obturation for post preparation, to verify whether the sealer reaction affected the quality of apical sealability of the obturation.

Hence, it is imperative that root canal sealer has sufficient time to set and minimize disturbance of the apical seal before post space preparation. Despite researchers such as Mattison et al insisting that simultaneous post space preparation and root canal obturation are advantageous, experimental results suggest that, when time is sufficient, it would be optimal to wait for the complete reaction and settlement of filling materials before other preparations.\(^3\) Additionally, determining whether or not CaOH pastes require longer setting time than other materials, such as ZnO eugenol and resin sealer, requires more in-depth research.

In conclusion, according to our experimental results and statistical analysis, the vertical compaction method is superior to lateral compaction in terms of yielding less dye leakage when heat pluggers are used to remove root canal filling materials. The least amount of dye leakage exists when post preparation occurs at 7 days after obturation, thus one should await completion of sealer setting before preparing post spaces.\(^16\) To sustain proper apical sealing, it is recommended that post spaces are better prepared when crown fabrication is ready to be initiated. Various techniques, materials and ingredients are available for root canal therapy, and whether these differences affect the outcome of apical sealing or post preparation requires further investigation.

References