The Influence of Orifice Sealing with Various Filling Materials on Coronal Leakage

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Received May 10, 2004/Accepted July 22, 2004

INTRODUCTION

Coronal leakage has recently been accepted as a cause of failure in root canal treatments. In a 1961 study which used a radioactive tracer, Marshall and Massler indicated that coronal leakage occurred despite the presence of an adequate coronal seal\(^{1}\). In 1979, Allison et al. suggested that poor coronal seal could be a possible cause for clinical failures\(^ {2} \). Swanson and Madison revealed that the all obturated teeth without temporary restoration, when exposed to artificial saliva, showed leakage ranging from 79% to 85% of the root length within 56 days\(^ {3} \). Torabinejad et al. found that when single-rooted teeth were obturated using the lateral condensation method with gutta-percha and a sealer, 50% of them were totally contaminated with bacteria after 19 to 42 days of bacterial exposure\(^ {4} \).

Clinical studies also showed the importance of a coronal seal in prognosis. Ray and Trope radiographically evaluated the relationship between the qualities of coronal restoration and root canal obturation, and concluded that apical periodontal health depended significantly more on the coronal restoration than on the technical quality of the endodontic treatment\(^ {5} \). Safavi et al. followed up a total of 464 endodontically treated teeth using radiographs, and suggested that upon completion of endodontic treatment, an appropriate and prompt permanent restoration should be performed\(^ {6} \).

These concerns that gutta-percha and sealer alone would not provide an adequate barrier against coronal leakage\(^ {7} \) have given researchers the idea that the coronal part of the root canal should be sealed as closely as possible. Although a number of studies have attempted to reduce or prevent coronal leakage by putting a second barrier in the orifice or pulp chamber\(^ {8} - {10} \), only a few investigations were designed to evaluate the various materials in the same experimental conditions\(^ {8,10,13} \). In this study, we compared the sealing ability of five materials that are currently used in various ways for endodontically treated teeth.

MATERIALS AND METHODS

Cavity preparation

One hundred extracted human mandibular single-rooted teeth that had no resorption, caries, cracks, or open apical foramen were selected. All teeth were carefully curedt to remove any calculus or soft tissue debris and were stored in deionized water until use. The crown of the tooth was removed, and the working length was established at 1 mm short of the apical foramen. The coronal third of the root canal was prepared by slowly rotating Gates-Glidden drills (Dentsply, Maillefer, Ballaignes, Switzerland) sized 2, 3, and 4, and the root canal was instrumented with K-files (Zipperer, VDW, Munich, Germany). The apical portion of the root canal was prepared with #40 K-files at the working length and flared by ProFile 04 taper files (Dentsply Maillefer, Ballaignes, Switzerland) using Tri Auto ZX (J. Morita Co., Kyoto, Japan). The root canal was irrigated with 6% sodium hypochlorite solution. Then, it was dried with paper points and obturated by a vertical condensation method with gutta-percha (GP Pellets Flow 150\(^ {TM} \), Obtura Corp., Fenton, MO, USA) and a sealer (Sealerpex, Kerr, Karlruhe, Germany) using Obtura II (Obtura Corp., Fenton, MO) and System B.
Cavity sealing
The sealing materials used in the six experimental groups are shown in Table 1. The cavities were sealed as follows.

Group 1: Protect Liner F (PL; Kuraray Medical Inc., Kurashiki, Japan) was filled in the cavity using a disposable syringe (Nipro Medical Corp., Osaka, Japan) and photo-polymerized using a light-curing unit for 40 seconds. Mega bond primer was applied for 20 seconds, and Mega bond (Kuraray Medical Inc., Kurashiki, Japan) was applied and photo-cured for 10 seconds according to manufacturers' instructions before filling.

Group 2: Panavia™ Fluoro Cement (PF; Kuraray Medical Inc., Kurashiki, Japan) was filled in the cavity using a disposable syringe in the same way as in Group 1. The cement was photo-polymerized for 40 seconds without OXYGUARD II (Kuraray Medical Inc., Kurashiki, Japan). ED primer (Kuraray Medical Inc., Kurashiki, Japan) was applied for 30 seconds according to manufacturer's instructions before filling.

Group 3: Clearfil™ DC core (DCL; Kuraray Medical Inc., Kurashiki, Japan) was filled in the cavity using a disposable syringe and photo-polymerized in the same way as in Group 1 and Group 2. ED primer was applied for 30 seconds and Photo bond (Kuraray Medical Inc., Kurashiki, Japan) was applied and photo-cured for 10 seconds according to manufacturers' instructions.

Group 4: Clearfil™ DC core (DCC; Kuraray Medical Inc., Kurashiki, Japan) was filled in the cavity using a disposable syringe and chemically cured. ED primer and Photo bond (Kuraray Medical Inc., Kurashiki, Japan) were used in the same way as in Group 3.

Group 5: Super-EBA™ (SE; Harry J. Bosworth Co., Skokie, IL, USA) was mixed according to manufacturer's instructions. It was then filled in the cavity with a plastic instrument (Hu Freidy, Chicago, IL, USA) and tamped down with Buchanan's condenser.

Group 6: Ketac™-Cem (KC; 3M, St Paul, MN, USA) was mixed according to manufacturer's instructions and put in the cavity using a disposable syringe.

Dye leakage and evaluation
Following the method of O'Connor et al.(10), the end of a 1.5 ml microcentrifuge tube was resected to fit with upper side of the root surface, and each was attached to the tooth with cyanacrylate glue. Then, methylene blue dye solution was poured into the tube to a height of 2 cm. The experimental teeth were wrapped with saline-moistened gauze and stored at 37°C for seven days. Each tooth was sectioned longitudinally, and maximum dye penetration along the boundary between the filling material and dentin wall was evaluated under a digital microscope (Digital HF microscope VH8000, Keyence Co., Osaka, Japan) at x40 magnification.

Statistical analyses
The number of teeth allowing dye penetration throughout the length of the cavity was analyzed using the Chi-squared test, and likelihood ration test was employed as the post hoc test (p<0.05). The mean distances at which dye penetration stopped in the filled materials were analyzed using Fisher's PLSD test (p<0.05).

RESULTS
All positive controls showed dye penetration throughout the length of the cavity, and all negative controls showed no dye penetration. The number of teeth allowing dye penetration throughout the length of the cavity differed statistically among groups using the
Table 2 Number of teeth allowing dye penetration

<table>
<thead>
<tr>
<th>Material</th>
<th>Stopped</th>
<th>Allowed</th>
<th>Sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL</td>
<td>15</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>PF</td>
<td>13</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>DCL</td>
<td>7</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>DCC</td>
<td>12</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>SE</td>
<td>4</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>KC</td>
<td>0</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

The numbers were statistically different among groups using the Chi-squared test, and the significant differences were detected using the likelihood ratio test between PL and DCL or SE or KC, PF and SE or KC, DCC and KC, DCL and KC (p<0.05).

Stopped: Dye penetration was stopped in the length of the cavity.
Allowed: Dye penetration was allowed throughout the length of the cavity.

Chi-squared test, and are shown in Table 2. The likelihood ratio test revealed significant differences between PL and DCL or SE or KC, PF and SE or KC, DCC and KC, DCL and KC (p<0.05).

For the teeth where dye penetration stopped within the length of the cavity, Fig. 1 shows the dye penetration distance along its respective filling material. Statistically significant differences between PL and SE, PL and DCC, PF and SE, PF and DCC were detected using the Fisher’s PLSD test (p<0.05).

**DISCUSSION**

The results of the number of teeth allowing dye penetration throughout the depth of the cavity and the mean distance of dye penetration in this study showed that Protect Liner F and Panavia F had higher sealing ability than light-cured and chemically-cured DC cores or Super-EBA, while Ketac had the poorest sealing ability. Although Super-EBA is the most commonly used root-end filling material[14], and glass-ionomer cements including Ketac are currently used in endodontic therapy in many ways[15], all the 15 Ketac teeth and 11 (out of 15) Super-EBA teeth failed to stop dye penetration. These results suggested an inferior sealing ability of non-adhesive materials. A recent study of post-core cementation has indicated a superior sealing ability of dentin-bonding resin cements compared with non-dentin-bonding cements[16]. Panavia F is categorized as a dual-curable resin cement that is mainly used in setting prostheses. We used this cement to compare mainly with Ketac, and correspondingly Panavia F emerged superior to Ketac in our experiment. This time round, we applied the photo-curing procedure to Panavia F to reduce water absorption and water solubility[17].

Protect Liner F is a low-viscosity resin — a so-called flowable composite. The first generation of flowable composites was introduced in 1996. Despite the concern about higher polymerization shrinkage that is brought about due to their lower filler content[18,19], several studies have reported reduced microleakage with the use of flowable composites[20-22]. In this experiment, Protect Liner F exhibited the best performance among the five materials. Although the mean distance of microleakage was not significantly different between Protect Liner F and Panavia F, Protect Liner F perfectly stopped coronal leakage while two (out of 15) of Panavia F’s failed to do so. Although the number of leaked samples was not statistically different between the two groups, the sealing accuracy of Protect Liner F might be attributed to its high flowability and adhesive system.

DC core is a dual-cure composite resin mainly used for core build-up. We used this material in two different ways — light-curing and chemically-curing — because various scenarios in clinical setup are assumed. Neither light-cured nor chemically-cured DC core showed superior sealing ability when compared to Protect Liner F. Although the primer and bonding agent used for DC core were different from those of Protect Liner F, a key advantage of Protect Liner F could be its flowability which relieved contraction stress and which improved marginal and internal adaptations[23,24]. It is difficult to explain the detailed mechanism as to why the light-cured composite had a larger number of leakages than the chemically-cured composite. The slower polymerization reaction of chemically-cured composites might be one of the reasons[25,26].

To compare the sealing ability of the five materials, we prepared 4-mm deep fillings in this experiment. However, the mean distance of dye penetration of Protect Liner F and Panavia F was 1.01 mm. For the next step, it would be to examine the shallower fillings of adhesive materials[27,28].

In this study, adhesive and flowable materials showed better sealing. However, some problems
remain when using adhesive materials on root canal dentin irrigated with NaClO. Previous studies have reported the difficulties of resin bonding with the root dentin \(^{29-31}\), and some studies have indicated the influence of NaClO irrigation on bonding systems \(^{32-34}\). We believe that further studies concerning adhesive materials and root canal irrigation would provide better protection of the root canal against coronal leakage.

**CONCLUSION**

The results of this study indicated the excellent sealing ability of the adhesive and flowable materials.

**REFERENCES**

31. Inoue S, Pereira PN, Kawamoto C, Nakajima M, Koshiro K, Tagami J, Carvalho RM, Pashley DH.