Effect of Resin Coating as a Means of Preventing Marginal Leakage beneath Full Cast Crowns

Satomi KOSAKA, Hirotada KAJIHARA, Hisanori KURASHIGE and Takuo TANAKA
Department of Fixed Prosthodontics, Kagoshima University Graduate School of Medical and Dental Sciences, 8-35-1 Sakuragaoka Kagoshima-shi, Kagoshima 890-8544, Japan
Corresponding author, E-mail: kajihiro@dentb.hal.kagoshima-u.ac.jp

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INTRODUCTION

After an abutment is prepared, the exposed dentin may be contaminated by oral fluids by the time the restoration has been finally cemented in place. Contamination can cause bacterial infection of the dental pulp via the dentinal tubules, frequently leading to much discomfort for the patient in the form of spontaneous pain and tooth sensitivity. Hyperesthesia is often caused by inflammatory reaction of the pulp due to stimulation during preparation or bacterial infection of the pulp through exposed dentinal tubules after preparation. An attempt is being made to prevent bacterial infection of the pulp due to bacteria or products created by bacteria entering through the dentinal tubules, by sealing exposed dentinal tubules using a bonding agent. It is known that a resin coating provides protection of the dental pulp for a period until the restoration is cemented. Resin coating may serve to protect the pulp, improve the resin cement’s bond to the tooth, and reduce the gap between the restoration and the cavity wall. However, the effectiveness of resin coating as a means of preventing marginal leakage beneath full cast crowns has hardly been discussed. Thus, it is not clear whether resin coating is effective or not over a long period in the oral cavity, where a variety of stresses such as temperature change are experienced.

In this study, preparations for full cast crown were made, restorations were mounted, and then, the specimens were thermal-cycled 10,000 times to evaluate the ability of the resin coating to seal dentinal tubules.

MATERIALS AND METHODS

Sixty-four extracted, sound human maxillary and mandibular premolars were used for the experiment. After extraction, they were kept in normal saline water at 3°C. The tooth root was scaled before the experiment. Standard dentin-bonded type abutments were prepared. The preparation was accomplished using diamond burs (Smooth Cut BR2 ISO No. 198016/GC, Tokyo, Japan) with a high-speed, air-turbine handpiece (Kavo, Biberrach, Germany) and a constant water spray as a coolant. The following points were taken into consideration: (1) removing all enamel from the abutment; (2) making a taper of 6° on the abutment; (3) giving a chamfer-edge finish at the cervical area, with a margin created in dentin.

The prepared teeth were then randomly divided into four major groups, each group was further divided into two subgroups (n=8). One subgroup of each of the major groups was coated with an experimental dentin coating material (code name RZ II — now commercially available as Brush and Bond, Parkell, Farmingdale, NY, USA). RZ II was a single-step, non-rinsing, self-etching adhesive. The RZ II kit consisted of a sponge and a liquid component. The liquid component contained water, acetone, 4-META, acrylic monomer, photoinitiator, and stabilizer. The sponge contained p-toluensulfinate salt, and amine as a catalyst. The groups coated with RZ II had the...
material applied to the dentin surface and left for 20 seconds before being dried with an air syringe for 5 to 10 seconds. Then, the coat was light-cured for 10 seconds using JETLITE1000 (J Morita, USA; Irvine, CA, USA)\(^\text{30}\). After light-curing, any unpolymerized material was removed from the tooth surface with an ethanol swab. A combined impression was taken on each prepared tooth using alginate impression material (Aroma fine, GC) and duplicating agar impression material\(^\text{19}\) (Cartloid, Dentochemical, Tokyo, Japan). After the impressions were taken, temporary crowns were prepared and cemented to the specimens for a short term using temporary cement (Freegenol Temporary Pack, GC). After which, the specimens were stored for three days in an incubator at 37°C and 100% humidity.

Full cast crowns were fabricated using a standard technique with Ag-Pd-Cu-Au alloy (Castwell MC, GC)\(^\text{30}\). Each crown was examined for adaptation to its prepared tooth. If any crown did not fit properly\(^{21,22}\), a new impression was taken and then a new crown fabricated. Before cementation, the inner surface of each crown was sandblasted with 50 μm aluminum oxide (Al₂O₃) for 10 seconds (Jet blast III, Morita, Tokyo, Japan). The luting materials used for cementing the crowns are shown in Table 1. Each crown was seated to its respective abutment tooth using finger pressure. When C&B Metabond (Parkell) was used as a luting cement, the pretreatment of the resin-coated specimen on the dentin surface area was omitted. All specimens fitted with crowns were stored in 37°C distilled water for 24 hours before being thermal-cycled in a water bath between 4°C and 60°C for 10,000 cycles (each cycle containing a 60-second dwell time and 3-second transfer time)\(^\text{1,23–27}\).

Leakage was evaluated using the dye penetration method. After thermal-cycling, the exposed surface of each specimen tooth was coated with two layers of nail varnish, leaving a 2-mm wide margin around the restoration uncoated. Each specimen was then immersed in a 2% erythrosine solution for 24 hours at room temperature and rinsed under tap water.

Thereafter, the specimen was embedded in a self-curing resin (Unifast, GC), sectioned in the buccoinferring direction using a diamond disk (Isomet, Buehler, Düsseldorf, Germany) and water spray. Sectioned specimens were evaluated by two different evaluators\(^\text{20}\). The extent of dye penetration at the buccal and lingual margin was assessed with a stereomicroscope at ×15 magnification and scored from two directions (the direction of the dental pulp and the direction of the tooth axis). The number of measurements was twice the number of samples because of measurement at two places (the buccal and lingual margin).

The amount of leakage was evaluated on a 5-point scale according to the extent of dye penetration\(^\text{21,23,30}\).

The penetration level in the direction of the tooth axis was evaluated as shown in Fig. 1. This extent of dye penetration was evaluated based on coloring the cement layer.

0: No leakage.
1: Dye penetration up to 1/3 of the entire tooth length.
2: Dye penetration up to 2/3 of the entire tooth length.
3: Dye penetration greater than 2/3 of the entire tooth length.
4: Dye penetration extending further, to the occlusal surface.

The penetration level in the direction of the dental pulp was evaluated as shown in Fig. 2.

0: No leakage.
1: Leakage was less than 1/3 of the distance from the crown margin to the dental pulp.
2: Leakage was less than 2/3 of the distance from the crown margin to the dental pulp.
3: Leakage was greater than 2/3 of the distance from the crown margin to the dental pulp.
4: Leakage reached the dental pulp.

Statistical analysis of the data was performed using non-parametric methods because the data did not have a normal distribution. The data were analyzed using the Mann-Whitney U test (p<0.01) to compare the difference between coated and uncoated specimens. In addition, comparison was made among the luting agents using the Kruskal-Wallis test (p<0.01) and Steel-Dwass test (p<0.01). Stat View (HULINKS, Tokyo, Japan) and Kyplot (Kyence, Tokyo, Japan) were used to perform the statistical analyses\(^\text{23,30}\).

<table>
<thead>
<tr>
<th>Luting Agent</th>
<th>Code</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Zinc phosphate cement</td>
<td>Zinc cement</td>
<td>Shofu, Kyoto, Japan</td>
</tr>
<tr>
<td>Hybond zinc cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Glass-ionomer cement</td>
<td>Fuji I</td>
<td>GC, Tokyo, Japan</td>
</tr>
<tr>
<td>Fuji I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Resin-modified glass-ionomer cement</td>
<td>Vitremer luting cement</td>
<td>3M-ESPE, Seefeld, Germany</td>
</tr>
<tr>
<td>4. Resin cement</td>
<td>C&amp;B Metabond</td>
<td>Parkell, Farmingdale, USA</td>
</tr>
</tbody>
</table>

Table 1  Luting agents used for experiment.
RESULTS

Figs. 3 and 4 show the leakage scores of all conditions.

Differences according to the presence of a resin coating

Table 2 shows the comparison results according to the presence of a resin coating. The resin coat did not influence the extent of dye penetration in the tooth axis direction. When Fuji I and Vitremer luting cements were used, the dye penetration level dropped significantly in the dental pulp direction in the resin-coated specimens. On the other hand, C&B Metabond cement behaved differently from the other cements in that uncoated specimens mounted using the C&B Metabond cement did not leak at all, but coated specimens mounted using the same cement had a slight amount of dye penetration. However, this was not a statistically significant difference.

Difference according to type of luting cement

Tables 3 and 4 show the results of comparing uncoated specimens by cement type. Although there were no significant differences between Hybond zinc cement and Fuji I, significant differences were recognized among all other combinations of cement. Especially notable was that no leakage occurred when a full cast crown was mounted with C&B Metabond.

Tables 5 and 6 show the results of coated specimens mounted using different luting cements. The
Table 3 Comparison of uncoated specimens by cement type (Kruskal-Wallis test)

<table>
<thead>
<tr>
<th>Group</th>
<th>Median of the tooth axis (P&lt;0.001)</th>
<th>Median of the dental pulp (P&lt;0.001)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>n</td>
</tr>
<tr>
<td>Zinc cement</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Fuji I</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Vitremer</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>C&amp;B Metabond</td>
<td>0</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 4 Comparison of uncoated specimens by cement type (Steel-Dwass test)

<table>
<thead>
<tr>
<th>Tooth Axis</th>
<th>Zinc cement</th>
<th>Fuji I</th>
<th>Vitremer</th>
<th>C&amp;B Metabond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc cement</td>
<td>P&lt;0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuji I</td>
<td>P&lt;0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitremer</td>
<td>P&lt;0.001</td>
<td></td>
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<tr>
<td>C&amp;B Metabond</td>
<td></td>
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</tbody>
</table>

Table 5 Comparison of coated specimens by cement type (Kruskal-Wallis test)

<table>
<thead>
<tr>
<th>Group</th>
<th>Median of the tooth axis (P&lt;0.001)</th>
<th>Median of the dental pulp (P&lt;0.001)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>n</td>
</tr>
<tr>
<td>Zinc cement</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Fuji I</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Vitremer</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>C&amp;B Metabond</td>
<td>0</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 6 Comparison of coated specimens by cement type (Steel-Dwass test)

<table>
<thead>
<tr>
<th>Tooth Axis</th>
<th>Zinc cement</th>
<th>Fuji I</th>
<th>Vitremer</th>
<th>C&amp;B Metabond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc cement</td>
<td>P&lt;0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuji I</td>
<td>P&lt;0.001</td>
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<td>C&amp;B Metabond</td>
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</tr>
</tbody>
</table>

coated specimens had the same type of leakage in the direction of the tooth axis as the uncoated specimens. However, the dye penetration levels in the direction of the dental pulp were significantly different, other than the comparison of Vitremer luting cement and C&B Metabond.

DISCUSSION

*Dye penetration in the direction of the tooth axis*

After a crown is cemented on the abutment, dye penetration into the dentin could be divided roughly into two stages. In the first stage, the dye penetrates in the direction of the tooth axis starting at
the margin. In the second stage, it penetrates the dental pulp along the dentinal tubules.

In this study, when the same cement was compared for coated and uncoated samples, dye penetration in the direction of the tooth axis was almost the same, suggesting that the result was closely related to the physical properties of the cements used. For example, the mechanical properties of zinc phosphate cement and glass-ionomer cement were comparatively low. After the adhesive interface was flaked by thermal cycling, water sorption and dissolution of the cement occurred, hence causing the cement layer to deteriorate. In contrast, resin cements and resin-modified glass ionomer cements have greater mechanical strength, which meant that the cement layer incurred a lower degree of dissolution, and thus prevented dye penetration. Conventional cements, such as zinc phosphate cement and glass-ionomer cement, are said to have high degrees of both solubility and water sorption. By contrast, it is reported that the solubility and water sorption of resin-modified glass-ionomer cement and resin cement are substantially lower. In particular, the solubility of resin cement is less than half of conventional cement's and its water sorption rate less than 1/5. A case-in-point in this study was C&B Metabond, a resin cement. It demonstrated good adhesion to both the tooth and resin-coated area due to the excellent solubility and water sorption properties.

Dye penetration in the direction of the dental pulp

The dye penetrated in the direction of the tooth axis during the first stage. In the second stage, it moved in the direction of the dental pulp via the dentinal tubules. The coating agent penetrated the dentinal tubules and hardened to form a resin-impregnated layer, thus blocking the opening of the dentinal tubules. This thin film seemed to block the penetration of dye. The zinc phosphate cement did not block dye penetration in the dental pulp direction for resin-coated specimens and had the same score on dye penetration as for the uncoated specimens. Dislodgment of the interface of zinc phosphate cement was probably accelerated due to thermal-cycling. Due to water sorption into the cement from this site and the resultant dissolution of the cement, the cement layer began to deteriorate severely. This seemed to expose the coated layer directly to the thermal load, thus causing the coat to deteriorate too. This reasoning was supported by the observation that the entire cement layer was stained by dye in these sectioned specimens. This was probably because there were many cracks in the cement layer which had already deteriorated, through which the dye could penetrate and become deposited.

In contrast, when glass-ionomer cement was used as the luting cement, the resin coating had some effect in preventing microleakage. The score was 1/4 for specimens cemented using glass-ionomer cement. This was probably because the physical property of glass-ionomer cement outperformed that of zinc phosphate cement. Thus, less of the adhesive interface was flaked by the stress of thermal-cycling. This then prevented the resin-coated layer from being exposed directly to thermal stress and suppressed the deterioration of the coat, leading to maintenance of leakage prevention. Upon observation of the sectioned specimens, it could be seen that the glass-ionomer cement layer had an area stained in a way similar to that of the samples cemented with zinc phosphate, but this was restricted to an area within 2 mm of the margin.

Both resin cement and resin-modified cement seemed to have blocked dye penetration completely. This was because they had a more excellent physical property than glass-ionomer cement, thus preventing the deterioration of the coat.

From the above results, it could be seen that the resin-coating technique can seal dentinal tubules effectively if an appliance is cemented on a vital tooth using glass-ionomer cement or resin-modified cement. In addition, after the restoration is cemented, this technique is effective in protecting the dental pulp against chemical and bacterial stimulation.

REFERENCES

9) Momoi Y, Akimoto N, Kida K, Yip KH, Kohno A.


