The purpose of this study was to evaluate the generation of enamel cracks and gaps at the cavosurface margin of resin composite restorations using various burs. Saucer-shaped cavities with a bevel were prepared on mid-coronal buccal or lingual surfaces of extracted human molars using a regular-grit round diamond bur, a fine-grit diamond bur, a superfine-grit diamond bur or a six-bladed tungsten carbide bur with an air turbine handpiece. The enamel margin of the cavity in each group was observed by a light microscope. Cavities were restored with a self-etching adhesive and a light-cured composite resin. After thermocycling, enamel cracks and gaps at the cavosurface margins were observed and scored. Specimens were sectioned longitudinally in two halves, and the resin-cavity interface was observed by means of a light microscope. In cavity preparation, the regular-grid diamond bur and the tungsten carbide bur caused more cracks in the marginal enamel than other groups. From the surface and sectioned surface observation of restored teeth, the superfine-grit diamond bur generated fewer cracks and gaps than the other burs.

Key words: resin composite, diamond bur, marginal gap, enamel crack, self-etching primer

Introduction

Polymerization contraction stress is still one of the major problems when restoring teeth with resin composite. However, the remarkable improvement of the bond strengths of resin-based adhesives to teeth has contributed to a reduction of the formation of gaps between the resin composite and cavity wall. On the other hand, it is important that enamel has a prismatic structure that can easily be pulled apart when stressed. When the stress of polymerization contraction exceeds the strength of a tooth, a crack is often initiated, usually in the enamel. Marginal gaps can lead to secondary caries and pulp irritation due to the accumulation and infiltration of bacteria between the restoration and the tooth substrate. In addition, when the enamel cracks have come to extend deeply and widely as the result of repeated occlusal loading stress, it is possible that extensive enamel cracks may also produce similar gap formation outcomes as caries and pulp irritation. Therefore, it is important for the longevity of resin composite restorations that the formation of marginal gaps and cracks can be prevented or at least controlled to the greatest degree possible. It has been recommended that a regular-grit diamond bur should be used to obtain a rough surface in cavity preparation in order to increase the surface area and the micro-mechanical bonding retention of adhesives. However, cavity preparation with dental burs can easily produce micro-fractures in the enamel. The degree of the generation of enamel damage induced during cavity preparation can be influenced by the diamond grit size and type of bur. Cavity preparation with minimal mechanical damage at the cavosurface...
margin may be an important factor for preventing enamel cracks at the site of resin composite restoration.

The purpose of this study was to evaluate the marginal integrity of cavities restored with resin composite prepared using various burs attached in an air turbine handpiece.

Materials and Methods

Twenty-four extracted intact human molars were used in this study after the informed consent of donors. There were no cracks observable on the surfaces of the teeth as determined by light microscope observation (Olympus colposcope ocs, Olympus, Japan, x 24). The teeth were divided into four experimental groups, each made up of six teeth. Experimental procedure was shown in Fig 1. Saucer-shaped cavities approximately 1.5 mm in depth and 2 mm in diameter were prepared on the mid-coronal buccal or lingual surfaces of each tooth and a concave bevel was placed with various burs (round-shape 1.4 mm in diameter) listed in Table 1 using an air turbine handpiece (Super-Torque 640B, Kavo, Germany) at 400,000 rpm under copious water spray coolant as follows:

Group 1: Cavity preparation and a bevel using a regular-grit diamond bur.
Group 2: Cavity preparation with a regular-grit diamond bur, then finishing and placing a bevel using a fine-grit diamond bur.
Group 3: Cavity preparation with a regular-grit diamond bur, then finishing and placing a bevel using a superfine-grit diamond bur.
Group 4: Cavity preparation and a bevel using a round-shaped, six-bladed tungsten carbide bur.

All cavities in each group were cut with just one bur. The cavity margin of one tooth in each group was observed using a measuring microscope (Measuring microscope MM-60, Nikon, Japan) at x200 magnification. The remaining five cavities were restored with a self-etching primer adhesive system (Clearfil SE Bond, Batch No.011228, Kuraray Medical, Japan) and a light-cured composite (Clearfil AP-X, Batch No.01122, Kuraray Medical, Japan).

Table 1. The cutting equipment used in this study

<table>
<thead>
<tr>
<th></th>
<th>diameter (mm)</th>
<th>average grit size(µm)</th>
<th>Code, ISO # (manufacturer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>regular diamond</td>
<td>1.4</td>
<td>100</td>
<td>Experimental (Shofu, Kyoto, Japan)</td>
</tr>
<tr>
<td>fine diamond</td>
<td>1.4</td>
<td>60</td>
<td>U440, ISO # 014 (Shofu, Kyoto, Japan)</td>
</tr>
<tr>
<td>superfine diamond</td>
<td>1.4</td>
<td>25</td>
<td>SF440, ISO # 015(Shofu, Kyoto, Japan)</td>
</tr>
<tr>
<td>carbide</td>
<td>1.4</td>
<td>#4, ISO # 014 (Shofu, Kyoto, Japan)</td>
<td></td>
</tr>
</tbody>
</table>
No.00772B, Kuraray Medical, Japan) according to the manufacturer’s instructions. The materials were polymerized with a light intensity of 600mW/cm² for 40 seconds using a light curing unit (Optilux 500, Demetron, USA). After finishing and polishing using a flame-shaped superfine diamond bur (SF215, GC, Japan) and silicone points (M2 and M3, Shofu, Japan) under copious air-water spray, then the specimens were thermocycled for 500 cycles between 5°C and 55°C with a 30-second dwell time. A 1.0% acid red propylene glycol solution (Caries Detector, Kuraray Medical, Japan) was applied on the margin of the restorations for 5 seconds, and then rinsed with water to enable the detection of cracks and gaps. The enamel margin was divided into equal eight areas shown Fig.1 and enamel cracks and marginal gaps were observed using the measuring microscope, and then scored the number of areas (0 to 8) in which crack or gap was detected in each tooth specimen. After the evaluation, the specimens were longitudinally sectioned at center of cavity and gap formation was observed in group 3 compared with group 1, 2 and 4. The light microscopic images of the cross sectional surfaces are shown in Fig 4. Small enamel cracks were often observed at the occlusal and gingival margin in many teeth of each group. Gap formation was rarely observed in group 3.

The number of teeth with cracks or gaps at occlusal and gingival margins in cross sectional surfaces is shown in Table 3. Enamel crack generation was observed at both occlusal and gingival margins in many teeth of each group. In group 3, gap formation was found at occlusal margin in one teeth. Two-way ANOVA revealed that the gap formation was influenced by type of bur (p<0.05). However, it was not influenced by the area (p>0.05). There was no significant interaction between the independent variables group and area (p>0.05). For the gap generation, group 3 was statistically lower than group 4 by the Scheffe’s test. The light microscopic images of the cross sectional surfaces are shown in Fig 4. Small enamel cracks were observed at the occlusal and gingival margin in many teeth of each group. Gap formation was rarely observed in group 3 compared with group 1, 2 and 4.

Discussion

There are many studies that have evaluated the marginal leakage of restorations, however, not only the microleakage due to the formation of gaps but also that due to cracks in the marginal enamel may influence the initiation of further caries. Marginal microleakage will occur when the bond strength of the adhesive is not sufficient to resist polymerization contraction stress. Enamel cracking is initiated by the damage caused during preparation with burs and is likely to be furthered by the contraction of the polymerizing resin composite. In this study, the effects of the various bur grits on the marginal integrity of the resin restorations...
were evaluated using a light microscope, because it suggested itself as an observation method with less artifacts likely to distort the outcome.

Enamel crack propagation and gap formation at the cavosurface margin varied among the experimental groups. The superfine diamond burs (group 3) produced the smoothest marginal enamel and generated fewer cracks at the margin of the restorations than the others. In terms of gap formation, the superfine bur resulted in fewer gaps than the regular diamond bur or carbide bur. For crack generation and gap formation, there was no statistical difference between group 2 and 3. However, crack generation and gap formation of group 3 were less than that of group 2 LM observation (Fig 2,3,4). Kanemura et al.\(^{11}\) reported that cavity preparation using a regular grit diamond bur or a carbide bur produced irreversible damage to superficial enamel. Xu et al.\(^{10}\) reported that the cracks produced by coarse diamond burs were effectively removed by finishing with finer diamond burs. On the other hand, it has been put forward that the rough enamel surface

![Fig. 2. Light microscopic images of the marginal enamel (x200). a: Prepared with regular-grit diamond bur (group 1). b: Prepared with fine-grit diamond bur (group 2). c: Prepared with superfine-grit diamond bur (group 3). d: Prepared with a tungsten carbide bur (group 4). An enamel micro-fracture was generated (arrow).]

<table>
<thead>
<tr>
<th>Group</th>
<th>Crack</th>
<th>Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.0 ± 0.7</td>
<td>1.6 ± 1.5</td>
</tr>
<tr>
<td>2</td>
<td>6.0 ± 2.0</td>
<td>1.0 ± 1.2</td>
</tr>
<tr>
<td>3</td>
<td>3.8 ± 1.9</td>
<td>0.2 ± 0.4</td>
</tr>
<tr>
<td>4</td>
<td>7.2 ± 1.8</td>
<td>2.4 ± 1.7</td>
</tr>
</tbody>
</table>

*statistically significant difference (p < 0.05) \(\text{mean } \pm \text{ S. D.}\)
using a regular diamond or carbide bur was effective when bonding to resin, because a roughened surface increases the area available for adhesion and hence, at least theoretically, is able to improve micro-mechanical retention. However, in our study, a great number of smeared enamel fragments were observed on the surface prepared with the regular-grit diamond bur, and a great number of enamel micro-fractures were observed for the carbide bur. Certain gaps were linkable with enamel cracks as reported by Staninec et al. However, in our study, a great number of smeared enamel fragments were observed on the surface prepared with the regular-grit diamond bur, and a great number of enamel micro-fractures were observed for the carbide bur. Certain gaps were linkable with enamel cracks as reported by Staninec et al. (Fig 4b). Indeed, the presence of microscopic enamel fragments and cracks seem to be closely relatable to

### Table 3. Number of teeth with cracks and gaps observed at occlusal and gingival margin in cross-section (N=5).

<table>
<thead>
<tr>
<th>Group</th>
<th>Crack</th>
<th>Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Occlusal</td>
<td>gingival</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Fig. 3. Light microscopic images at the surface of the cavosurface margin of restoration (x200). (E: enamel, R: composite resin)

a: Prepared with regular-grit diamond bur (group 1). Arrow showed enamel crack.
b: Prepared with carbide bur (group 4). Arrow showed gap formation.
c: Prepared with superfine diamond bur (group 3). No gap and crack were observed.
gap formation. Since the bond strength of the resin adhesive systems used in current practice has been improved dramatically, it might be unnecessary to create a rough cavosurface so as to obtain a greater area for adhesion and micro-mechanical retention. According to the results of this study, finishing with a superfine diamond bur is recommended for clinical cavity preparation to improve the marginal integrity of resin restorations.

A concave-bevel (0.5mm width) was placed in this study so as to afford a means of removing unsupported enamel. However, unsupported enamel noted in several specimens nevertheless, especially at the gingival margin, might be due to the non-uniform orientation of the enamel rods. The cracks often accompanied unsupported enamel. Øilo & Jørgensen report that a wider bevel at the margin gave an increased number of restorations without fractures in the enamel. Clinically, however, it is sometimes difficult in practice to place a wide bevel at the gingival margin. It is also necessary to consider therefore various methods, including incremental filling technique, the polishing time, and varying the light intensity during polymerization as well as the thickness of bonding layer to improve the marginal integrity of the resin restorations.

In this study, the two-step self-etching primer adhesive system was used. The self-etching primer is less aggressive than phosphoric acid when etching enamel. It has been reported that intact ungrounded enamel surface reduces the efficacy of bonding when self-etching primer was used such as Clearfil Liner Bond 2V, Mac Bond II, Clearfil SE Bond and Prompt L-Pop.

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**Fig. 4.** Light microscopic images of cavosurface margins of the cross-section (x200).

- a: Prepared by regular-grit diamond bur (group 1). Arrow showed enamel crack.
- c: Prepared by superfine diamond bur (group 3). No gap and enamel crack were observed. Arrow showed the bonding resin.
On the other hand, Shimada et al. report that self-etching primer system (Clearfil SE Bond) exhibited considerable strength in bonding enamel regardless the direction of the enamel prisms and exhibited a great strength in bonding to parallel prismatic enamel than adhesive system with phosphoric acid etching (one-bottle: Single Bond). Furthermore, cracks along the prisms near the bonding interface were produced, resulting in reduced bond strength when phosphoric acid was applied. Phosphoric acid appears to produce more cracks at the cavity margin than self-etching primers. Phosphoric acid etching may be too aggressive on the parallel prismatic enamel surface. Further research comparing these bonding systems will be necessary to make a conclusive determination. Micro enamel cracks were more often observed than gaps at the cavosurface margin, and no gaps were found to have formed between the dentinal cavity walls and the resin restorations except in one specimen in Group 1. This result suggests that the adhesive material used in this study was able to satisfactorily bond to both enamel and dentin, and to thus resist polymerization contraction stress.

Conclusion

Cavity preparation using a regular-grit diamond bur and a six-bladed tungsten carbide bur caused the greatest degree of enamel crack and gap formation. The superfine-grit diamond bur reduced the enamel crack formation and improved the adaptation of adhesive composites to the cavity.

Acknowledgments

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References