Effects of abrasive and fiber components in medium on wear of composite resins

Kiyoshi KAKUTA and Hideo OGURA

Department of Dental Materials Science, School of Life Dentistry at Niigata, The Nippon Dental University, 1-8 Hamauracho, Niigata-shi, Niigata 951-8580, Japan
Corresponding author, Kiyoshi KAKUTA; E-mail: kakuta@ngt.ndu.ac.jp

Effects of abrasive and fiber components in a medium on the wear behavior of composite resins were evaluated. Calcium diphosphate and methyl cellulose were included in the medium as abrasive and fiber components respectively. A range of 0, 4, or 8 mass% abrasive- or fiber-containing media were prepared for the study. Four composite resins, Clearfil AP-X, Z100 Restorative, SOLARE P, and SOLIDEX F, were tested to evaluate the effects of these components in the medium.

Presence of abrasive material in the medium increased the wear of composite resins significantly, but its effect differed among the composite resins. Presence of fiber material in the medium significantly decreased the wear of two composite resins, whereas the other two composites showed no significant differences. Nonetheless, presence of fiber in the medium generally tended to prevent the wear of composite resins.

Key words: Composite resin, Wear, Medium

INTRODUCTION

Wear resistance is one of the most important properties of dental restorative materials. Many researchers have investigated the wear behavior of dental restorative materials to clarify a specific wear character as well as the clinical wear behavior of dental materials. However, the wear property of restorative dental materials is very complicated due to a variety of factors. In a study that involved a ten-year clinical evaluation of a posterior composite resin, 37% of the restorations exhibited non-anatomical change whereas 7% deteriorated over the span of 10 years. The remaining 56% were evaluated as slightly deteriorated in some region. This study suggested that the wear of composite resins changes depending on different conditions, such as location and shape of the restoration, applied force, and contact between tooth and restoration.

Besides tooth contact, wear of restorations should also be evaluated from the perspective of contact with different types of food. This is because during mastication, dental restorations come into contact with different types of food with different textures. A hard component in food may act as an abrasive material, while another component may act as an effective lubricant during mastication. In light of the positive versus negative impact of masticated food on dental restorations, it is therefore necessary to clarify the influence of food types and textures on the wear properties of restorative dental materials.

Set forth in ISO Technical Specification ISO/TS 14569-2:2001, there are eight test methods to assess the wear resistance of materials occurring on the occlusal surface of restorations. Five of which use water as the medium, and the other three methods use rice and husks of millet spray, poppy seeds, and PMMA beads. However, the effects of these different media, especially those of the component in each medium, have not been well described.

The purpose of this study, therefore, was to investigate the effect of medium components—abrasive or fiber material—on a simulated occlusal wear of resin composites.

MATERIALS AND METHODS

Experimental media

Table 1 shows the two types of experimental media used, containing either abrasive particles or fibers. A 5% cornstarch solution was used as the medium solvent. The abrasive particle-containing medium included calcium diphosphate as the abrasive in the solvent. A range of 0, 4, or 8 mass% calcium diphosphate-containing media were prepared for the study. For the fiber-containing medium, methyl cellulose was dispersed in the solvent at contents of 0, 4, and 8 mass%. During the simulated occlusal wear test, an abrasive-containing or fiber-containing medium was introduced to the wear specimen surface.

Composite resins

Four commercially available light-cured composite
resins, Clearfil AP-X (Lot No. 1117AA, Kuraray, Okayama, Japan; Code: APX), Z100 restorative (Lot No. 20050525, 3M ESPE, MN, USA; Code: Z100), SOLARE P (Lot No. 0508261, GC, Tokyo, Japan; Code: SRE), and SOLIDEX F (Lot No. 070510, Shofu, Kyoto, Japan; Code: SDX) were used for the wear specimens. APX and Z100 were intended for both anterior and posterior restorations, while SRE and SDX were for posterior restorations. The filler systems of these composite resins included a hybrid filler (APX), fine hybrid filler (Z100), or organic composite filler with hybrid filler (SRE and SDX).

**Specimen preparation**

Specimen preparation was carried out following ISO 4049. Wear specimens were prepared using a metal mold of 15 mm diameter and 8 mm depth. Specimen thickness was adjusted to 2 mm using a spacer in the mold. Figure 1 shows the metal mold and a prepared specimen.

To prepare the specimens, the mold was overfilled with composite resin and then covered with a polyester film (0.1 mm thickness). The latter was in turn covered with a glass sheet under pressure to remove excess material. Specimens were polymerized using a curing light (Optilux 500, Kerr, Orange, CA, USA) through the film. The curing light was applied on the specimen surface for 40 seconds, and this procedure was overlapped nine times following ISO 4049 specification. After curing, specimens were polished using a #1000 silicone carbide paper with water, and then stored in distilled water at 37°C for 24 hours before the wear test. Three specimens were prepared for each concentration of the experimental media.

**Simulated occlusal wear test**

Figure 2 shows a schematic diagram of the simulated occlusal wear test, and Table 2 lists the conditions of the simulated occlusal wear test in detail. For the

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Table 1  Experimental media containing abrasive or fiber component

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent</td>
<td>5% Cornstarch solution</td>
</tr>
<tr>
<td>Cornstarch</td>
<td>(Wako Pure Chemical Industries, Osaka, Japan, KLH1090)</td>
</tr>
<tr>
<td>Abrasive-containing medium</td>
<td>0%, 4%, 8% abrasive + Solvent</td>
</tr>
<tr>
<td>Abrasive</td>
<td>Calcium diphosphate</td>
</tr>
<tr>
<td></td>
<td>(Wako Pure Chemical Industries, Osaka, Japan, KLM4174)</td>
</tr>
<tr>
<td>Fiber-containing medium</td>
<td>0%, 4%, 8% fiber + Solvent</td>
</tr>
<tr>
<td>Fiber</td>
<td>Methyl Cellulose (4000cP) (Kanto Chemical Co., Tokyo, Japan, 703X1991)</td>
</tr>
</tbody>
</table>

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Table 2  Conditions of simulated occlusal wear test

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material of antagonist</td>
<td>Aluminium nitride (HV 390)</td>
</tr>
<tr>
<td>Configuration of antagonist</td>
<td>Round tip (2mm curvature)</td>
</tr>
<tr>
<td>Occlusal force</td>
<td>40N</td>
</tr>
<tr>
<td>Sliding distance</td>
<td>1mm</td>
</tr>
<tr>
<td>Loading and sliding cycle</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Medium</td>
<td>① 0%, 4%, 8% Fiber-containing medium</td>
</tr>
<tr>
<td></td>
<td>② 0%, 4%, 8% Abrasive-containing medium</td>
</tr>
<tr>
<td>Interval of medium supply</td>
<td>Once per 500 cycles</td>
</tr>
<tr>
<td>Total cycles</td>
<td>12,000 cycles</td>
</tr>
<tr>
<td>Repetition number of wear test</td>
<td>3</td>
</tr>
</tbody>
</table>
test, the ceramic antagonist was made of aluminum nitride, the hardness of which was close to enamel. The antagonist was applied to the specimen surface, which was covered with an experimental medium, with a 40 N occlusal force. After the ceramic antagonist slid over the surface with a 1-mm reciprocating motion at a rate of 1 Hz, it was removed from the specimen surface. This process was repeated to simulate the mastication motion in the oral environment.

To evaluate the effects of the abrasive- or fiber-containing medium on simulated occlusal wear, 12,000 cycles of occlusal wear were performed for each concentration of the experimental media. The medium was applied once per 500 cycles during the simulated occlusal wear test. The surface of each specimen was cleaned by water spray before applying the medium.

Worn volume measurement
After the simulated occlusal wear test, the worn surfaces of the composite resins were scanned using a computer-controlled, three-dimensional measuring microscope (STM6DF, Olympus, Tokyo, Japan). Worn volume, which is the lost volume by wear, was calculated from the scanned data. The effects of abrasive particles and fibers in the two experimental media on worn volume were analyzed using two-way ANOVA and Tukey’s multiple comparison test for each composite resin.

SEM observation
The worn surfaces of composite resins after the occlusal wear test were observed by SEM (S-800, Hitachi, Tokyo, Japan) to compare the effects of the abrasive particles and fibers in the media on wear behavior.

RESULTS
Figure 3 shows the effects of calcium diphosphate powder in the experimental medium on the worn volume of composite resins. The worn volume of composite resins increased when the medium contained calcium diphosphate. ANOVA showed that the effects of composite resin and concentration of calcium diphosphate on worn volume were significant (p<0.01), as well as the interaction between both factors (p<0.01). The results indicated that the effect of abrasive particles on worn volume was different among the composite resins. Tukey’s multiple comparison test showed that worn volumes of APX, Z100, and SRE significantly increased when 4 and 8% calcium diphosphate were used in the occlusal wear test (p<0.05), but no significant differences were observed between 4 and 8% concentrations. In the case of SDX, worn volume was significantly different between 0 and 8% calcium diphosphate-containing media (p<0.05). No significant differences in worn volume were found between 0 and 4%, and 4 and 8% concentrations.

Figure 4 shows the effects of methyl cellulose in the medium on the worn volume of composite resins. With increasing concentration of methyl cellulose in the medium, there showed a tendency for the worn volume of composite resins to decrease. ANOVA showed that the effects of composite resin and concentration of methyl cellulose on worn volume were statistically significant (p<0.01), and so was the interaction between both factors. The results indicated that the effect of fiber on worn volume was different among the composite resins. Tukey’s multiple comparison test showed that the worn volumes of APX and SRE were significantly decreased when 4% methyl cellulose-containing medium was used in the occlusal wear test (p<0.05). However, no significant difference was observed.
between 4 and 8% concentrations (p>0.05). In the case of Z100 and SDX, no significant differences in worn volume were seen among the different concentrations of methyl cellulose (p>0.05).

Figure 5 shows the SEM images of the worn surfaces of composite resins. The worn surfaces of 0% abrasive- and fiber-containing media showed a rough surface for APX, a flattened but cracked surface for Z100, SRE, and SDX. After the occlusal wear test using 8% calcium diphosphate-containing medium, the worn surface of APX showed a striped pattern — a result of being scraped by an abrasive material. A smooth surface was observed for Z100 when the calcium diphosphate-containing medium was used, and that both SRE and SDX showed scratched but smooth surfaces. With 8% methyl cellulose-containing medium, all composite resins exhibited worn surfaces that were flattened.

**DISCUSSION**

**Abrasive and fiber components in experimental media**

Our daily food comprises a diverse range of substances with different textures. These food substances with varied textures may act as an abrasive or a lubricant to the restorative materials during mastication. In this study, calcium diphosphate was used as a reference abrasive component whereas methyl cellulose as a reference fiber component in the medium.

Figure 6A shows a SEM image of calcium diphosphate particles which are smaller than 10 um. Calcium diphosphate is a fine powder, which can be included as a food ingredient. Apart from this use, calcium diphosphate is indicated as a reference abrasive toothpaste slurry according to ISO 11609:1995 standard. In the context of this study, the worn volumes of all composite resins were significantly increased when calcium diphosphate was included in the medium. Taken together, it was plain that calcium diphosphate powder in the
medium acted as an abrasive effectively.

Figure 6B shows the SEM image of a methyl cellulose fiber, which was bigger than the calcium diphosphate particles. Methyl cellulose is known as a water-soluble fiber, and the texture of the methyl cellulose-containing medium was glue-like. It was thus expected that the fiber-containing medium could reduce the friction between the antagonist and the specimen surface, thereby resulting in decreased surface abrasion for the composite resins. Based on the results of this study, the worn volumes of two composite resins were significantly decreased when methyl cellulose was included in the medium. However, the worn volumes of the other two composite resins showed no significant differences among 0, 4, and 8% concentrations. Therefore, it was suggested that the presence of fiber component in a medium reduced the wear of some composite resins.

With respect to the individual presence of abrasive or fiber component alone in a medium, this study has clarified their respective effects. However, the daily food consumed comprises an assortment of both abrasive and lubricant components. Therefore, to gain a practical perspective, it warrants further study to investigate the combined effect of both abrasive and fiber in a medium.

Effect of abrasive particles in medium on wear of composite resins

The effect of calcium diphosphate-containing medium on worn volume varied with different composite resins. The worn volume of APX was greatly affected by the calcium diphosphate-containing medium. Figure 5 shows a rough, stripe-patterned surface of APX after the occlusal wear test. It was clear that calcium diphosphate powder removed the filler particles of APX during the occlusal wear test. It should be noted that APX had a hybrid filler system comprising filler particles of varied sizes — including large filler particles — packed in the material. In the absence of an abrasive material, APX might not incur such a high volume loss by wear. However, with calcium diphosphate powder present as an abrasive material, both the resin matrix and filler particles of APX could be easily removed by the antagonist. In other words, this suggested that an ample amount of filler particles, including large particles, could be removed from the worn surface during mastication. Consequently, the removed filler particles could act as an effective abrasive material in the occlusal wear cycle, whereby both the abrasive particles and removed filler particles contributed to exacerbating the volume loss by wear for APX. In this study, distilled water was used to wash the wear specimen surfaces after every 500 cycles during the occlusal wear test. Nonetheless, this measure could not entirely cancel the abrasive effect of removed filler particles. In light of this result, it could be said that composite resins which have large filler particles may incur more wear in the presence of an abrasive material or removed filler particles — even if the composite resins have resistance to wear under no-abrasive condition.

Like APX, the worn volume of Z100 was affected by the calcium diphosphate-containing medium. Figure 5 shows a smooth worn surface of Z100, but the surface was vastly abraded. It was therefore clear that the Z100 surface was more easily abraded because it had small filler particles which were removed together with the resin matrix. As in the case of APX, the removed small filler particles then acted as an abrasive material.

The average worn volume of SRE was smaller than those of APX and Z100. According to manufacturer’s information, SRE had an organic composite filler comprising very fine filler particles. The SEM image showed that SRE consisted of large organic composite filler and small inorganic filler particles in the resin matrix. During the occlusal wear test, calcium diphosphate powder abraded both the organic composite filler and resin matrix, including the small inorganic filler particles. Consequently, some organic composite filler and small inorganic filler particles were removed from the surface. In the case of SRE, only the small inorganic filler particles acted effectively as an abrasive material because the organic composite filler particles were very fine and covered with polymerized resin.

The worn volume of SDX was the smallest among the composite resins used in this study. According to manufacturer’s information, SDX also had an organic composite filler like SRE. The SEM image of SDX surface shows only a smooth and scratched worn surface. Neither organic composite...
filler nor inorganic filler particles were observed in the resin matrix. This suggested that a smooth surface aided in reducing occlusal wear.

For composite resins with an organic composite filler, their occlusal wear will be less than typical hybrid composite resins when an abrasive material is included in the medium. Since composite resins with organic composite fillers are commonly used in dentistry, it warrants further study to clarify the effect of organic composite fillers on the occlusal wear of composite resins.

Effect of fiber in medium on wear of composite resins

The effect of methyl cellulose-containing medium on worn volume was different among the composite resins. With APX, the worn volume was tremendously decreased. The SEM image (Fig. 5) of the worn surface by the fiber-containing medium was remarkably different from that which contained neither abrasive nor fiber. As shown in Fig. 5, the filler particles of APX, which could be smoothened by an antagonist, became flat. Therefore, this SEM image suggested that filler particles could not be easily removed from the surface, and that the resin matrix hardly wore out during the occlusal wear test.

In the case of APX, the methyl cellulose-containing medium acted as an effective lubricant in dispersing the friction stress on the filler particles. In the case of Z100, no significant differences in worn volume were observed among the 0, 4, and 8% fiber-containing media. Nonetheless, the SEM image (Fig. 5) showed that the fiber-containing medium acted as a lubricant on Z100 as well as APX, whereby the fine filler particles of Z100 were also smoothened. However, the effects of reduced wear and dispersed friction stress by the lubricant became attenuated due to the fine filler particles.

In the case of SRE, the worn volume was significantly decreased when the fiber-containing medium was used. The filler system of SRE consisted of both large organic composite filler particles and small inorganic filler particles. Comparing the surface worn by the fiber-containing medium against those by the abrasive-containing medium and 0% containing medium, no scratches and cracks were found on the surface as shown in Fig. 5. Therefore, the methyl cellulose-containing medium acted as an effective lubricant for SRE as in the case of APX.

In the case of SDX, which showed the lowest worn volume, no significant differences in worn volume were observed when methyl cellulose was used in the medium. Under SEM observation, the worn surfaces by both the abrasive- and fiber-containing media were not different whereby smooth surfaces were observed after the occlusal wear test by both experimental media. SDX might have a low friction surface against the antagonist used in this study, even if no experimental medium were used. The lowest worn volume of SDX could be attributed to the low friction property of SDX, especially if the fiber-containing medium had the effect of reducing wear. According to manufacturer’s information, SDX comprised spherical filler particles. The low friction property of this composite might thus be related to the spherical filler particles as well as the organic composite filler particles.

When a fiber-containing medium was used for the occlusal wear test, the worn volumes of two composite resins were decreased, whereas the other two composite resins showed no significant differences. It was thus suggested that methyl cellulose in the medium tended to prevent and protect composite resins from wear. In a practical situation, it meant that the presence of fiber components in food or saliva would protect composite resins from wear during mastication. At this juncture, it suffices to propose that further study be carried out to clarify the effects of real foods on the wear behavior of composite resins.

CONCLUSIONS

The worn volumes of four composite resins, APX, Z100, SRE, and SDX, increased significantly when calcium diphosphate powder was included in the experimental medium. The abrasive material in the medium increased the wear of composite resins, but the effect thereof differed among the composite resins.

The worn volumes of two composite resins, APX and SRE, decreased significantly when methyl cellulose was included in the medium. However, no such significant decreases in worn volume were observed for the other two composite resins, Z100 and SDX. Nonetheless, presence of fiber in the medium generally tended to prevent the wear of composite resins.

In light of the results obtained with both calcium diphosphate powder and methyl cellulose, it was concluded that the wear behavior of composite resins is greatly affected by the components in a medium.

REFERENCES


