A New Method for the Evaluation of the Wear of Restorative Materials on Class V Cavity

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The wear level of restorative materials in class V cavities was evaluated by a new in vitro method using a tooth brushing apparatus. The result corresponded well with clinical findings. The conventional composite resin showed a higher abrasive resistance than the enamel surface, while the glass ionomer cement and light cure composite (BF) showed an abrasive resistance equal to the enamel surface. Though the wear resistance of 4-META/MMA (S) was low, the PMMA-acrylic resin containing dimethacrylate showed an improved wear resistance. The wear resistance of S and PA samples after 30 min brushing which equal to two years of intraoral tooth brushing showed comparable wear resistance to C, PC and I samples'. From the SEM photographs, all the composite resin surface showed obviously rough surfaces compared to unfilled resins after 30 min of brushing. Unfilled resin may be worth being reconsidered in class V restorations from an aesthetic point of view.

Key words: Abrasion, Restorative resin, Glass ionomer cement

INTRODUCTION

For esthetic reasons and the less requirement for resistance to the biting force during mastication and to the contact rubbing of the teeth, tooth-colored restorative materials such as restorative resins or glass ionomer cement are likely to be chosen in filling class V cavities. Low tooth brushing abrasion resistance of the restorative material, which results in a roughening of the surface of the material, will tend to encourage the adherence of dental plaque and other materials resulting in discoloration and staining. The loss of a smooth appearance is always accompanied by secondary caries. Therefore, the wear property is the most important factor in choosing a filling material for class V cavities.

Wear properties have been studied by either in vivo or in vitro methods. Leinfelder et al.1) and other researchers2-5) have evaluated the abrasion resistance of filling materials in vivo by replica methods in classes I, II and III by measuring the exposed cavity wall height. However, it is very difficult to quantify the wear because of complex individual differences and only a limited number of materials can be examined under the same conditions. Moreover, clinical evaluation is time consuming and always takes one or two years to obtain results. Several in vitro methods have been reported. For example, a two-body system has been used by Tillitson6) and other researchers7-16) and has been designed to let the abrasive particles attach to one of the sliding surfaces. A three-body system has been used by Peterson17), Phillips et al.18) and Aker19) and has been designed to let the abrasive particles attach to both the sample surface and brush. So far, these in vitro wear data have concen-
trated on the effects in the posterior teeth cavity and have not shown a good correlation with the clinical findings in anterior teeth.

The authors inspected fifty class V replica casts with composite resin (Clearfil F II) fillings which had been filled for more than two years. On the casts, none of the composite surface level was lower than the enamel surface level of the cavity rim (Fig. 1). On the contrary, most of the composite surface was seen to bulge and had a higher level than the enamel, although it had been polished even with the enamel surface after filling. Unfortunately, there seldom have been reports concerning the wear of class V cavity filling materials.

The purpose of this study was to simulate intra-oral abrasion conditions and to evaluate the wear level of restorative filling materials which were filled in class V cavities of human teeth.

MATERIALS AND METHODS

Freshly extracted human molar teeth were selected and were sectioned longitudinally on the occlusal surfaces into two parts (Fig. 2). Either the buccal or lingual part of the molar teeth were polished with silicon carbide paper first using #200 followed by #400, #600 and #800 grid to obtain a flat enamel surface area ranging from 6.5 mm² to 7.5 mm². Three random

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Fig. 1 Photograph of the replica cast of class V cavities with bulging of the Clearfil F II composite resin two years after filled.

Fig. 2 Diagrammatic representation of the resection of the tooth sample. L: lingual side, B: buccal side, M: mesial side, D: distal side.
tooth pieces were arranged in a line so that the flat enamel surfaces were exactly on the same surface, and were fixed with acrylic resin (Fig. 3). Each cavity sizes was 1.5, 2.0 and 2.5 mm in diameter and was prepared in the center of one flat enamel surface. Counterparts of the three tooth pieces were also prepared in the same way and were arranged in the same order on the other resin block and used as the control sample block. At least five sample blocks were prepared for each test material. The materials investigated are listed in Table 1. Light cure composites (PC and BF), 4-META/MMA (S), PMMA-MMA (PA), Glass ionomer (I) served as the test materials, while the composite (C) served as the control.

The materials were used in accordance with the manufacturer's instructions. The cavities were filled by means of a small spatula and were slightly overfilled. Soon after placement of the filling material, the surface of the material was pressed with a polyester matrix tape. A final polish of the material surface was done with #1000 silicon carbide paper to level the filling material surface even with the enamel surface. Twenty-four hours after filling, specimens were stored in distilled water at 37°C for a minimum period of 7 days before testing.

The block specimens including one control and one test sample were mounted as a pair on two reciprocal arms of a tooth brushing apparatus* (Fig. 4, 5). The sliding surface was set horizontally on the tip of the brush line under a load of 130 g. The water level of the slurry bath was high enough to ensure that the sliding surface was under the dissolved dentifrice**

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* Ishiyama Co., Tokyo
** White Lion, Lion Co., Tokyo
which was added on the tooth brush every 30 min. The two specimens on the two reciprocal arms were exchanged every 30 min. The mechanical arms operated at 50 strokes (double slides) per min. The arms moved 15 cm for each slide in a direction parallel to the flat enamel surface or perpendicular to the axis of the tooth. The specimens were brushed for 30 min, 2 h and 6 h. The 6 h specimens were cross sectioned at the middle of the filled cavity by a diamond cutter. The wear level values of the test material relative to the enamel surface were measured by a profile projector. The surface roughness of the 30 min and 2 h specimens was observed by a scanning electron microscope. Three pairs of block specimens including 18 enamel surfaces without any cavity formation were brushed for 6 h. The abrasive loss of the height of the enamel surface before and after the 6 h abrasion were measured by a micrometer.

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# Büchner, U. S. A.
# Nikon, Model 6CT3, Tokyo
# Comtec, CSM-501, Tokyo
RESULTS

The relative wear level values of the 6 h abrasion group are shown in Table 2 and Figs. 6, 7 and 8 and the profiles of the 6 h specimens are shown in Fig. 9. C and PC exhibited the highest resistance to brushing. In a 2.5 mm cavity, the average surface levels of C and PC were 20 μm. In 2.0 mm and 1.5 mm cavities, C also showed a higher wear resistance than enamel. BF and I had almost the same wear resistance as the enamel in a 1.5 mm cavity and had a slightly higher resistance than enamel in 2.0 mm and 2.5 mm cavities. For the unfilled resin S, the average wear loss was 187 μm below the enamel surface in 2.5 mm cavity. Even in a 1.5 mm cavity, S was worn 113 μm below the enamel surface. PA showed less surface

<table>
<thead>
<tr>
<th>Cavity size (mm)</th>
<th>Wear level (S. D.) (μm)</th>
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<tbody>
<tr>
<td></td>
<td>S</td>
</tr>
<tr>
<td>2.5</td>
<td>-187 (51)</td>
</tr>
<tr>
<td></td>
<td>+23 (10)*</td>
</tr>
<tr>
<td>2.0</td>
<td>-153 (45)</td>
</tr>
<tr>
<td></td>
<td>+21 (2)*</td>
</tr>
<tr>
<td>1.5</td>
<td>-113 (9)</td>
</tr>
<tr>
<td></td>
<td>+8 (5)*</td>
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</tbody>
</table>

* wear level of the control group
C the total average of control teeth with Clearfil filling
+ value: the wear level above the enamel surface
- value: the wear level below the enamel surface

Fig. 6  The wear level of the test materials in a 2.5 mm cavity groups.
→ : enamel surface before brushing.
► : enamel surface after 6 hr brushing.
■ : control Clearfil F II.
□ : test restorative materials.

Fig. 7  The wear level in a 2.0 mm cavity group.
See Fig. 6 for the caption.
WEAR OF CLASS V RESTORATIVE MATERIALS

Fig. 8  The wear level in a 1.5 mm cavity group. See Fig. 6 for the caption.

Fig. 9  Photographs of the profile of the filled cavities after 6 h brushing.
S: Super Bond, PA: PMMA+MMA (Unifast), I: Fuji ionomer type II, PC: Photo Clearfil A, BF: Bell-Feel LX, C: Clearfil F II.
wearing than S.

The average wear level for the enamel surface without a cavity formation was 23 μm with a SD value of 6 μm. Figure 10 shows SEM photos of the surface of the filling materials after being brushed for 30 min. The resin matrix of C was worn and large fillers were projected. Filler exfoliation was observed. The PC surface showed a filler smaller than the

Fig. 10  SEM micrographs of the surfaces of the materials after 30 min, of brushing. (×1000)
S: Super Bond, PA: PMMA + MMA (Unifast), I: Fuji ionomer type II, PC: Photo Clearfil A, BF: Bell-Feel LX, C: Clearfil F II.
WEAR OF CLASS V RESTORATIVE MATERIALS

Table 3  The results of the wear level of S, PA, and C at 20, 25, 30 min and 2 h brushing

<table>
<thead>
<tr>
<th>Abrasion time (min)</th>
<th>Wear level (S.D.) (μm)</th>
<th>S</th>
<th>PA</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>20</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
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<tr>
<td>25</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>30</td>
<td>0 (0)</td>
<td>-12 (4)</td>
<td>-15 (6)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>120</td>
<td>-28 (9)</td>
<td>-41 (12)</td>
<td>-60 (8)</td>
<td>-16 (7)</td>
</tr>
</tbody>
</table>

* cavity size, (mm)
+ value: the wear level above the enamel surface
- value: the wear level below the enamel surface

C filler, but the filler projection was also conspicuous. The filler of BF differed from those of C and PC. Round or triangular heterogeneous fillers were seen.

The relative wear level values of the 20 min, 25 min, 30 min and 2 h abrasion groups of S and PA are shown in Table 3 and their profiles are shown in Fig. 11. In all size cavities of unfilled resins S and PA, the wear level after 20 min and 25 min abrasion were the same as the wear level of the control group C. The surface scratch of the unfilled resins S and PA were not evident within 30 min's brushing.

The surface of the 2 h specimens was not significantly different from that of the 30 min specimens except the unfilled resins S and PA in which the wearing track of the 2 h specimens was much deeper than those after brushed for 30 min.

DISCUSSION

Many investigators have claimed that data from the in vitro three-body system often disagree with clinical studies, and recently tend to use two-body systems for evaluating wearing. In this study, however, we tried to use a three-body system because it is close to daily intraoral tooth brushing and a class V cavity does not have an occlusal force and impacted food like class I or II cavities. Our total result agrees with data reported by Swartz et al.20 who have described that the unfilled acrylic resin was more vulnerable to abrasion by tooth brusing and abrasion than any of the composite resins, either conventional or microfilled. Li et al.21 also have described that the conventional composite resin generally showed the most resistance and the unfilled resins were the least, with the microfilled in between.

In vitro studies, most of the wear values are based on measuring the weight loss of the test piece. Although it yields data on the pure wear of the material, the relationship between the tooth enamel surface and the filling has not been reported. In our study, conventional composite resin C showed a higher wear resistance than enamel in all sizes of cavities. This result corresponded well with our clinical findings in class V cavities that the composite material surface bulged and had a higher level than the enamel surface. This suggests that these higher surfaces are not always necessary in a class V cavity. Lutz et al.22 have reported the effects of the size of the cavity of class I and II and found that wear resistance
tended to increase as cavity size decreased. As shown in Table 2, the average wear values tended to decrease slightly from a 2.5 mm cavity to a 1.5 mm cavity for all materials. Class I and II cavities bear more stress than class V cavities which actually mainly bear the abrasion of the tooth brush only. However, our results were similar to those of Lutz.

The unfilled resins S and PA have the same base component, i.e. PMMA and MMA. The
difference is the addition of a functional monomer (5% 4-META in S and 5% ethylene dimethacrylate in PA) and initiator (TBB-O for S and BPO/amine for PA). PA showed a wear resistance one and a half times that of S. This suggests that for a cavity such as a class V which requires less wear resistance, the surface wear resistance can possibly be improved by functional additives instead of fillers.

In recent years, glass ionomer cement has been widely used in class V cavity restoration, because it easily adapts to the tooth surface and has less pulpal irritation. In our study, the wear level was comparable to enamel, i.e. 23 μm after 6 h of brushing. In SEM (Fig. 10), the polymer matrix of I including poly (acrylic acid) and other organic acids showed severe cracks. Though the crack was formed by the dehydration of the aqueous ingredient during preparation of the SEM specimen, this suggests the possibility of the degradation of glass ionomer cement in a class V cavity which will possibly be exposed to air.

Although S and PA showed quite a high abrasion loss after 6 h compared to composite resins and glass ionomer cement, the scratching of the material surface that was brushed less than 30 min was not grossly visible. With our brushing apparatus, one brushing stroke will lend one tooth cavity to pass 20 tooth brushes. If the teeth are brushed twice per day and each time brushed with 20 strokes at one position by one toothbrush, the 30 min brushing will result in 1500 strokes and, therefore, will be equivalent to 2 years of tooth brushing. This revealed that within a 2 year period, the unfilled resin was comparable to C. This result is in good agreement with the clinical data reported by Leinfelder et al. who have described that the rate of wear of unfilled acrylic resin did not differ appreciably from that of the composite resins during the first 2 years of service.

All the composite resin surfaces showed obviously rough surfaces compared to unfilled resins after 2 h of brushing. Although a microfiller has been introduced into the composite resin, the appearance of the rough surface of the composite resin seems inevitable after tooth brushing.

On the basis of wear resistance measurements and SEM observations, the application of unfilled resins in the restoration of class V cavities may have to be reconsidered from a clinical and esthetic point of view.

CONCLUSION

The wear level of restorative materials to enamel surfaces was evaluated by a new in vitro three-body method which closely simulated intraoral abrasion conditions. The results of the wear level measurement agreed with the clinical findings reported by other researchers. Considering the abrasion wear of enamel surfaces and the roughening effect of the composite filler, unfilled resin may be reconsidered as a restorative material for class V cavities from a clinical and esthetic point of view.

REFERENCES


ワックスバタンの熱応力と収縮に関する数値解析

IV. 熱応力を最小にするための冷却条件

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ワックスバタンを製作する過程において、バタンの外側性部分は、ワックスの冷却に伴って熱応力が発生する。この熱応力は、ワックスのもつ緩和特性に応じて、時間とともに減少してゆきが、その緩和速度は、冷却条件によって異なる。今回、バタンを歯型から取りはずす時点で、バタン内に残留する熱応力を最小にするための冷却条件を理論的に導き、その数値解を3種の市販インレーワックスについて求めた。

解析方法として、既に報告したワックスの単軸熱応力方程式（汎関数）を用いて、Euler-Lagrange の変分法を採用した。そして、その数値解法をFortran でプログラミングし、コンピュータ処理を行った。

ある境界条件、つまり、冷却開始温度、最終温度および冷却時間のある設定値の下で得られた冷却条件は、同じ境界条件の下で任意に定めたいくつかの冷却条件の中で、ほぼ最小の残留熱応力を与える条件であった。

五級窩洞に充填した材料の摩耗性的新しい評価法

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東京医科歯科大学医用機材研究所機能性高分子部門

歯プラン摩耗試験装置を用いた新しいin vitro の方法により五級窩洞に充填した材料の摩耗性的評価を行った。その結果は臨床所見と良く一致した。従来型のコンポジットレジンはエナメル質より耐摩耗性がよく、グラスアイオノマーセメントと光重合型コンポジットレジン（BF）はエナメル質と同じような耐摩耗性を示した。4-META/MMAレジン（S）の耐摩耗性は低かったが、ジメタクリレートの入ったアクリルレジンでは耐摩耗性が向上した。五級窩洞の充填にはフィラーの入っていないうレジン充填材が見直されてもよいと思われる。

口腔内での2年間の歯磨き釜に相当する30分の摩耗実験では、アクリルレジンの耐摩耗性はコンポジットレジン、グラスアイオノマーセメントとほぼ同程度であった。30分摩耗した試料のSEM像で、すべてのコンポジットレジンの表面にフィラーの突出が認められた。