Sliding Wear of Various Composite Resins and Bovine Enamel

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Received on April 16, 1986
Accepted on November 5, 1986

INTRODUCTION

Amalgam which has been used as posterior restorative material is less frequently used now due to such problems as environmental contamination and marginal fracture, and a substitute composite resin is widely employed. However, when conventional composite resin is applied in posterior restoration, the hard filler could damage the enamel of the opposing dentition and the wear of the composite resin itself could also be severe.

With the recent advances in high molecular chemistry, the mechanical properties of composite resin have been improved markedly1). As a resin for posterior restoration, a hybrid type resin, consisting of the organic matrix and the traditional macrofillers and microfillers to increase its filler contents and density, has been developed2). A submicron type resin, which contains submicronized spherical filler particles (0.2-0.3 µm) also has been developed3). On the other hand, microfilled resin when applied to posterior restoration shows adequate wear resistance and little effect on the enamel of the opposing dentition4,5); therefore application of microfilled resin to posterior restoration is expected.

In the present study, sliding wear tests have been performed on 8 different types of composite resins using bovine enamel as the counterface. The wear level of composites and the effect induced on bovine enamel by sliding these composites were examined. Filler content and mechanical properties of composite resins were also studied in relation to wear.

MATERIALS AND METHODS

Materials: Table 1 shows the eight different types of materials used. P30 is a light cured composite resin and the others are chemically cured ones.

Wear test: Chemically cured resins were mixed according to the manufactures' directions and then filled in tubes* (10 mm in diameter) to prepare hemispherical samples. On the
Table 1 Materials used

<table>
<thead>
<tr>
<th>Code</th>
<th>Materials</th>
<th>Filler type</th>
<th>Manufacturer</th>
<th>Batch No</th>
</tr>
</thead>
<tbody>
<tr>
<td>P10</td>
<td>P-10</td>
<td>Hybrid</td>
<td>3M</td>
<td>2885-2</td>
</tr>
<tr>
<td>CP</td>
<td>Clearfil Posterior</td>
<td>Hybrid</td>
<td>Kuraray</td>
<td>11113</td>
</tr>
<tr>
<td>CE</td>
<td>Clearfil F II</td>
<td>Regular</td>
<td>Kuraray</td>
<td>11132</td>
</tr>
<tr>
<td>PA</td>
<td>Palifique</td>
<td>Submicron</td>
<td>Tokuyama Soda</td>
<td>53018</td>
</tr>
<tr>
<td>MJ</td>
<td>Microjar</td>
<td>Microfilled</td>
<td>GC</td>
<td>190721</td>
</tr>
<tr>
<td>MA</td>
<td>Microrest AP</td>
<td>Microfilled</td>
<td>GC</td>
<td>031041</td>
</tr>
<tr>
<td>SI</td>
<td>Silar</td>
<td>Microfilled</td>
<td>3M</td>
<td>8601</td>
</tr>
<tr>
<td>P30</td>
<td>P-30</td>
<td>Hybrid</td>
<td>3M</td>
<td>9330S</td>
</tr>
</tbody>
</table>

Fig. 1  Schematic illustration of sliding wear machine.

Sliding wear machine contains the following parts, A: 500 g of load, B: hemi-spherical specimen of composite resin, C: specimen of bovine enamel, D: stage with sliding motion, E: distilled water.

other hand, light cured resin filled in the tube was exposed for two min with an exposer**, cured, and then employed as a sample. After placing each sample in 37°C water for 24 h, the sample was embedded in acrylic resin with the spherical surface being exposed. The bovine enamel sliding against these samples was embedded horizontally in the acrylic resin with the labial coronal side facing upward and after polishing up to #2000 emery paper, the enamel was exposed and a smooth surface was prepared.

Figure 1 shows a schematic diagram of the load adjustable continuous reciprocal horizontal motion type, sliding wear machine used. Bovine enamel was fixed to the middle of the movable tray. One hundred ml of water was poured into the tray. The specimen was fixed in the horizontal drive arm, which was reciprocated on the bovine enamel at a velocity of 60 strokes per min for 100,000 wear times. Each specimen was held stationary in an arm under a load of 500 g. Upon completion of the sliding wear test, a replica was obtained of the wear surface of each specimen. A ten-power photograph was taken with a stereoscope and the wear area was measured. Thereafter, the wear surface was coated with a layer of gold and observations were made with a scanning electron microscope \( \theta \), hereinafter referred to as SEM.

* Nunc tube, Nunc, Roskilde, Denmark
** Translux, Kulzer, Bad Homburg, West Germany
\( \theta \) Hitachi, S-430, Hitachi Co., Tokyo, Japan
After 100,000 wear tests of bovine enamel, with the use of a surface texture measuring instrument *, three random sites on the wear surface were selected and the deepest site of the wear depth prior to and after the tests was measured. The mean value of three sites was used as the wear depth of the enamel sample.

Filler content and the mechanical properties of Knoop hardness, elastic modulus and compressive strength were measured with methods previously reported6). In the preparation of light cured resin samples, the sample was exposed from the top and bottom for one minute each and from both sides adequately.

RESULTS AND DISCUSSION

Figure 2 shows the wear area of each composite resin and the wear depth of bovine enamel subjected to a 100,000 times wear test. There was no statistically significant difference among P30, P10, CP, CF and PA, but there was a significant difference between these and microfilled resins (p<0.01). In microfilled resins, a significant difference could be observed between MA or SI and MJ (p<0.01).

Resins listed in decreasing the wear depth of bovine enamel are CF and CP of about 24 \( \mu \)m, P10 and PA of about 14 \( \mu \)m, P30 of about 10 \( \mu \)m, SI of about 3 \( \mu \)m, and MJ and MA presenting hardly any enamel wear. Statistically, a significant difference was observed between CP and P30 and between SI and P10, CP or CF (p<0.01). The higher the resin wear level, the stronger was the tendency of bovine enamel wear with a correlation coefficient of 0.81 (p<0.05).

This study also supported the previously published reports that the microfilled resin does not damage enamel but that a large filler is prone to damage the enamel4,5). However, the reason why PA with a small filler particle wore the bovine enamel as much as P10 and P30, which contains traditional macrofillers and microfillers, is not clear the presence of another factor is speculated.

![Fig. 2](image)

Fig. 2 The wear level (mm²) of composite resin and the wear depth (\( \mu \)m) of bovine enamel subjected to 100,000 times wear test. Plain bars: composite resin, Spotted bars: bovine enamel, Vertical lines indicated range of six specimens.

* Surfcom 100A, Tokyo Seimitu Co., Tokyo, Japan
Fig. 3  Scanning electron microphotographs of surfaces of each composite resins after 100,000 times sliding wear against bovine enamel.
Figure 3 shows the SEM pictures of each resin after 100,000 times wear test. The sizes of the filler content of P10, P30 and CP were almost the same, but the filler margin of CP was sharp. The resin matrix around the filler of these resins was worn, and the fillers were found to be evidently projecting, but the fillers hardly fallen off. On the other hand, with the conventional type CF, large fillers evidently floating upward and fillers had partially fallen off. The fillers did not fall off in PA, a submicron type resin, but it was rougher than the microfilled resins. Microfilled resins showed a homogeneous picture throughout, but bubbles under the surface layer appeared predominantly due to wear. Microcracks could be observed in MA, which appeared to be running along the organic matrix.

Table 2 shows the measured values of filler content, Knoop hardness, compressive strength and elastic modulus. A tendency was observed for the Knoop hardness to be higher, the higher the filler content. The filler content and Knoop hardness correlated with resin wear level (both with a correlation coefficient of 0.86, $p<0.01$). Thus, the higher the filler content, and the higher the Knoop hardness, the greater was the resin wear level.

The wear of composite resins through the process of sliding can be considered to have been promoted by wear of the resins themselves with fallen filler particles and resin matrices serving as abrasive particles.

As the occlusal phenomenon in the oral cavity is brought about by the wear of the matrix deteriorated by saliva and others through the process of compression and irritation and by the repeated exposure and dropping off of the filler, the wear resistance was expected to be greater, the higher the compressive strength and the higher the elastic modulus. However, in this study, not compressive strength but elastic modulus correlated with resin wear level (0.84 of correlation coefficient, $p<0.01$). On the other hand, the correlation coefficient between the wear depth of bovine enamel and filler content of these resins was 0.73 ($p<0.05$), which was not great. Tanaka, et al. have demonstrated a rather high correlation between surface roughness of the composite resin and the wear depth of the enamel and have suggested that the wear of the counterfaced material depended on the surface roughness. CF, a conventional composite resin having the largest filler size and also a high surface roughness, brought about the greatest wear on the bovine enamel. On the contrary, MJ and MA having minute particles did not induce any wear. It is thus assumed that not filler content but the filler size is intimately associated with

<table>
<thead>
<tr>
<th>Code</th>
<th>Filler content (wt%)</th>
<th>Knoop hardness</th>
<th>Compressive strength (kg/cm²)</th>
<th>Elastic modulus (kgf/cm² × 10⁴)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P10</td>
<td>83.3±0.2</td>
<td>91.9±7.1</td>
<td>3187±102</td>
<td>14.3±0.1</td>
</tr>
<tr>
<td>CP</td>
<td>80.6±0.2</td>
<td>77.5±5.3</td>
<td>2958±41</td>
<td>12.6±0.6</td>
</tr>
<tr>
<td>CF</td>
<td>76.2±0.1</td>
<td>50.5±1.6</td>
<td>2176±54</td>
<td>11.7±0.5</td>
</tr>
<tr>
<td>PA</td>
<td>62.5±1.5</td>
<td>59.6±5.7</td>
<td>2265±167</td>
<td>8.4±0.6</td>
</tr>
<tr>
<td>MJ</td>
<td>56.5±1.7</td>
<td>40.9±3.1</td>
<td>2596±251</td>
<td>7.8±0.5</td>
</tr>
<tr>
<td>MA</td>
<td>43.9±2.8</td>
<td>29.2±3.2</td>
<td>2300±97</td>
<td>6.9±0.4</td>
</tr>
<tr>
<td>SI</td>
<td>51.4±0.1</td>
<td>34.6±0.9</td>
<td>2519±88</td>
<td>6.9±0.4</td>
</tr>
<tr>
<td>P30</td>
<td>84.4±0.2</td>
<td>80.8±2.3</td>
<td>2732±57</td>
<td>11.3±0.5</td>
</tr>
</tbody>
</table>

mean ± SD, n=6
tooth enamel wear. No correlation was found between the wear depth of bovine enamel and compressive strength or elastic modulus of the opposing resins.

In conducting wear tests with the polishing machine\textsuperscript{6}, we found that the higher the filler content, the greater was the wear level, and the wear level of microfilled resin was small\textsuperscript{6}. Jørgensen\textsuperscript{7} and Tani \textit{et al.}\textsuperscript{8} also reported that the wear level of microfilled resin is small. However, it has been confirmed in tooth brush wear tests with the use of tooth paste that the wear level of microfilled resin is considerably higher than that of conventional resins\textsuperscript{9,10}.

In \textit{in vitro} wear tests\textsuperscript{11-14}, contradictory results such as the foregoing can be obtained depending on the method employed. Basically, in the method employed in sliding resin against the opposing material, there is a difference whether a two body type or a three body type is employed. If an abrasive slurry is used, it is evident that the difference in the physical properties and particle size of the abrasive slurry will bring rise to differences in wear level. In the study of wear resistance of composite resins \textit{in vitro}, a conclusion can not be drawn just by testing a single method and therefore a multipronged approach should be employed.

Generally, in the study of wear resistance of composite resins the replica method is used \textit{in vivo}, but in view of the limitation in the number of materials that can be used in the oral cavity and the need for a long period of observation, studies have been primarily made \textit{in vitro}. However, it is difficult in \textit{in vitro} wear tests to reproduce the complicated mastication in the oral cavity and a well established methodology has yet to be established. Furthermore, there is a paucity of reports on studies made on the effects on the opposing dentition. Among the \textit{in vitro} wear tests, the wear test of the two body type is regarded to be the most closely simulated to the clinical situation and the method employed in the present wear test is considered to belong to this category.

\textbf{SUMMARY}

With the use of a continuous reciprocal horizontal motion type wear tester, sliding wear tests between various composite resins and bovine enamel were conducted and the physical properties of various resins were studied in relation to wear. The following conclusions were derived from these studies.

1. Among the resins subjected to a 100,000 times wear test, the wear of microfilled resin was minimal with a significant difference being demonstrated between microfilled resins and other resins (p<0.01). MA and SI showed hardly no wear.

2. The wear depth of bovine enamel was the greatest with CF, a conventional resin, followed in decreasing order by CP, P10, PA, P30, SI which showed minimal enamel wear, and MJ and MA both showing no wear at all.

3. A positive correlation was observed between the wear level of resin and the wear depth of the bovine enamel.

4. The larger the filler content, the greater the hardness and the higher the elastic modulus of the resin, the greater was the wear level.

\textsuperscript{6} Vibro-Polish, ML-201, Marutou KK, Tokyo, Japan
REFERENCES

熱衝撃試験による金属焼付陶材中の残留応力の評価
浅岡憲三、桑山則彦
徳島大学歯学部歯科理工学講座

金属焼付陶材の熱衝撃試験をコンピュータシミュレーションした。まず、最初に3次元熱伝導有限要素法を利用して陶材中の温度分布を求め、その結果をもとに解の理論から試験片内の応力分布を計算した。シミュレーションは陶材、陶材－オランゼ陶材、陶材－オランゼ陶材－合金の3種の試料について試みた。そして、板厚、熱膨張係数、焼き入れ温度とTransient stressとの関係について調べ、以下の結論を得た。

接着力レジンによるアマルガムの漏洩への結合に関する研究
バールガ・ユディト*、松村英雄**、増原英一**
*東京医科歯科大学歯学部第二歯科補綴学教室
**東京医科歯科大学医療器材研究所材料部門

アマルガム充填の際の辺縁封鎖性の向上や破折防止のための基礎的研究として、接着性レジンを窪面に塗布してから、アマルガムを充填する術式について検討した。接着材としては酸無水物系モノマー、4-METAを含むMMA-TBB系レジン、および、リン酸エステル系モノマーを含むバナジア EXを使用した。これらのレジンを窪面に塗布してからアマルガムを充填し、辺縁の漏洩防止効果と接着強さを測定した。その結果、接着性レジンを塗布してからアマルガムを充填すると辺縁封鎖に対し有効であることが明らかになった。また、エナメル質を酸処理した後、4-META-MMA-TBB系レジンを塗布し、アマルガムを充填した場合、水中浸漬1ヶ月後でも高い接着強さが得られた。

各種コンポジットレジンとエナメル質の擦り合わせ摩耗に関する研究
甲斐真貴子*、佐藤淳子*、佐藤尚毅*、新谷英章*、藤岡道治**
*広島大学歯学部歯科保存学第一講座
**広島大学歯学部歯科補綴学第一講座

各種コンポジットレジン（P-10, Clearfil Posterior, Clearfil F II, Palfigue, Microjat, Microrest AP, Silar, P-30）と牛齧エナメル質を連続往復水平運動型摩耗試験機を応用し、100,000回の擦り合わせ摩耗試験を行い、各種コンポジットレジンの諸性質（フィラー含有量、ヌーブ硬度、圧縮強度、弾性率）を調べ、擦り合
牛歯エナメル質のコンポジットレジンによる摩耗はClearfil F II によるものが最も強く、以下Clearfil Posterior, P-10, Palfique, P-30, Silar の順となった。

Microjar と Microrest AP による牛歯エナメル質の摩耗は認められなかった。

歯科用インプラントにおける成分元素の溶出について

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口腔内における歯科用インプラントの成分元素の挙動を考察する基礎的資料を蓄積するために、5 種類の市販インプラント：アパセラム、バイオセラム、フリーデザインプレードインプラント、形状記憶プレードインプラント、パイタルリムと松本歯科大学で作製したハイドロキシアパタイトコーティングプレードインプラントをリングル液、1.0%乳酸溶液、0.05%塩酸溶液の3 種類の溶液に7 日間全浸漬し、成分元素の溶出について検討した。溶出元素の定量は、誘導結合プラズマ発光分光分析装置で行った。その結果、バイオセラムを除く5 種類のインプラントに成分元素の溶出がみられ、アパセラム、ハイドロキシアパタイトコーティングプレードインプラントについては、きわめて強い脱灰現象がみられた。また、形状記憶プレードインプラントからは、微量であるが、Ni の溶出がみられた。

アマルガム粉末含有飼料を用いて飼育したラットの臓器内水銀量について

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アマルガム粉末を10 wt %、20 wt %の割り合いで混入した飼料、ならびに10 ppm、20 ppm 硝酸第一水銀水溶液をラットに4 週間投与し、各臓器（脳、肝臓、腎臓）の水銀量と病理学的観察の結果を先に報告した。本研究では、さらに長期間の観察を行なうために、8 週間投与し、ラットの発育ならびに各臓器への影響と各臓器の水銀量について検討した。さらに、人工胃液、人工腸液内での水銀の溶出についても検討を加えた。ラットの発育は、アマルガム粉末 20 wt %投与群においてその抑制が認められた。10 wt %、20 wt %アマルガム粉末投与群ならびに10 ppm、20 ppm 硝酸第一水銀投与群の各臓器とも腎臓の発育を抑制する傾向が認められた。ラット臓器内の水銀量は腎臓に最も多く認められ、次の順で肝臓、腎の順であった。人工胃液、人工腸液内での水銀の溶出は時間の経過とともに増加する傾向を示し、水銀量は人工胃液に多く認められた。

生体膜モデルとしてのりん脂質リポソームと光重合開始剤の相互作用に関する熱量的研究

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光重合開始剤（増感剤：ベンジル、カンファミノン、9-フルオレノ+還元剤：ジェミチアルミノエチルメタ）クリレート）は可視光線照射による高い溶血性を示した。このメカニズムを明らかにするため、生体膜モデルとし