In vivo Wear Pattern of Experimental Light-cured Hybrid Composite Resins

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This study evaluated the effect of various types of microfiller on the *in vivo* wear resistance of composite resins. Experimental light-cured composites with two different microfiller systems were prepared: (1) 56 wt % fine quartz filler, 21 wt% organic filler and 3 wt% colloidal silica filler (Hybrid type 1), and (2) 64 wt% fine quartz filler and 21 wt% colloidal silica filler (Hybrid type 2). The resin monomer consisted of 50 wt % Bis-GMA and 50 wt% TEGDMA. These materials were placed in 2 mm diameter cylindrical cavities located in the OCA (occlusal contact area) or the CFA (contact free area) in cast gold-silver-palladium alloy full coverage crowns, which were temporarily set in a volunteer patient's mouth. The crowns were removed at monthly intervals for SEM observation. Hybrid type 1, which contained organic fillers, showed bulk fractures in the OCA, by the second month of the experiment. However, reinforcement of the resin matrix by dispersion of microfiller provided Hybrid type 2 with superior wear resistance for up to two months.

Key words: Wear, Hybrid composite, SEM observation

INTRODUCTION

Amalgam has, until recently, been regarded as the standard material for use in direct fillings of posterior restorations. Now, however, with the ever greater demand for esthetic dentistry and, especially in Japan, the increasing awareness of the environmental damage caused by mercury, composite resins are being used on a much wider scale for Class I and Class II restorations. The most frequent clinical problem associated with the first generation of conventional composites was occlusal wear. Recent developments in filler and monomer systems of composite resins hold the promise of improving wear resistance. At this stage, however, little is known about the structural effects of composite resin on *in vivo* wear behavior. A prior comparative study¹⁾ described a method using temporary metal crowns, whereby *in vivo* wear patterns of conventional and MFR composites were examined by SEM (scanning electron microscope). In the present study, the occlusal wear pattern of experimental light-cured hybrid composites with two different microfiller systems were examined.

MATERIALS AND METHODS

Experimental light-cured composite resins* with two different microfiller systems, Hybrid types 1 and 2, were used in this study. Hybrid type 1 consisted of 56 wt% fine quartz filler,

* Experimental materials, Kuraray Co., Ltd., Osaka, Japan

21 wt% organic filler and 3 wt% colloidal silica filler. Hybrid type 2 was formulated from 64 wt% fine quartz filler and 21 wt% colloidal silica filler (Table 1). The principal composition of the resin monomer was 50 wt% Bis-GMA and 50 wt% TEGDMA (Table 2).

In vivo wear patterns of the composite resins detailed here are similar in all respects to those reported in a previous study¹⁾, in that, young adult volunteer-patients (24-26 years old) needing full-crown molar restorations were used for the study and the crowns came into direct contact with enamel antagonists. First, cast gold-silver-palladium alloy ** full coverage crowns were formed for these molars, and three or four small cylindrical cavities (2mm in diameter $\times$ 1mm in depth) limited to the occlusal contact area (OCA) or contact free area (CFA) were prepared, on each occlusal surface of the crowns (Fig. 1). The composite resins were then placed into the prepared cavities. After occlusal adjustments were made, to assure the proper fit, these resin fillings were polished using silicon polishing points[#] and 0.06 μ m alumina paste^{##}. Before placing in the mouth, the fillings were gold-ion coated[@], and observed at the baseline, by SEM^{@@}. These micrographs showing the centers of the fillings

Table 1 Formulas for two experimental composite resins (wt %)

	Hybrid type 1	Hybrid type 2
Filler ¹⁾	80	85
Fine quartz filler ²⁾	(56)	(64)
Organic filler ³⁾	(21)	(-)
Colloidal silica filler treated with silane ⁴⁾	(3)	(21)
Monomer	20	15

¹⁾ Coupling agent : γ -methacryloxypropyltrimethoxy silane

²⁾ The mean particle-size is 4 micrometers in diameter.

³⁾ Resin binder : Bis-GMA/TEGDMA (50wt%/50wt%) 40wt%
Colloidal silica filler 60wt%

⁴⁾ The mean particle-size is 0.04 micrometers in diameter.

Table 2 Monomer composition of experimental resins (wt %)

Bis-GMA	50
TEGDMA	50
Camphoroquinone	0.5
Dimethylaminoethylmethacrylate	2.0
Inhibitor	small amount
Pigments	small amount

** Pallatop 12, Sankin Industry Co. Ltd., Tokyo, Japan

Silicone point M-2 & M-3, Shofu Co. Ltd., Kyoto, Japan

Alumina polishing powder, Marumoto Industry Co. Ltd., Tokyo, Japan

@ Ion Coater IB 3, Eiko Engineering, Co. Ltd., Ibaragi, Japan

@@ S-430, Hitachi Co. Ltd., Tokyo, Japan

were taken at magnifications of $50\times$, $200\times$, $1000\times$ and $3000\times$. The crowns were successively removed, after one and two months, and microstructures of the worn surfaces of each material were longitudinally compared with baseline figures. Three fillings were observed in each group.

RESULTS

The wear processes in Hybrid type 1 and 2 composites are shown in Fig. 1-4 and Fig. 5-8, respectively.

Wear-damage was greater in the OCA than in the CFA for both types of hybrid composites.

Photographs of Hybrid type 1 composite in the CFA, taken over a period of two months,

Fig. 1 Serial SEM pictures of the wear process on Hybrid type 1 composite in CFA.

Original magnification $50\times$.

(a : base-line b : 1 month c : 2 months)

Fig. 2 Serial SEM pictures of the wear process on Hybrid type 1 composite in CFA.

Original magnification $1000\times$.

(a : base-line b : 1 month c : 2 months)

showed that surface roughness increased slightly, with filler-contours becoming distinct (Fig. 1). The higher magnification of the CFA (Fig. 2) showed the preferred abrasion of the matrix resin and dislocation of quartz filler particles, after two months. However, the organic fillers showed higher resistance to wear than the quartz fillers. In the OCA, the resin surface showed bulk fracture followed by loss of material (Fig. 3). At a higher magnification, microcracks, possibly attributable to fatigue, were observed along the interface between the organic fillers, which were subsequently lost, resulting in marked bulk fracturing (Fig. 4).

Sequential low-level magnifications of Hybrid type 2 in the CFA (Fig. 5) show that the surface texture underwent little change, at two months. Even under high magnification, there appeared to be little abrasion of resin matrix, so that, after two months, the fillers were

Fig. 3 Serial SEM pictures of the wear process on Hybrid type 1 composite in OCA.
Original magnification $50\times$.
(a : base-line b : 1 month c : 2 months)
White arrows indicate wear facets.

Fig. 4 Serial SEM pictures of the wear process on Hybrid type 1 composite in OCA.
Original magnification $1000\times$.
(a : base-line b : 1 month c : 2 months)

still tightly supported in the resin matrix (Fig. 6). However, a distinct wear facet was observed in the OCA (Fig. 7), the surface of which was relatively smooth. Under higher magnification, the surface of the OCA appeared ground away and some fillers were chipped, under the high occlusal stress (Fig. 8).

From the previous study¹⁾ and these observations in the OCA and the CFA, Hybrid type2 showed the greatest wear resistance by the second month. The dispersion of colloidal silica among larger filler particles was effective in enhancing the wear resistance of the resin matrix itself.

Fig. 5 Serial SEM pictures of the wear process on Hybrid type 2 composite in CFA. Original magnification 50 $\times$.
(a : base-line b : 1 month c : 2 months)

Fig. 6 Serial SEM pictures of the wear process on Hybrid type 2 composite in CFA. Original magnification 1000 $\times$.
(a : base-line b : 1 month c : 2 months)

DISCUSSION

A number of classification systems have been proposed for composite resins²⁻⁹. Recently developed "Hybrid composites" have become popular for use as stress bearing anterior or posterior composite restorative materials. The hybrid composite can be generally described as a composite that contains two different sizes of filler, ground fillers ($1-30\mu\text{m}$) and microfillers ($0.04\mu\text{m}$). The incorporation of submicron filler in composites can be traced to such conventional composites as Adaptic and Concise, where it was used to improve viscosity and / or handling characteristics². In the modern hybrid composites, these microfillers were used to augment various physical and mechanical properties¹⁰. The results of this study

Fig. 7 Serial SEM pictures of the wear process on Hybrid type 2 composite in OCA.

Original magnification $50\times$.

(a : base-line b : 1 month c : 2 months)

White arrows indicate the wear facets.

Fig. 8 Serial SEM pictures of the wear process on Hybrid type 2 composite in OCA.

Original magnification $1000\times$.

(a : base-line b : 1 month c : 2 months)

revealed that the wear pattern of composite resins was effectively changed by the use of additional microfillers.

Wear patterns in each of four experimental composite resins were distinct, as reported in a previous study¹¹ and confirmed in this study. The wear facet in the OCA was divided into two groups. MFR and Hybrid type 1 showed bulk fracturing followed by loss of material. The degree of catastrophic damage was more severe in the former, than in the latter. The localized wear in the central holding areas may be caused by the microcracking and debonding of the prepolymerized particles from the resin matrix^{4,12}. These types may be not suited to occlusal posterior restorations. In the CFA, the organic fillers showed higher resistance to abrasive wear from food bolus. MFR has become the resin of choice for esthetic restoration of anterior teeth, particularly in non-stress bearing situations⁹. The mechanical properties of hybrid type 1 were higher than those of MFR¹¹. In this study, hybrid type 1 contained the same type of macrofillers as used conventionally. When smaller and softer glass macrofillers are used in hybrid type 2 cases, the smooth surface necessary for esthetic restorations is obtainable, making this type useful for anterior restorations, including the stress-bearing Class IV and veneer restorations.

Hybrid type 2 showed a distinct wear facet in the OCA similar to that of conventional types. However, the surface roughness of the wear facet in hybrid type 2 was relatively smooth, when compared with that of the conventional variety. Furthermore, in the CFA, the resin matrix of hybrid type 2 showed a high degree of wear resistance. From these observations, it is apparent that the dispersion of colloidal silica among larger particles was effective in enhancing the wear resistance of the resin matrix itself. The submicronfiller also contributes significantly to compressive strength, elastic modulus and water absorption^{10,11}. Hybrid composite resins, such as type 2, may be desirable in stress-bearing posterior restorations. After two months, experimental composite resins showed characteristic wear patterns. There has been sufficient time to evaluate the final properties of composite materials after two months *in vivo* observation in this study.

CONCLUSION

- 1) Wear-damage was greater in the OCA than in the CFA in both types of hybrid composites.
- 2) Hybrid type 1, which contained organic fillers showed bulk fracturing in the OCA. By contrast, the facet surface of hybrid type 2, which contained colloidal silica, had a smooth appearance.
- 3) In the CFA, hybrid type 1 showed the preferred abrasion of the matrix resin and dislocation of quartz filler particles. Hybrid type 2 showed good wear resistance up to two months, due to reinforcement of the resin matrix by the dispersion of microfiller.
- 4) It was shown that the filler system contributed significantly to the wear resistance of composite resins.

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デンチンボンディング材と Phenyl-P を含有するセルフエッチング デンチンプライマーの併用効果について

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20% Phenyl-P を含む 35% HEMA 水溶液または、35% GM 水溶液からなるセルフエッチングデンチンプライマーを試作し、これらを 3 種類の市販ボンディング材または、1 種類の介在レジンと組み合わせた場合の接着性能を、ヒト抜去歯に形成された象牙質円柱窩洞内での市販可視光線重合型コンポジットレジンのコントラクションギャップの計測により評価した。その結果、今回用いた材料の組み合わせでは、試作プライマーで前処理した窩洞に MDP を含む市販 Dual cure 型ボンディング材を併用してコンポジットレジンを填塞した場合にのみ

完全な象牙質窩壁適合性が観察された。また、機能性モノマーを含まない介在レジンと併用した場合にも、Phenyl-P を含有するプライマーの前処理により、コントラクションギャップの幅は有意に減少した。すなわち、Phenyl-P を含有する HEMA または GM 水溶液をプライマーとして用いる場合には、それに続くデンチンボンディング材を選択する必要がある、さらにプライマー中に含まれる Phenyl-P は、単にスメア層処理のみならず、接着性の改善にも有効である可能性が示唆された。

試作光重合型ハイブリッドコンポジットレジンの口腔内磨耗像

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本研究の目的は、in vivo における試験により、ハイブリッド型コンポジットレジンの耐磨耗性に及ぼすマイクロフィラーの影響を評価することである。2 種類のフィラーシステムを用いた試作光重合型レジン、すなわち、有機複合フィラーを添加したハイブリッドタイプ1と、コロイダルシリカを添加したハイブリッドタイプ2、が試作された。なお、試作レジンには、Bis-GMA (50 wt%) と TEGDMA (50 wt%) からなるレジンモノマーが用いられた。Au-Pd 合金製クラウンの咬合接触部

(OCA) と非接触部 (CFA) に設けた直径 2 mm の円筒形窩洞に試作レジンを充填し、ボランティアの口腔内にクラウンを仮着した。クラウンは1月毎に撤去され、SEM による連続的観察が行われた。有機複合フィラーを添加したハイブリッドタイプ1はOCAにおいて破壊像を示した。一方、ハイブリッドタイプ2は、高い耐磨耗性を示し、これはマイクロフィラーによりレジンマトリックスが強化されたためと思われる。

電気抵抗測定による合金の相変態点決定上の測定電流の影響

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合金の相変態点 (T_c) を決定するための有効手段の1つである電気抵抗測定上における測定電流の影響を検討した。試料としては相変態に伴う電気抵抗変化の大きい

等原子比合金 CuAu を用いた。温度計測は熱電対を試料にスポット溶接した場合と、通常のように試料近傍で両者を接触させない場合の2方法で行なった。後者の場合、