In vitro Wear of Microfilled and Visible Light-cured Composites

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Wear of microfilled composites, a visible light-cured composite, and a conventional composite were characterized by two-body abrasion and single-pass sliding. There were differences in abrasion rates among the materials. Tangential forces, wear track widths, and surface failure modes were different among materials. Wear characteristics are combinations of these properties.

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Introduction.

In vitro wear of restorative materials can be characterized by abrasion testing and single-pass sliding. Two-body abrasion tests have shown different wear characteristics for unfilled resins, composites, and amalgam.[1-4] Different surface failure modes have been reported for various restorative materials and sealants.[3-5] Recently, microfilled composites with submicrometer filler particles and composite resins cured by visible light have been introduced. Preliminary clinical applications of these materials have been studied.[6,7] However, the *in vitro* wear characteristics of these materials have not been investigated.

The purpose of this study was to characterize the wear of microfilled and visible light-cured composites by two-body abrasion and single-pass sliding, and to compare the wear characteristics with those of a conventional composite.

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Materials and methods.

Four commercial microfilled composites (IC, IP,. MA, and SF), one visible light-cured composite (F) and one conventional, amine-cured composite (C) were studied for their wear characteristics. Product names, codes, batch numbers, and manufacturers are given in Table 1.

The materials, except F, were mixed according to manufacturers' instructions and packed into appropriate molds for curing. Six cylindrical samples (6 mm diameter, 12 mm length) of each material were formed in stainless steel molds. Samples for single-pass sliding were formed in troughs (5 mm x 15 mm, 2 mm deep) cut in acrylic discs (25 mm diameter, 15 mm high). All surfaces were cured against glass. Material F was cured using visible light from a tungsten bulb* after passing through a blue filter. The curing time was from two to 20 minutes depending on the size of the sample. All samples were stored in 37°C water for 24 hours before testing.

Two-body abrasion experiments were performed using a surface grinder as described by Tillitson, Craig, and Peyton.[8] Each specimen was abraded under a normal stress of 0.18 MN/m^2 against 600 grit SiC paper+ moving at 2.5 mm/sec. The total travel distance was 10 m on a fresh abrasive surface. Wear debris was removed by a constant jet of distilled water. The length of the specimen before and after abrasion was measured by means of a micrometer accurate to 0.001 mm.† The abrasion data are reported as volume of material lost per unit length of travel (mm^3/mm).

Single-pass sliding experiments were performed on an apparatus described in detail

*Riluma, PN 161, Switzerland

+Carborundum SiC C600 A965 F, Carborundum Company, Niagara Falls, NY 14032

†Laboratory Supplies Company, Inc., Hicksville, NY 11801

TABLE 1
CODE, PRODUCT NAME, BATCH NUMBERS AND MANUFACTURERS OF MATERIALS EVALUATED

Code	Product	Batch No.	Manufacturer
Conventional composite:			
C	Concise	Universal 8U6 Catalyst 8U6	3M Company St. Paul, MN 55101
Visible light-cured composite:			
F	Fotofil	F3762 ADM 44092/76	Imperial Chemical Industries, Ltd. Macclesfield, Cheshire England
Microfilled composites:			
IC	Isocap	11.79	Vivadent Schaan, Liechtenstein
IP	Isopast	Base 141 277 Catalyst 281 177	Vivadent
MA	Silar	Paste A MPP501-B7 Paste B MPP397-B7	3M Company
SF	Superfil	Universal 80338 Catalyst 80329	Harry J. Bosworth Company Skokie, IL 60076

by Powers and Craig.[9,10] Six samples of each material were used in this study. Surfaces of the restorative materials were subjected to the sliding of a diamond hemisphere (360 μm diameter) at a sliding speed of 0.25 mm/sec. The normal loads were from 1 to 10 N in increments of 1 N. Tangential force was recorded using a strain gauge transducer. The wear track widths were measured using a calibrated eyepiece in a metallurgical microscope. Surface failure modes were examined using optical microscopy and scanning electron microscopy. The failure modes were classified as: ductile, class 1; tensile cracking, class 3; and extensive chevron formation, class 5. Intermediate classifications, classes 2 and 4, represent a mixture of the above mentioned failure modes. These failure modes have been described by Powers and Craig.[11]

The percent by weight of inorganic filler content was measured gravimetrically.[‡] Five samples (3.7 mm in diameter and 7.7 mm long) of each composite were weighed before and after burnout at 500 C.

Results.

The two-body abrasion rates and the percent by weight of inorganic filler content of the restorative materials are shown in Table 2. A one-way analysis of variance[12] showed significant differences among means of abrasion rate. At the 95 percent level of confidence, the Scheffe interval[13] was 2.2×10^{-4} mm^3/mm. There were no significant differences among materials IP, IC, F, and MA. Materials C and SF were significantly different from the others and from each other. The inorganic filler content of each composite was significantly different from that of the others. At the 95 percent level of confidence, the Scheffe interval[13] was 0.7 percent.

Average values of tangential forces at various normal loads during single-pass sliding are shown in Fig. 1. The average wear track widths versus normal loads are shown in Fig. 2.

Scanning electron micrographs of wear tracks resulting from single-pass sliding at a normal load of 6 N are shown in Fig. 3. IC, IP, F, and C exhibited class 4 failure; SF, class 3; and MA, class 1. The transition points from one surface failure mode to another occurred at different normal loads for the materials. IC and IP had changes in the modes of surface failure from class 1 to class 4 at 3N; C from class 1 to class 4 at 4N; F from class 1 to class 4 at 6N; SF from class 1 to class 3 at 6N; and MA from class 1 to class 4 at 8N. Furthermore, the degree of mixing of failure modes in class 4 varied among materials.

‡Mettler balance H14, Mettler Instruments, Princeton, NJ

TABLE 2
ABRASION RATES AND INORGANIC FILLER CONTENT OF COMPOSITES

Material	Abrasion rate, 10^{-4} mm^3/mm of travel	Inorganic filler content, % by weight
SF	14.9 (0.9)*	35.1 (0.4)†
MA	12.4 (1.0)	49.7 (0.7)
F	12.2 (1.7)	77.7 (0.2)
IC	12.0 (1.2)	33.2 (0.1)
IP	12.0 (0.5)	37.3 (0.3)
C	6.3 (0.4)	76.7 (0.1)

*Mean of six replications with standard deviations in parentheses. The Scheffe interval was 2.2×10^{-4} mm^3/mm of travel.
†Mean of five replications with standard deviations in parentheses. The Scheffe interval was 0.7%.

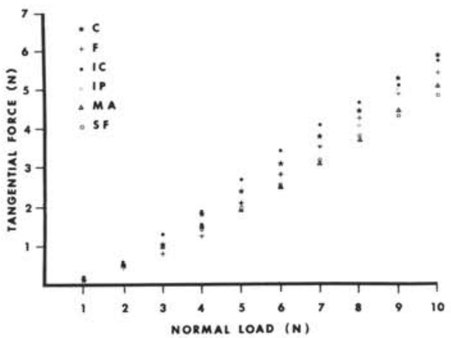

Fig. 1 – Tangential force versus normal load.

to class 4 to 8N. Furthermore, the degree of mixing of failure modes in class 4 varied among materials.

Discussion.

The four microfilled composites (IC, IP, MA, and SF) have higher volume loss per unit travel in two-body abrasion than the conventional composite (C). This may result from the smaller amount of inorganic filler incorporated into these materials. Previous studies by Powers, Roberts, and Craig[2-4] showed that unfilled resins and sealants have higher abrasion rates than filled resins. The microfilled composites have abrasion rates less than unfilled resins, but higher than conventional composites. However, the silica particles used in the microfilled composites have different sizes and size distributions than conventional composites. A strict comparison based on the amounts of fillers probably is not applicable. Material F also has a higher abrasion rate than C, even though the percentages of inorganic filler are similar. The differences in composition both in the resins and fillers could have considerable influence on the results of two-body abrasion experiments.

There was a similar sequence in wear track widths and abrasion rates. Material

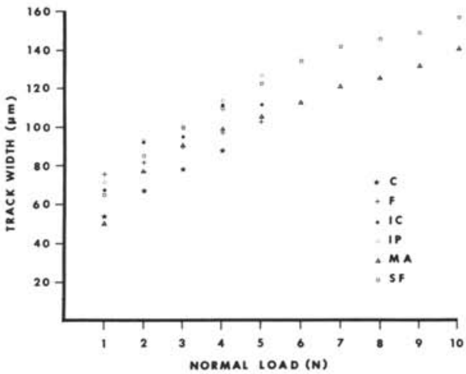

Fig. 2 – Wear track width versus normal load.

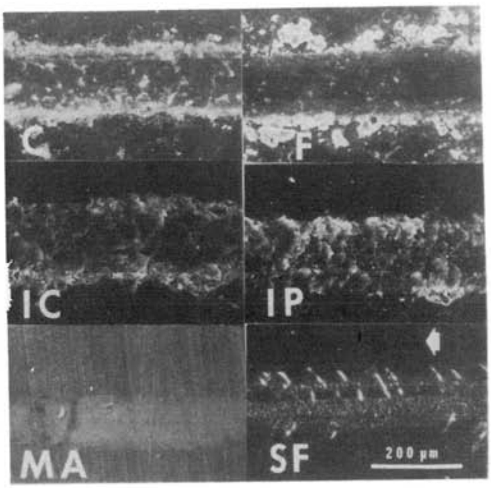

Fig. 3 – Scanning electron micrographs of wear tracks at a normal load of 6 N. Arrow indicates direction of sliding.

C has the lowest abrasion rate and the narrowest wear track width up to normal loads of 4 N. As the materials reached the class 4 surface failure mode, measurements of wear track width became increasingly difficult. Dislodging of materials by plowing of the diamond slider obscured the boundaries of the wear tracks. Also, the different extents of mixing of failure modes were conspicuous under microscopy. For better information on the wear characteristics of the materials, both the wear track widths and the surface failure morphology have to be taken into consideration.

Tangential forces on single-pass sliding did not have a simple correlation to wear track widths or to abrasion rates. However, at low normal loads (1–2 N) all materials have similar tangential loads and class 1 failure. At the onset of class 4 failure at higher normal loads, the tangential forces increased appreciably, while at similar normal loads, materials with class 1 or class 3 failure modes had lower tangential forces.

Modes of surface failure involving plowing out of materials (class 4) resulted in considerably higher resistance to sliding and, consequently, higher tangential forces. Materials SF and MA, therefore, had lower tangential forces at higher normal loads (7-10 N) than the other materials.

Wear of the composites used in this study can be characterized by the following properties: abrasion rate in two-body abrasion; and tangential force, wear track width and surface failure mode in single-pass sliding. All of these properties contribute to the wear characteristics of these materials. The results of this study showed that there are considerable differences in the *in vitro* wear characteristics of the composites. There are also differences among the microfilled composites.

Summary.

Two-body abrasion and single-pass sliding tests were used to characterize the wear of four microfilled composites, one visible light-cured composite, and one conventional composite. The abrasion rate of the conventional composite was the lowest. There were differences in abrasion rates, tangential forces, wear track widths, and surface failure modes among the microfilled composites. Lower tangential forces were associated with ductile failure modes. The visible light-cured composite had wear properties more similar to the microfilled composites than the conventional composite. The wear characteristics of restorative materials are a combination of abrasion and mode of deformation during sliding.

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