

WEAR OF FILLED AND UNFILLED DENTAL RESTORATIVE RESINS

J. M. POWERS, J. C. ROBERTS and R. G. CRAIG

The University of Michigan, School of Dentistry, Ann Arbor, Mich. 48109 (U.S.A.)

(Received December 24, 1975)

Summary

The influence of double-pass sliding on the surface failure of filled and unfilled dental restorative resins was evaluated. Damage was more severe for double-pass than for single-pass sliding. Wear of restorative resins and composites was influenced by the resistance to penetration and by the mode of deformation during sliding.

Introduction

One approach to the study of wear involves the characterization of surface failure under conditions of single-pass sliding. Such an approach has been used to show that the wear of commercial and experimental restorative resins and composites is determined by the resistance of the material to penetration and by the mode of deformation during sliding [1].

The purpose of this investigation was to characterize the surface failure of unfilled diacrylate and acrylic resins and to determine the influence of inorganic filler and a silane coupling agent on the mode of failure of the diacrylate resin under conditions of double-pass sliding. The results were compared with those of single-pass sliding.

Materials and methods

An experimental formulation of a diacrylate resin A without filler, an unfilled acrylic resin B, a commercial composite resin C and a diacrylate resin D with non-silanated filler were evaluated for mode of and extent of surface failure. Product names, batch numbers and manufacturers are listed in Table 1.

The resins were mixed according to manufacturers' instructions and were packed into a cylindrical hole (6.4 mm in diameter and 2.5 mm in depth) in a cylindrical sample mold (2.5 cm in diameter and 1 cm thick)

TABLE 1

Code, product names, batch numbers and manufacturers of materials evaluated

Code	Material tested	Manufacturer
Experimental formulation A	Smile, without filler, no. 38-251-3 (paste), no. 31170 (catalyst)	Kerr Sybron Corp. Romulus, Mich. 48174
Unfilled acrylic resin B	Sevriton, no. LAILD (powder), no. ML9MM (liquid)	Amalgamated Dental Trade Distributors Ltd., London
Composite restorative resin C	Smile, no. 0351-10.44 (paste) no. 41235 (catalyst)	Kerr Sybron Corp. Romulus, Mich. 48174
Experimental formulation D	Smile, with non-silanated filler, no. 38-251-3 (paste) no. 41004 (catalyst)	Kerr Sybron Corp. Romulus, Mich. 48174

made from acrylic rod. A glass slide was placed on the surface of the mold to provide a smooth surface on the resin sample. The samples were stored at 37 °C for 24 h before testing.

The apparatus used to scratch the surface of a specimen and measure the tangential force has been described in detail elsewhere [2, 3]. It consisted of a surface grinder, loading jig, diamond slider, friction transducer and sample holder. A diamond hemisphere (360 μm in diameter) was slid across the surface of the specimens. The sample holder was mounted on the table of a surface grinder moving at a speed of 0.025 cm s^{-1} .

The surface failure that resulted when two one-traversal scars were superimposed on one another in the same sliding direction with the same normal load was studied. The second scar was made only half of the length of the first in order to identify differences between the single- and double-pass regions. Fourteen parallel scratches that resulted from sliding a normal load of 50 - 700 g in increments of 50 g were made on each of the materials. All runs were made in water at room temperature.

Five specimens were tested for each material and each condition, and track width data were collected for each run. Track width was measured on a metallograph with the use of a calibrated eyepiece. A scanning electron microscope was used to study wear scars further.

Results

Average values of track width in the double-pass region *versus* normal load are plotted in Fig. 1 for each material (curves A - D, respectively). Curve E represents single-pass data for material C. For each material the values of track width for double passes were higher than for single passes.

Surface damage of material A, an unfilled diacrylate, was more severe in the double-pass region than in the single-pass region above a normal load

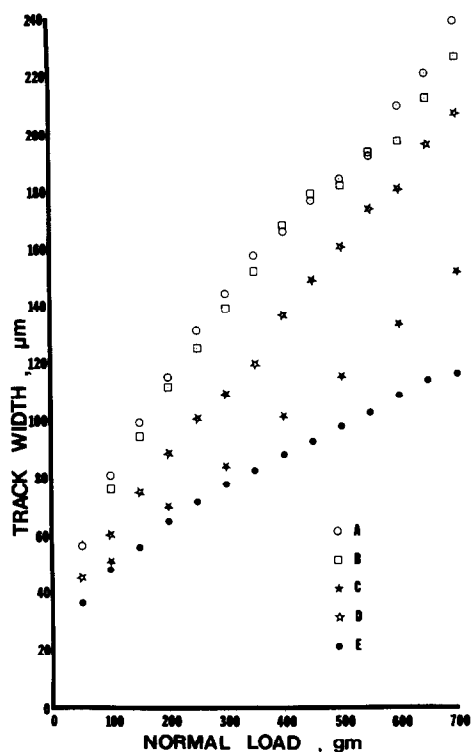


Fig. 1. Track width in double-pass region vs. normal load for materials A - D. Curve E represents single-pass data for material C.

of 450 g. A photomicrograph of the surface failure observed for material A at 500 g at the change from double- to single-pass sliding is shown in Fig. 2. Direction of sliding, normal load used and a magnification scale are indicated on the photomicrograph. Above 450 g for material A tensile cracking with some flaking occurred in the single-pass region, although extensive flaking occurred in the double-pass region. Above 450 g for material B, an unfilled acrylic, a ductile mode of surface failure occurred in the single-pass region, whereas minor flaking (compared with material A) occurred in the double-pass region. The mode of surface failure for material C, a commercial composite resin, was ductile above 500 g in the single-pass region but was brittle in the double-pass region. The mode of surface failure for material D, a diacrylate resin with non-silanated filler, was brittle in both single- and double-pass regions over the normal load range studied. Damage observed for material D was more extensive than that observed for material C at the same loads. The aforementioned modes of surface failure observed in double-pass regions are compared, under the same magnification, in Fig. 3 for materials A - D, respectively, at a normal load of 700 g.

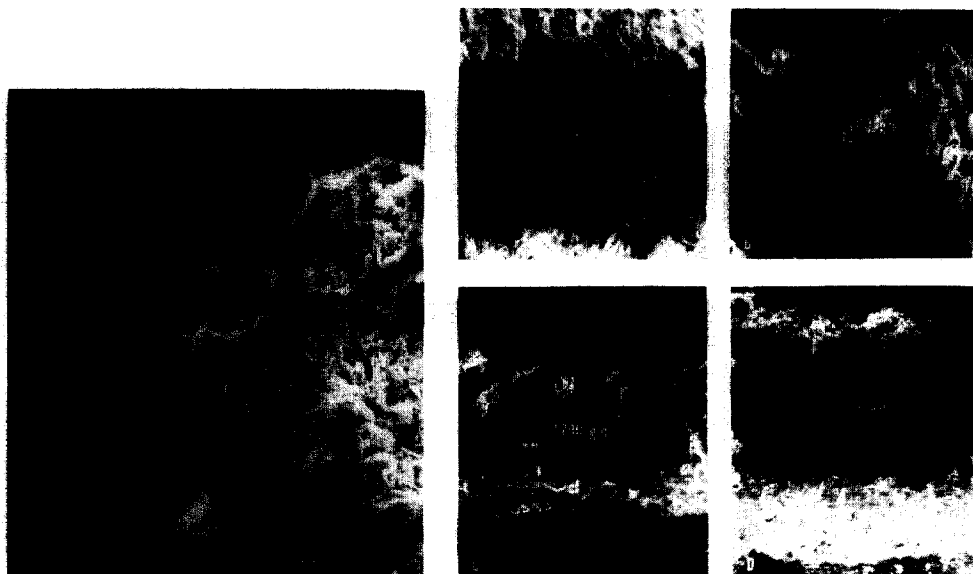


Fig. 2. Scanning electron photomicrograph of the change from double- to single-pass sliding for material A under a normal load of 500 g.

Fig. 3. Scanning electron photomicrographs of double-pass wear scars of materials A - D under a normal load of 700 g.

Discussion

In double-pass regions the diacrylate A and acrylic B resins had similar values of track width; they were higher than those of the diacrylate resin D with non-silanated filler. The composite resin C (with silanated filler) had the lowest values of track width. A similar ranking was observed in the single-pass region which is consistent with the relative hardness of the materials [1]. Track widths in the double-pass regions were higher than those in single-pass regions, especially at higher loads, because subsurface damage caused by the first traversal is propagated by the second traversal.

The surface damage observed for the acrylic resin, linear poly(methyl methacrylate), was less severe than that observed for the diacrylate resin (a highly crosslinked, bisphenol A-glycidyl methacrylate polymer) in double-pass regions at the same loads, although the penetration (or track width) was similar. Abrasion tests on silicon carbide paper have shown that the acrylic resin was more resistant to abrasion than the diacrylate resin (Table 2) [4]. The addition of non-silanated filler (a mixture of lithium aluminum silicate and barium aluminum silicate) to the diacrylate matrix resulted in reduced penetration in comparison with the unfilled resin but also in a more brittle mode of failure. Addition of filler treated with a silane bonding agent reduced the penetration further and caused the surface damage to be less extensive, although the mode of failure remained brittle at high loads. Abra-

TABLE 2

Comparison of abrasive wear of experimental and commercial restorative resins [4].

Materials	Wear rate (10^{-4} mm ³ mm ⁻¹ of travel)	
	Mean*	Standard deviation
Unfilled diacrylate resin A	17.0	1.1
Diacrylate resin D with non-silanated filler	13.8	1.5
Unfilled acrylic resin B	13.3	1.6
Diacrylate resin C with silanated filler	7.7	1.0

*Mean of six replications. Vertical rule indicates no significant difference at the 95% level.

sion tests have shown that the resin C with silanated filler was the most resistant to abrasion (Table 2) [4].

The wear of restorative resins and composites in double-pass sliding is determined by the resistance to penetration and by the mode of deformation during sliding. Wear resistance of composite resins may be improved by the use of hard fillers treated with improved silane bonding agents to increase resistance to penetration and by the use of a polymer matrix with less tendency to fail by a brittle mode during sliding.

Both single- and double-pass sliding tests provide data valuable in interpreting wear behavior, but double-pass sliding provides additional information about the nature of subsurface damage that may not be apparent from single-pass tests. Use of single- and double-pass sliding in conjunction with simplified abrasion testing is a powerful technique in the characterization of the wear behavior of dental restorative resins.

Conclusions

Double-pass sliding was used to study the surface failure of filled and unfilled restorative resins. Damage was more severe for double-pass than for single-pass sliding. A highly crosslinked diacrylate resin showed more severe surface failure than a linear acrylic resin. Addition of non-silanated filler to the diacrylate resin increased resistance to penetration but the mode of surface failure became more brittle. The use of silanated filler improved the wear resistance of the composite. The wear of restorative resins and composites in double-pass sliding is determined by the resistance to penetration and by the mode of deformation during sliding.

Acknowledgements

This investigation was supported by USPHS Research Grant DE-03416 from the National Institute of Dental Research, National Institutes of Health, Bethesda, Md. 20014, U.S.A.

References

- 1 J. M. Powers, J. C. Roberts and R. G. Craig, Surface failure of commercial and experimental restorative resins. *J. Dent. Res.*, 55 (1976) 432 - 436.
- 2 J. M. Powers and R. G. Craig, Wear of fluorapatite single crystals: I. A method for quantitative evaluation of wear, *J. Dent. Res.*, 51 (1972) 168 - 176.
- 3 J. M. Powers and R. G. Craig, Wear of fluorapatite single crystals: II. Frictional behavior, *J. Dent. Res.*, 51 (1972) 605 - 610.
- 4 J. M. Powers, L. J. Allen and R. G. Craig, Two-body abrasion of commercial and experimental restorative and coating resins and an amalgam, *J. Am. Dent. Assoc.*, 89 (1974) 1118 - 1122.