Comparison of *in vitro* and *in vivo* Wear of Composites

J.M. POWERS, M.D. RYAN, D.J. HOSKING, and A.J. GOLDBERG*

*School of Dentistry, The University of Michigan, Ann Arbor, Michigan 48109, and *School of Dental Medicine, The University of Connecticut, Farmington, Connecticut 06032*

In vitro *wear data were determined for nine experimental composites and compared with two-year clinical data. The* in vitro *tests included single-pass wear and two-body abrasion. The* in vivo *data were obtained between 1978 and 1980 for 54 class 2 posterior composite restorations in 25 patients. Correlations between the* in vitro *and* in vivo *data were found with values of* α *less than 0.08.*

J Dent Res 62(10):1089-1091, October 1983

Introduction.

The wear of composite restorative materials has been characterized *in vitro* using experimental procedures such as single-pass wear[1], two-body abrasion[2], and accelerated aging[3]. Kusy and Leinfelder[4] and O'Brien and Yee[5] studied wear patterns and surface structures of composites *in vivo;* however, there are few reports in which *in vitro* and *in vivo* wear data of a group of composites have been compared[6].

The purpose of this research was to compare the *in vitro* mechanical wear of nine experimental composites with two-year clinical wear data reported by Goldberg and associates[7].

Materials and methods.

Two visible light-cured (A and B) and seven chemically-cured (C to J) experimental composites* were evaluated. Codes, batch numbers, and composition of the experimental composites are listed in Table 1. The original ten experimental materials were tested clinically[7] between 1978 and 1980 and were refrigerated until the *in vitro* tests were started in May, 1982. Material I was excluded from the present study because there was insufficient material to prepare the samples for testing.

TABLE 1
CODES, BATCH NUMBERS, AND COMPOSITION OF EXPERIMENTAL COMPOSITES TESTED.

Code	Batch Number	Filler and Resin Composition*
A	5005-57-16	70% BG
B	5005-120-25	35% Q, 35% BG
C	5005-109-21	38% Q, 38% BG
D	4571-146-12	38% Q, 38% BG
E	5005-56-15	38% Q, 38% BG
F	5005-114-23	75% Q
G	5005-119-24	75% Q
H	4571-148-14	70% BG
J	5005-124-26	54% PG

*BG is barium glass, Q is quartz, and PG is porous glass. The resin composition of the materials was BISGMA/TEGDM, except G which was BISGMA/TEGDM/polymer. All composites except J contained a small amount of colloidal silica.

Received for publication February 8, 1983
Accepted for publication June 13, 1983
This investigation was supported in part by Training Grant DE-07101 from the National Institute of Dental Research, National Institutes of Health, Bethesda, MD 20205.
The cooperation of Johnson & Johnson Dental Products Co. for supplying the experimental composites used in this study is acknowledged.
Request reprints from Dr. Powers.
*Johnson & Johnson Dental Products Co., East Windsor, NJ 08520

The *in vitro* tests included 24-hour compressive strength, single-pass sliding, and two-body abrasion. Cylindrical specimens 6 mm in diameter and 12 mm in length were prepared for measurement of compressive strength and two-body abrasion. The two pastes of the chemically-cured formulations were mixed in equal amounts by weight, packed into split stainless steel dies, and allowed to cure for 30 min. Light-cured formulations were packed into borosilicate glass tubing and cured with five 60-second exposures from a curing light§. All samples were stored in distilled water at 37°C for 24 hr before testing.

For the single-pass sliding test, the chemically-cured composites were packed into a stainless steel mold 20 mm in diameter and 1 mm thick, whereas the light-cured samples were cured in a plastic mold 6 mm in diameter and 2 mm thick. The surfaces of the single-pass sliding samples were cured against an acetate sheet 0.25 mm thick. These samples were stored in distilled water at 37°C for three wk before testing.

Compressive strengths were determined on a testing machine+ at a cross-head speed of 0.5 mm/min. Five samples for each of the nine formulations were tested.

Two-body abrasion was determined on apparatus that

§Fotofil Light, Johnson & Johnson Dental Products Co., East Windsor, NJ 08520
+Model TT-BM, Instron Corporation, Canton, MA 02021

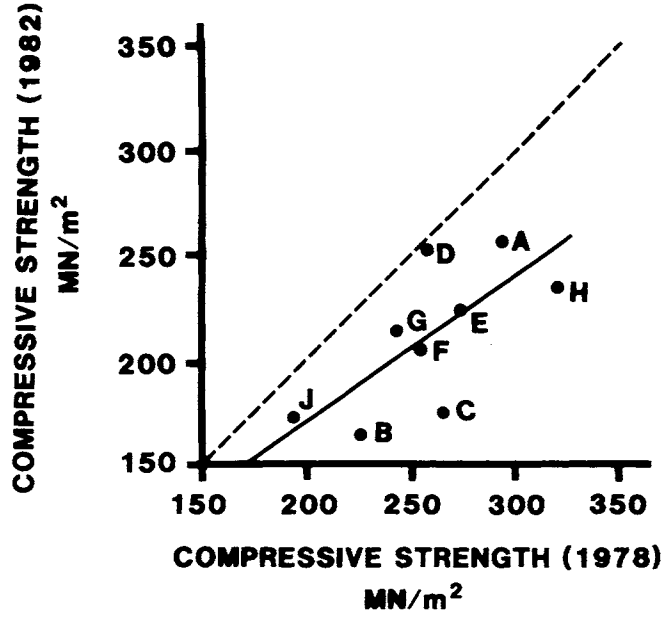

Fig. 1 – Values of 1982 compressive strength *vs.* 1978 compressive strength.[10] The dashed line represents a theoretical curve for which the strengths at both times are identical. The solid line represents a regression curve.

has been described in detail elsewhere.[2] Each specimen was held stationary in a jig under a normal load of 5.0 N and abraded for a distance of 7110 mm. Abrasion was caused by 600-grit silicon carbide paper attached to the table of the surface grinder# moving at a speed of 2.5 mm/sec. Each pass was made on a fresh abrasive surface that was continually flushed with distilled water to remove wear debris. Twelve replications were made for the chemically-cured formulations, and eight replications were made for the light-cured formulations. Wear was determined by measurement of the change in length of the sample with a micrometer accurate to 0.001 mm. Data were reported as volume loss per mm of travel.

The apparatus used to describe single-pass sliding characteristics has been described in detail elsewhere[1], but consisted of a diamond slider, a counterbalanced loading jig, a surface grinder, and a sample holder. A diamond hemisphere (360 μm in diameter) was slid across the surface of a sample mounted on the table of a surface grinder moving at a speed of 0.25 mm/sec. Fourteen single-pass scratches at loads ranging from 0.5 to 7.0 N were made on each specimen in an environment of distilled water. Ten replications were made at each load for each chemically-cured formulation, whereas five replications were made for each light-cured formulation.

Track widths were measured with a calibrated eyepiece on a metallurgical microscope. The wear scratches were further classified as to mode of failure by visual observation at 500 X magnification. Class A failure was characterized by ductile failure, whereas class B tracks showed evidence of chipping. The transition load was the lowest load at which class B failure was first observed. A scanning electron microscope was used to observe the wear scratches further.

Depths of ledges were determined from stone models of 54 class 2 posterior restorations 22 to 26 mo in age in 25 patients as described elsewhere.[7] Silicone rubber impressions of the restored bicuspids and molars were made and poured in dental stone. The dies were then analyzed with a categorical scoring procedure that measured the depth of the ledge from the cavosurface margin to the surface of the restoration at four locations on each stone die.

Means and standard deviations were computed. The data were analyzed statistically by analysis of variance[8], and means were compared by a Scheffe multiple comparison interval[9] calculated at the 95% level of confidence. Differences between two means that were larger than the Scheffe interval were statistically significant.

#Model 250, Gallmeyer and Livingston Co., Grand Rapids, MI 49502

Results.

Mean values of compressive strength obtained in 1982 are compared with values obtained by the manufacturer[10] in 1978 with a linear regression curve (Fig. 1). The correlation coefficient (r) was computed to be 0.71 and was statistically significant ($\alpha = 0.031$). The compressive strengths obtained in 1982 ranged from 2% to 33% less than those obtained in 1978.

Mean values and standard deviations of the *in vitro* and *in vivo* wear data are listed in Table 2. Two-body abrasion data ranged from 6.0 to 14.0 x 10^{-4} mm^3/mm of travel. Values of track width measured at a normal load of 6.0 N ranged from 126 to 189 μm. Values of transition load ranged from 2.5 to 3.8 N. Depths of ledges measured from the clinical study[7] ranged from 0.18 to 0.40 mm. Scheffe intervals are listed in Table 2.

The two-body abrasion data are plotted *vs.* the depths of ledges determined from the clinical dies in Fig. 2. A line determined from an analysis of regression is shown. The correlation coefficient (r) was computed to be 0.69 and was statistically significant ($\alpha = 0.039$). The correlation coefficient increased to 0.85 ($\alpha = 0.007$) if material B was excluded from the analysis.

The track width data determined from single-pass sliding at a normal load of 6.0 N are plotted *vs.* the depths of ledges determined from the clinical dies in Fig. 3. A line determined from an analysis of regression is shown. The correlation coefficient (r) was computed to be 0.85, excluding material J, and was statistically significant ($\alpha = 0.008$). If J was included, r was 0.62, and α was 0.078.

The transition load data determined from single-pass sliding are plotted *vs.* the depths of ledges determined from the clinical dies in Fig. 4. The correlation coefficient (r) was computed to be −0.82, excluding material J, and was statistically significant ($\alpha = 0.012$). If J was included, r was −0.63, and α was 0.068.

Discussion.

Correlations between the *in vitro* data (two-body abrasion, track width, and transition load) and the *in vivo*

TABLE 2
DATA FROM *IN VITRO* AND *IN VIVO* WEAR TESTS.

Code	Two-body Abrasion 10^{-4} mm^3/mm of Travel	Single-pass Track Width, μm	Single-pass Transition Load, N	Clinical Wear Ledge Depth,[7] mm
A	11.0 (1.9)*	168 (5)	3.5 (0)	0.29 (0.07)
B	8.6 (2.7)	189 (8)	2.5 (0.4)	0.40 (0.15)
C	6.6 (1.4)	164 (9)	3.3 (0.4)	0.25 (0.09)
D	6.0 (1.0)	138 (8)	3.8 (0.3)	0.18 (0.06)
E	7.5 (2.0)	137 (8)	3.8 (0.3)	0.23 (0.14)
F	6.3 (1.3)	138 (6)	3.3 (0.2)	0.24 (0.10)
G	6.3 (1.0)	140 (5)	2.6 (0.2)	0.28 (0.07)
H	8.3 (1.5)	126 (6)	3.8 (0.3)	0.22 (0.10)
J	14.0 (2.2)	142 (7)	3.4 (0.5)	0.39 (0.09)
Scheffe Interval	3.4	13	0.6	0.11+

*Mean with standard deviation in parentheses.
+Average standard deviation computed from analysis of variance.

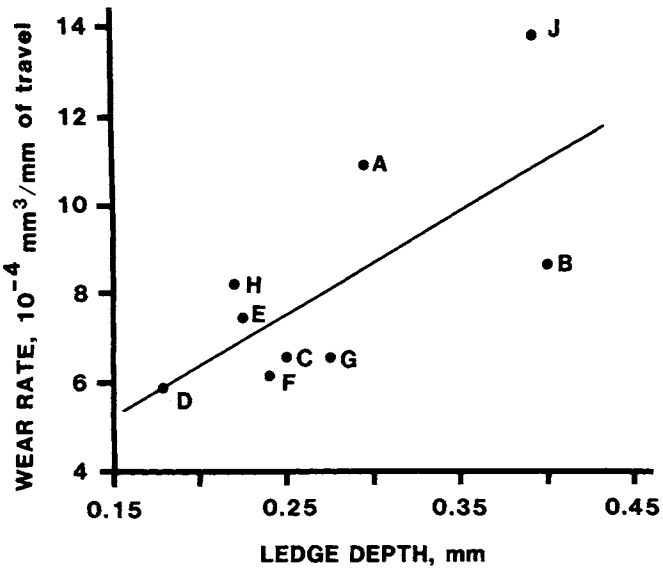

Fig. 2 – Two-body abrasion data *vs.* depths of ledges determined from an *in vivo* study.[7] The solid line represents a regression curve.

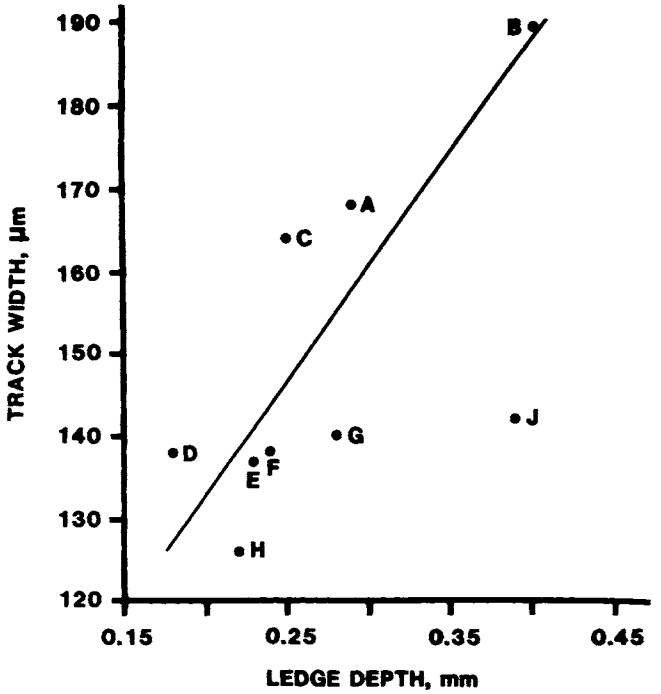

Fig. 3 – Values of track width at a normal load of 6.0 N *vs.* depths of ledges determined from an *in vivo* study.[7] The solid line represents a regression curve that excludes material J.

data all had values of α less than 0.08. The level of significance could be improved by excluding certain composites (such as B or J) from the statistical analysis, although there was no experimental reason for excluding these materials. The correlation coefficients are sufficiently high to suggest that the *in vitro* tests reported here can be used as screening tests for new composite materials. These correlations do not mean, however, that the wear mechanisms associated with the *in vitro* tests are the same mechanisms that caused wear in the clinical study. The *in vitro* tests do appear to rank a set of chemically similar composites. The study was not designed to evaluate the effects of resin and filler

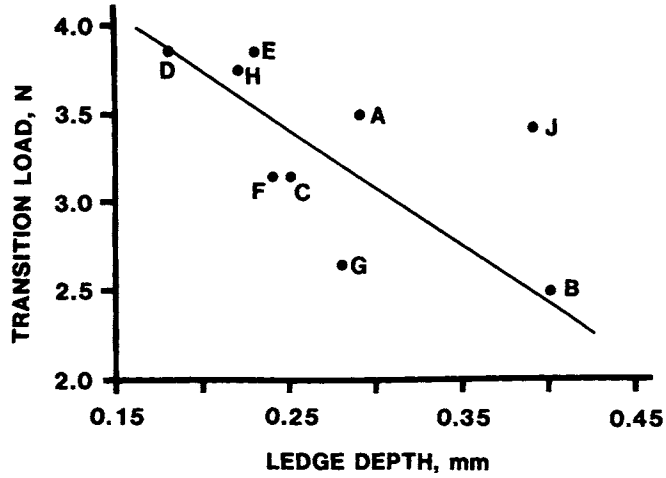

Fig. 4 – Values of transition loads *vs.* depths of ledges determined from *in vivo* study.[7] The solid line represents a regression curve that excludes material J.

composition on the properties of these experimental composites.

Conclusions.

In vitro mechanical wear data were determined for nine experimental composites and compared with two-year clinical data. The *in vitro* tests included single-pass wear and two-body abrasion. The *in vivo* data were obtained between 1978 and 1980 for 54 class 2 posterior composite restorations in 25 patients. Correlations between the *in vitro* and *in vivo* data had values of α less than 0.08.

REFERENCES

1. POWERS, J.M.; ROBERTS, J.C.; and CRAIG, R.G.: Surface Failure of Commercial and Experimental Restorative Resins, *J Dent Res* 55:432-436, 1976.
2. POWERS, J.M.; ALLEN, L.J.; and CRAIG, R.G.: Two-body Abrasion of Commercial and Experimental Restorative and Coating Resins and an Amalgam, *JADA* 89:1118-1122, 1974.
3. POWERS, J.M.; FAN, P.L.; and MARCOTTE, M.: *In vitro* Accelerated Aging of Composites and a Sealant, *J Dent Res* 60:1672-1677, 1981.
4. KUSY, R.P. and LEINFELDER, K.F.: Pattern of Wear in Posterior Composite Restorations, *J Dent Res* 56:544, 1977.
5. O'BRIEN, W.J. and YEE, J., Jr.: Microstructure of Posterior Restoration of Composite Resin after Clinical Wear, *Oper Dent* 5:90-94, 1980.
6. DENNISON, J.B.; POWERS, J.M.; and CHARBENEAU, G.T.: Measurement of *in vivo* Wear on Posterior Composite Restorations, AADR *Progr & Abst* 59:No. 202, 1980.
7. GOLDBERG, A.J.; RYDINGE, E.; LAMBERT, K.; SANCHEZ, L.; and SANTUCCI, E.: Clinical Evaluation Methods for Posterior Composite Restorations, IADR *Progr & Abst* 60: No. 1089, 1981.
8. **A Manual of Elementary Statistics Using MIDAS**, Ann Arbor, MI: University of Michigan, Statistical Research Laboratory, 1975, 301 pp.
9. GUENTHER, W.C.: **Analysis of Variance**, Englewood Cliffs, NJ: Prentice-Hall, 1964, 199 pp.
10. SANTUCCI, E.A.: Personal communication, 1982.