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Comparison of In-Vitro Wear with Physical Properties of Composite Resins

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INTRODUCTION

Development of an in-vitro wear test method to simulate oral wear of restorative materials was previously described[1]. In this study, physical properties of earlier generations, as well as current generations of composite resins, were measured and compared to the wear data. The goal was to determine if these properties are predictive of the long-term wear properties of particulate reinforced composite resins. Such data have previously predicted the tribology of different materials for other applications[2].

In this study, compressive strength and hardness were correlated to soft, third-body wear. These properties are predictive of the events that occur during the wear process.

OBJECTIVE

This study compares in-vitro soft, third-body wear with physical properties of composite resins.

MATERIALS

Adaptic (Johnson & Johnson)	Lot 7G027	Concise (3 M)	Lot 8060T10
DRS (American Hospital Sup.)	Lot 80706	Prestige (Lee Pharmaceuticals)	Lot HPR 0113
Exact (S.S. White)	Lot 747804	Profile (S.S. White)	Lot 112079
Herculite XRV (Kerr Corp)	Lot 208548	Filtek Supreme (3M)	Lot 2AA
Premise (Kerr Corp)	Lot 403039	Belleglass NG (Kerr Corp)	Lot 445602

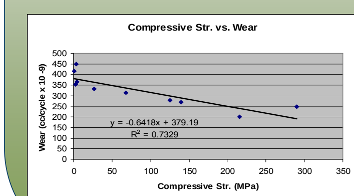
METHOD

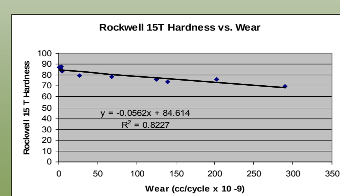
The development of a soft, three-body wear method was previously described[1]. In this study, physical properties of composite resins including compressive strength (CS), diametral tensile strength (DTS), flexural strength (FS) and hardness (H) were measured and compared to the wear data. Properties were measured according to ISO 4049 (FS), ADA Specification No. 1 (CS) No. 27 (DTS) and Rockwell 15T instructions. Five samples each were measured and the means and standard deviations (S.D.) calculated. All samples were cured according to manufacturer's instructions and stored in 37ºC water for one week before testing. Anova analysis ($p<0.05$) was conducted for each property to determine significant differences between the means. The physical property data were plotted against soft-third body wear and correlation coefficients were reported for positive correlations.

RESULTS

The individual data for the products are reported in the attached table. Superscript letters in each row indicate significant differences between the means. Positive correlations were found for plots of CS (0.73) and H (0.82) vs. wear; whereas, poor correlation was found for DTS and FS. Threshold limits for CS (379 MPa) and H (84) were found corresponding to the y-intercept of a linear trend line (fig. 1,2).

MATERIAL	ADAPTIC	CONCISE	HERCULITE	FILTEK-SUPREME	PREMISE	BELLEGLASS NG	DRS	PRESTIGE	EXACT	PROFILE
Wear Rate (S.D.), cc/cyc. x 10-9)	290 (50)^{a}	140 (40)^{c}	4.4 (0.8)^{g}	3.3 (1.5)^{g,h}	2.7 (0.5)^{h}	0.7 (0.2)^{i}	27 (6)^{f}	68 (17)^{e}	125 (31)^{c,d}	202 (30)^{b}
Compressive Str. (S.D.), MPa	248 (6.6)^{g,h,i}	268 (5.0)^{g,h}	376 (18)^{d}	479 (21)^{a}	451 (6)^{a,b}	417 (34)^{b,c}	332 (8.2)^{e}	314 (22.8) ^{e,f}	279 (11.6)^{f,g}	216 (6.6)^{i}
Rockwell 15T Hardness (S.D.)	69.3 (2.7)^{i}	73.4 (2.4)^{g,h,i}	83.0 (0.3)^{a,b,c}	86.3 (0.3)^{a,b}	80.8 (0.6)^{c,d}	87.0 (1.0)^{a}	79.6 (2.4)^{c,d,e,g}	78.6 (1.7)^{c,d,e,f,g}	76.1 (2.1)^{e,f,h}	76.2 (3.9)^{d,e,f,g}





DISCUSSION

The wear of particulate composite resins may be described by the physical properties of the material. In the case of two-body abrasive wear, Rabinowicz derived a quantitative expression to describe the wear in terms of material properties and the wear couple[2]. He used a simple model in which the asperities on the hard surface are conical in shape. Based on this model, the volume of softer material removed is proportional to the applied load, the distance traversed and inversely proportional to the hardness of the softer material (Eq.1).

$$1)\quad \frac{dV}{dL} = \frac{L \tan\theta}{\pi P}$$

Where: dV = incremental volume of softer material removed per incremental distance, dL, traversed; L = load and P = hardness of the softer surface.

Rabinowicz went on to compare two-body and three-body wear. He consolidated the constants of eq. 1 to a coefficient of wear (k_{abr}) and compiled it for a variety of materials. It was concluded that coefficients of wear in the two-body case range from 2.10^{-1} to 2.10^{-2}, whereas in the three-body case, they are about an order of magnitude smaller, namely 10^{-2} to 10^{-3}. The abrasive grains in the third-body case spend about 90% of the time rolling, thus producing no abrasive wear particles and only about 10% of the time sliding and abrading the surfaces. This explained the low coefficient of friction measured during third-body abrasion (0.25) versus two-body abrasion (0.60).

In this study, soft, third-body wear of particulate dental composite resins was compared to material properties. It was found that CS and H correlate to soft, third-body wear with correlation coefficients (0.73) and (0.82) respectively. It was also found that threshold limits exist, corresponding to the y-intercept of a linear regression plot. The threshold limits of 379 MPa in compressive strength and 84 in Rockwell H hardness, suggest that soft, third-body wear may approach zero at the limit. CS and H may represent parameters involved in the wear couple (H is the same as P in Eq. 1). This relationship will be explored next.

CONCLUSION

Positive correlations were found for CS and H vs. soft, three-body wear. The plots indicate that threshold limits may exist for strength and hardness where wear approaches zero (Research funded by Kerr Corp.).

REFERENCES

1. A. Kobashigawa et al; "Three-Body In-Vitro Wear Test Method". Abst. # 424, IADR New Orleans 2007.
2. E. Rabinowicz, Friction and Wear of Materials; J. Wiley and Sons, Inc., N.Y., 1965.