

Two-Body Wear Resistance of Some Indirect Composite Resins

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Abstract - The aim of this study was to evaluate two-body wear of five indirect composites and compare them with enamel. Signum, belleGlass HP, SR Adoro, Dialog, GC Gradia and enamel were formed into cylinders ($n=10$). Two-body abrasive wear rates were determined using a porcelain disk and a pin on disk apparatus. The height and weight loss of the specimens were measured by stereomicroscope and digital scale. The data were subjected to analysis of variance and Tukey HSD tests to determine significant differences ($\alpha=0.05$). GC Gradia showed significantly less wear resistance than the other materials. Enamel was more resistant than any of the tested composites. Within the limitations of this study it can be concluded that the type of resin, filler size and method of polymerization could have affect the two-body abrasion resistance of indirect composites.

KEY WORDS: Dental restoration wear, Composite resins, Dental materials, Dental restorations.

INTRODUCTION

The use of tooth-coloured restorative materials especially resin materials has become very popular because these materials offer excellent aesthetics, the ability to bond to tooth structure and low thermal conductivity¹. In spite of improvements in the physical properties caused by increased filler loading and decreased filler particle size, excessive polymerization shrinkage and incomplete cure still remain a problem²⁻⁴. To overcome these problems, laboratory processed composites were introduced⁵. Indirect composite restorations have improved wear resistance⁶⁻¹⁰, mechanical properties^{11,12} and colour stability.^{13,14}

Introduction of the poly-glass composites is the most recent development in this area. These materials are hybridization of composite and ceramics, although they are essentially still a composite resin matrix with varying filler components¹⁵.

The wear resistance of dental composites depends on filler particle size and the percentage of fillers¹⁵⁻²⁶. On the other hand some investigators found no direct correlation between filler content and wear resistance²⁷⁻²⁹. In addition, it has been shown that the degree of polymerization can affect the mechanical properties of composite resins³⁰⁻³³.

Wear resistance is essential because of the tremendous occlusal stresses that occur during normal mastication³⁴. Wear is a common phenomenon in dental composites due to abrasive, adhesive and fatigue processes. Abrasive wear occurs when surfaces pass each other and the harder material cuts the softer material¹⁵. Adhesive wear is the result of the friction generated by two moving surfaces causing local cold welding between particles on both surfaces which results in fracture of these small pieces¹⁵. Fatigue wear occurs as a result of propagation of microcracks through the material, leading to the separation of surface particles¹⁵.

Condon and Ferracane³⁵ described two mechanisms of abrasion and attrition for wear of composite resins. It is known that abrasive wear is the most common type of wear^{36,37}.

In oral cavity wear is a complicated phenomenon³⁸ and the wearing testing devices have been developed to simulate this phenomenon^{35, 39, 40}.

The aim of this study was to evaluate the wear rates of five indirect composite resins and compare them with human enamel. The null hypothesis was that there was no difference between wear resistance of these indirect composite resins and enamel.

MATERIALS AND METHODS

The materials evaluated in this study were: SR Adoro (Ivoclar Vivadent AG, Schaan, Liechtenstein), GC Gradia (GC America, Alsip, Ill), Signum (Heraeus Kulzer, Hanau, Germany), belleGlass HP (Kerr, Orange, Calif) and Dialog (Schutz, Rosbach, Germany). The type, main filler composition and polymerization method of the tested composite resin materials are presented in Table 1. Indirect composites were initially light cured for 60 seconds with light intensity of 800 mW/cm² (Blue phase c8, Ivoclar Vivadent). Final polymerization was according to the manufacturer instruction and special units.

Ten cylindrical shaped specimens of each test composite were prepared by inserting resin into Teflon washers (4 mm deep and 3.5 mm in diameter) and subsequently pressing the washers between two glass plates. This glass plate-washer assembly were then placed under a constant weight of 1.5 kg and polymerized with the respective proprietary curing units. Polymerizing the composite materials against a glass surface is a method commonly used to produce a standardized surface finish for testing²⁷. This technique excluded air from the composite surface and minimized oxygen absorption and oxygen-inhibition layer¹⁵.

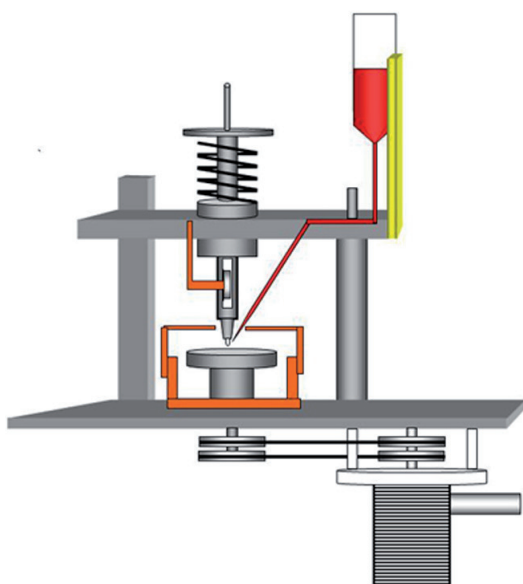
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Table 1. *Materials tested.*

Material	Type	Composition	Polymerization method	Lot No
belleGlass HP (Kerr, Orange, Calif)	Microfilled	Matrix: Bis-GMA, TEGDEMA Filler: Ba-silicate glass (78%)	Light, heat (140°C) and pressure (80 psi) in nitrogen atmosphere for 20 min (HP curing unit)	007825
Signum (Heraeus Kulzer, Hanau, Germany)	Microfilled	Matrix: UDMA, TEGDEMA Filler: SiO ₂ (73%)	Light for 3 min (HiLite power)	010040
SR Adoro (Ivoclar/Vivadent, Schaan, Liechtenstein)	Microfilled	Matrix: UDMA Filler: SiO ₂ (63%)	Light, heat (104°C) for 25 min (Luma-mat100)	K48058
GC Gradia (GC America, Alsip, Ill)	Microhybrid	Matrix: UDMA Filler: SiO ₂ (75%)	Light for 5 min (Gradia Lablit)	0707021
Dialog (Schultz, Rosbach, Germany)	Microhybrid	Matrix: Bis-GMA, UDMA, 1,4 Butandioldimethacrylate Filler: Glass, pyrogenic silica (72%)	Light for 9 min (Spectra 2000 Fast)	946000

**Figure 1.** *Schematic drawing of pin on disk apparatus*

Ten specimens of human enamel were prepared in cylinder shape from buccal surface of freshly extracted lower molars. The enamel specimens were placed in Teflon washers with autopolymerizing acrylic resin (Meliodent, Heraeus Kulzer, Hanau, Germany). The surface of enamel specimens was ground and polished using a high-speed handpiece and diamond burs with copious amounts of water. The final polish was achieved with 1000-grit silicon carbide sandpaper.

All specimens were stored in distilled water at 37°C for one week before wear testing. The storage period allowed water sorption and complete polymerization reaction for each specimen.

A two-body pin-on-disk type apparatus was used for determining the relative abrasive wear rates. Each cylindrical specimen was tightly fitted inside a plastic holder attached to upper component of the wear machine so that it could be worn by an opposing porcelain disk (20 mm in diameter and 2.75 mm in height). Specimens traced a circular movement at the constant rate of 130 cycles per minute

while they were held in contact with the abrasive surface using a continuous 15 N load (Fig 1). All experiments were conducted for a period of 8 hours for each specimen under running distilled water which served as a lubricant.

Weight of each specimen was recorded using a digital scale with 0.1 mg accuracy of the weight balance (Scaltec, Koln, Germany) before and after testing. Height of the specimens was measured (before and after testing) by a stereomicroscope (Motican 480, Moscow, Russia) equipped with digital micrometer (Carl Zeiss) calibrated to 0.001 mm, at $\times 10$ original magnifications. As the enamel specimens were embedded in acrylic resin and the dimensions were not measureable, it was not possible to calculate height loss. To compare the wear of the composites tested with that of the enamel specimens, a comparison was made for percentage of weight loss.

The data were statistically analyzed by ANOVA, and differences between the materials were analyzed by Tukey HSD ($\alpha = 0.05$).

RESULTS

The mean and standard deviation of height and weight loss of the tested groups are presented in Table 2. One way ANOVA indicated that there was significant difference in height and weight loss of tested groups (Tables 3 and 4). Tukey HSD multiple range test determined that GC Gradia had significantly more wear than the other tested groups ($p < 0.05$). There was no significant difference between the other composites. (Table 2)

The enamel specimens showed the least amount of wear but significant difference was not observed between Signum, belleGlass HP and SR Adoro and enamel specimens (Table 2).

DISCUSSION

Several factors can contribute to wear of posterior resin composites, for example material characteristics, preparation design, intraoral location, operator ability and patient characteristics such as diet, oral hygiene and fluoride history³⁸.

Although clinical wear is a complex process, the wear testing devices used to date have generally been successful in simulating certain aspects of oral wear^{35, 39, 40}. This study was conducted using a pin-on-disk type wear machine to simulate two-body abrasive wear.

It has been reported that the wear rate of composites relates to the type, amount, and size of filler and degree of bonding of the filler particles in the matrix²⁰⁻²³. In this study the type of filler, matrix and method of initiation of polymerization varied for each composite (Table 1). In addition, the materials tested were filled 63% to 78% by weight.

According to the results, GC Gradia exhibited the highest amount of wear among the tested materials ($p < 0.05$) and there was no significant difference between the other composites.

Resins with high volume fraction of inorganic filler exhibit improved mechanical properties^{21,22,24} like wear resistance¹⁵⁻¹⁸. In the current study GC Gradia with 75% of filler by weight, has significantly higher wear rate than the other materials tested with lower filler content. Frazier *et al*²⁷ and Tanoue *et al*²⁸ found no direct correlation between filler content and wear resistance.

The wear of indirect composites also might be affected by their respective microstructure such as molecular structure and composition of the resin matrix of the composite²⁸. The resin matrix of GC Gradia is UDMA, of which its structure is linear. Bis-GMA molecules contain aromatic groups, causing much larger barrier to rotation about the bonds. Thus, strength, hardness, and certain other mechanical properties are influenced by the nature of the monomeric subunits in the polymer⁴¹.

The UDMA molecule features higher flexibility with the ability for monomer chain rotation thereby producing a lower tendency to form stable hydrogen bonds than Bis-GMA which contains an isopropylidene-diphenoxy centre core which hampers mobility and increases stiffness – hence improved wear compared with UDMA.

Asmussen⁴² pointed out composites which utilized Bis-GMA/TEGDMA blend exhibited a higher degree of conversion when the quantity of TEGDMA was increased. This may explain the lower wear resistance of GC Gradia compare to the other composites in this study which contain Bis-GMA and/or TEGDMA.

Composite materials that are highly polymerized have been shown to exhibit improved mechanical properties including greater wear resistance, hardness, and flexural strength^{11,30-32}. In addition to mechanical properties, the degree of conversion may also influence clinical performance in areas such as resistance to fracture, wear, and degradation at the margin³². BelleGlass HP and SR Adoro had different method of polymerization. Heat curing in addition to visible light curing has been shown to substantially increase the degree of conversion and cross-link density which leads to lower wear rate^{32,33}. SR Adoro and belleGlass HP are polymerized at elevated temperature (104 and 140 °C). According to de Gee *et al*⁴³ heat treatment will accelerate the relaxation of the local stress conditions around the filler particles into a more homogenized distribution which will be maintained after cooling. This may improve adhesion between resin matrix and fillers and improve the mechanical properties of the composite such as wear resistance by stress transfer at the resin/filler interface. In addition, belleGlass HP is cured under pressure (80 psi) in a nitrogen atmosphere. Nitrogen pressure eliminates internal oxygen before the material begins to cure. Elimination of oxygen prevents inhibition of polymerization, voids and microscopic inclusions of air, and thus influences degree of conversion, aesthetics, wear and abrasion⁴⁴. The wear resistance of SR Adoro can also be related to the high proportion of inorganic fillers in the nanoscale range and the matrix that is based on a newly developed urethane dimethacrylate (UDMA).

Direct comparison of the results to other studies is difficult due to differences in materials, methodology and specimen configuration. Dickson⁴⁵ examined various abrasion tests and reported that many restorative materials were not ranked the same way in different tests. It should be

Table 2. Percentage of height and weight loss of the tested materials

Materials	Height loss % (SD)	Weight loss % (SD)
GC Gradia	18.6(5.0)	1.8(0.5)
Dialog	10.4(7.7)	1.0(0.7)
SR Adoro	9.6(8.4)	0.9(0.8)
belleGlass HP	8.0(5.3)	0.7(0.5)
Signum	7.7(3.8)	0.6(0.3)
Enamel		0.2(0.1)

Values connected by vertical lines are not significantly different ($p > 0.05$).

Table 3. Analysis of variance for percentage of height loss

Source	Sum of squares	df	Mean of square	F	p-value
Between group	802.233	4	200.558	5.066	0.002
Inside groups	1781.671	45	39.593		
Total	2583.905	49			

Table 4. Analysis of variance for percentage of weight loss

Source	Sum of squares	df	Mean of square	F	p-value
Between group	14.041	5	2.808	9.969	0.000
Inside groups	15.212	54	0.282		
Total	29.253	59			

noted that this study was an in vitro experiment, thus it is necessary to examine long-term clinical data to determine the wear resistance of these indirect composites.

CONCLUSION

Within the limitations of this study, it can be concluded that the type of resin and method of polymerization could have affect the two-body abrasion resistance of indirect composites. Some of indirect composites have comparable wear resistance to enamel.

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