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In Vitro Wear of New Indirect Resin Composites

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Clinical Relevance

The application of indirect resin composites for full-coverage restorative purposes still remains a concern due to wear. New indirect composites behave differently under different wear-testing conditions. Overall, Belleglass-NG showed the lowest wear when tested *in vitro* under different wear tests.

SUMMARY

This *in vitro* study evaluated the toothbrush abrasion wear, three-body Alabama wear and two-body pin-on-disc wear of four commercial indirect resin composites. Enamel shades of Radica (R), Sculpture Plus (S), Belleglass-NG (B) and Gradia Indirect (G) were used. For measuring wear due to toothbrush abrasion, six specimens of each group were fabricated, then brushed in a toothbrush abrasion machine for 20,000 cycles. Material loss was determined by weighing and conversion to volume loss. Three-body wear was measured on six samples for each group using an Alabama-type wear testing machine for 400,000 cycles. Wear depth was measured with a contact profilometer. For two-body wear, five disc specimens were prepared and tested in a two-body wear-testing machine against hydroxypatite sliders for 25,000 cycles.

Data were analyzed with one-way analysis of variance (ANOVA) and Tukey test (alpha=0.05). Wear was the highest in Sculpture Plus by all three methods tested and the lowest wear was observed in Belleglass-NG. No statistical difference in wear was noted from Radica.

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INTRODUCTION

New indirect composites are microhybrid resin composites with a high density of fillers that are dramatically different in form, size and composition compared to the earlier generation of indirect composites.[1] They are indicated in several clinical applications, such as inlays and onlays, laminated veneers and jacket crowns, implant-supported restorations and prostheses.[2-3] When compared to direct composite restorations, the indirect composite technique offers a better potential for generating appropriate anatomic form, as well as proximal contacts and contours, excellent occlusal morphology and good marginal accuracy.[2-4]

Wear is an important property and prerequisite for dental materials to establish durable esthetics and function of the restored teeth.[5] Wear remains a strong concern in resin composites, especially when used in stress-bearing areas, full-coverage crowns and veneers.[6-7] Efforts were made to improve the wear resistance of composite materials.[8-10] Current indirect composite systems have newer formulations of matrix resins and fillers and have different curing mechanisms. Curing with light and heat is conducted in a vacuum and nitrogen atmosphere to prevent oxygen incorporation into the composite.[11-12] Contradictory opinions exist about indirect composite restorations. Some authors have suggested that indirect composites offer no distinct advantages over direct composites.[13-14] Others have observed improved wear resistance in indirect composites.[15] Factors, such as the tooth restored, the size and complexity of the restoration and the presence and nature of the occlusal contacts, the materials used and the age of the restoration make the design of the clinical studies for wear rates complicated and thus *in vitro* studies have been developed to predict the materials' clinical performance.[7]

Wear may be defined as a progressive loss of substance from the surface of the body as a result of mechanical action.[16] Wear of resin composite materials has been evaluated in terms of two main clinical components: occlusal contact wear and contact-free wear. Occlusal contact wear is a localized process, while contact-free wear is more generalized.[17] Mechanical wear of composites occurs mainly by abrasive, adhesive and fatigue wear processes. Abrasive wear (2-body and 3-body) occurs when surfaces pass over one another and the harder material cuts the softer material, resulting in loss of structure. When the friction generated by two moving surfaces causes a local cold welding between the particles on the surfaces and the small pieces are fractured off, the process is termed adhesive wear. When flaws in the composite become microcracks that propagate through the material, leading to the separation of surface particles, the resulting wear is called fatigue wear.[18-19] Toothbrush and dentifrice abrasion can occur on any exposed tooth surface. However, it is most commonly observed on the labial surfaces of anterior teeth and the buccal surfaces of posterior teeth.[20]

Wear of new indirect resin composites has not been adequately studied. It is important to know how new indirect resin composites behave under different wear conditions.[21] The current study evaluated the toothbrush abrasion wear, three-body Alabama wear and two-body pin-on-disc wear of four commercial indirect resin composites. The null hypothesis of the current study was that, for each of the investigated wear testing methods, the four composite materials would not be significantly different from each other.

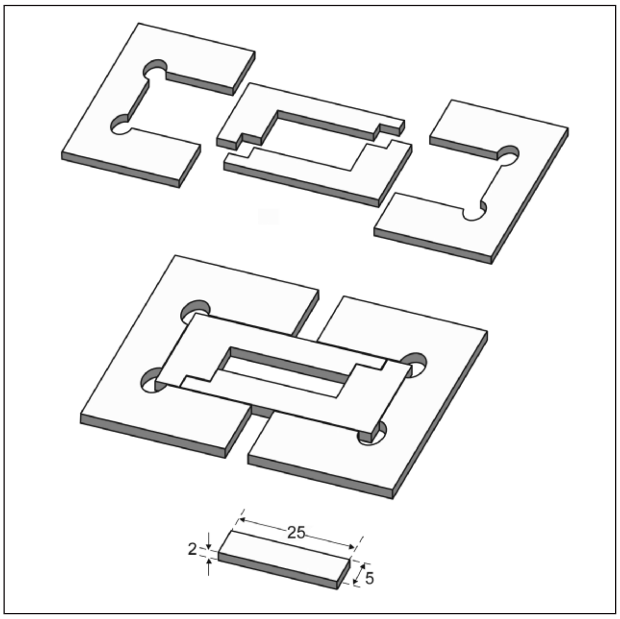

Figure 1. *Stainless steel mold.*

METHODS AND MATERIALS

The resin composites examined were obtained directly from the manufacturers. "Enamel" or "Incisal" shade composites were selected.

Toothbrush Abrasion Test: A custom-made, stainless steel mold (Figure 1) was used to fabricate six spec-

Table 1: *Polymerization Method of the Four Commercial Indirect Resin Composites*

Material (Shade: Enamel)	Curing Method
Radica (Dentsply International, York, PA, USA) Lot #061101	**Enterra Curing Light:** Heat (80°C approximately) and Halogen light. Two-step process: five minutes of initial cure cycle followed by two minutes of Pontic cure cycle.
Belleglass-NG (Kerr Corp, Orange, CA, USA) F-Lot #2714305	**Belleglass Curing Unit:** Heat (140°C approximately) and pressure. Two-step process: Initial light cure with LED visible light for 20 seconds followed by a 20-minute cycle under nitrogen pressure (60 psi) in a Belleglass Curing Unit.
*Gradia Indirect (GC, Tokyo, Japan) Lot #0612251	**Gradia Curing Unit and Step Curing Light:** (halogen light). 20 seconds of step curing followed by a five-minute cycle in a Gradia Curing Unit.
*Sculpture Plus (Pentron Lab, Wallingford, CT, USA) Lot #156905	**Sculpture Curing Unit:** (heat, pressure, light); Two-step process: Build-up cycle and final cycle of eight minutes each. (Each cycle consists of five minutes under Nitrogen Pressure [80 psi] and three minutes under a halogen light).

imens of each composite material. The dimensions of each specimen used in the current study were 2 mm thick, 5 mm wide and 25 mm in length. They were placed in the mold in 1 mm increments. Each specimen was then polymerized in its respective curing unit as described in Table 1. A Mylar strip was placed over the final increment and pressed with a cover slide to ensure that the material was flush with the surface of the mold. After polymerization, the specimens were carefully removed and stored in distilled water at 23°C for 24 hours. The Mylar covered surfaces were not touched and the side surfaces were finished up to 1200 grit with silicon carbide (SiC) discs. They were then kept in desiccators, maintained at (23 ± 1)°C and weighed to obtain a constant mass with resolution of ± 0.1 mg. Volume (V_1) was calculated and used to determine the density (ρ) of each specimen, which was expressed in units of mg/mm^3.

$$\rho = \frac{M_1}{V_1} \qquad (1)$$

The specimens were then brushed in a mechanical toothbrushing machine (Pepsodent Co, Chicago, IL, USA) for two hours (20,760 strokes) in a direction perpendicular to the length of the specimen using aqueous slurry with a proportion of 1:1 by weight of Colgate Total Tooth Paste and deionized water. After toothbrushing, the specimens were removed, cleaned with distilled water in an ultrasonic bath and dried with canned air and delicate task papers. The specimens were kept in a desiccator and weighed every 24 hours to obtain a constant weight M_2. The volume of the material lost to toothbrushing was calculated in units of mm^3.

$$V_2 = M_2 \times \rho \qquad (2)$$

$$\text{Volume loss } (\Delta V) = V_1 - V_2 \qquad (3)$$

Three-body Alabama Wear: Six specimens were prepared. After polymerizing the composite material, the specimens were stored in distilled water at 23°C for 24 hours. Poly-acetyl resin sliders were finished through 600 grit SiC. A digital micrometer (Nikon Digimicro ME05, New York, NY, USA) was used to measure the slider height. The testing media slurry was prepared by mixing 15.0 grams of orthodontic resin powder (Dentsply Caulk [Lot #070924]) with 9 ml of distilled water. The load on the piston was adjusted to about 75 Newtons of pressure and the speed was set to 75 revolutions per minute. The specimens were measured with a contact profilometer traced across the wear track and the volume loss was calculated using software (Surftronic 3+, Taylor Hobson Pneumo, Leicaster, England).

Two-body Pin-on-disc Wear: Five disc specimens (12 mm in diameter, 3 mm thick) of each group were fabricated and stored at 23°C in distilled water for 24 hours before testing. Sintered calcium hydroxypatite cylinders were mounted in small brass holders. They were machined to form cylindrical sliders 2 mm in diameter and 1.5 mm in height and finished through 600 grit SiC. The length of each slider was measured with a digital micrometer and recorded prior to each wear run.

A pin-on-disk wear-testing machine containing four wear stations was run for 25,000 cycles at 120 revolutions per minute. The wear field was washed continuously with distilled water. After the test was complete, the sliders were removed and measured under a digital micrometer. The specimens were removed and cleaned with distilled water in an ultrasonic bath. They were then scanned in the contact profilometer and area was recorded at six different positions of the wear tract using software as in three-body wear. Integration was applied to calculate the volume wear loss using the average radius and area from the software.[22]

Data collected for each test material were analyzed with one-way analysis of variance (ANOVA) and Tukey's multiple comparison procedure (SigmaStat, Version 3.5, Jandel Corporation, Germany). The level of statistical significance was α=0.05.

RESULTS

Volume Loss Due to Toothbrush Abrasion: Results from this test are summarized in Table 2 and Figure 2. Statistically lower volume loss was observed in Radica and Belleglass-NG, while Sculpture Plus showed the highest volume loss. No significant differences were found in the volume loss of Radica and Belleglass-NG (p=0.05).

Three-body Alabama Wear: Results from this test are summarized in Table 2 and Figure 3. The results are similar to the volume loss due to toothbrush abrasion. Radica and Belleglass-NG showed statistically

Table 2: *Volume Loss (mean [standard deviation]) Due to Wear for Each of the Wear Testing Methods*

Material (enamel shade)	Volume Loss (toothbrush abrasion wear) (units: mm^3)	Volume Loss (three-body Alabama wear) (units: mm^3)	Volume Loss (two-body Pin-on-disc wear) (units: mm^3)
Radica	1.75 (0.59)[a,b]	0.31 (0.13)	0.16 (0.08)[a]
Sculpture Plus	4.58 (1.18)	0.56 (0.11)[a]	0.72 (0.34)
Belleglass NG	1.18 (0.21)	0.12 (0.04)	0.12 (0.03)[a]
Gradia Indirect	2.42 (0.82)[b]	0.65 (0.23)[a]	0.19 (0.07)[a]

Mean values (std dev) in columns with the same letters are not statistically different $p \leq 0.05$.

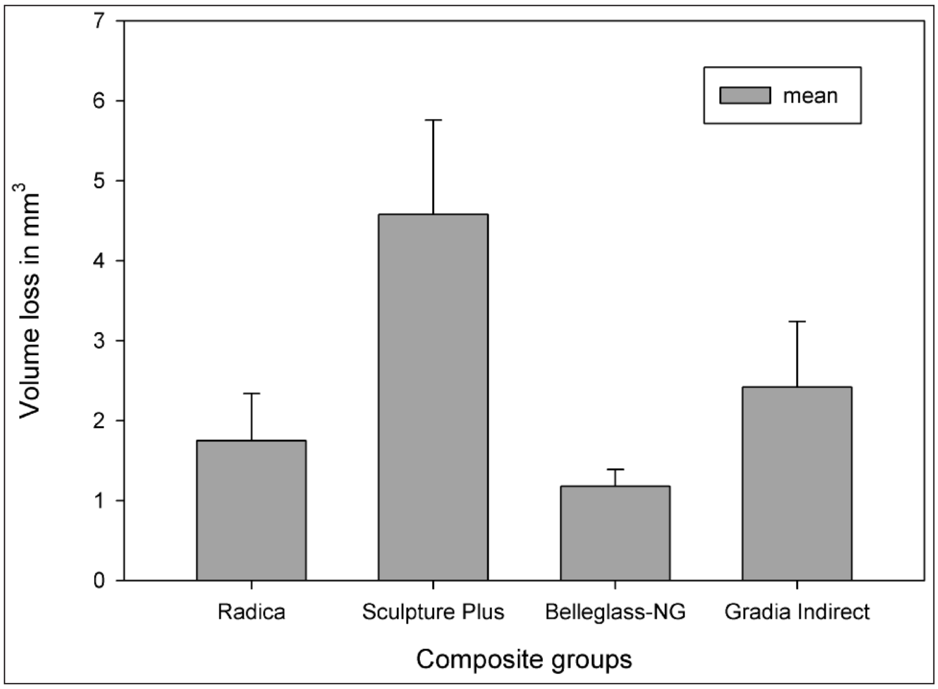

Figure 2. *Toothbrush abrasion wear (mean and std dev).*

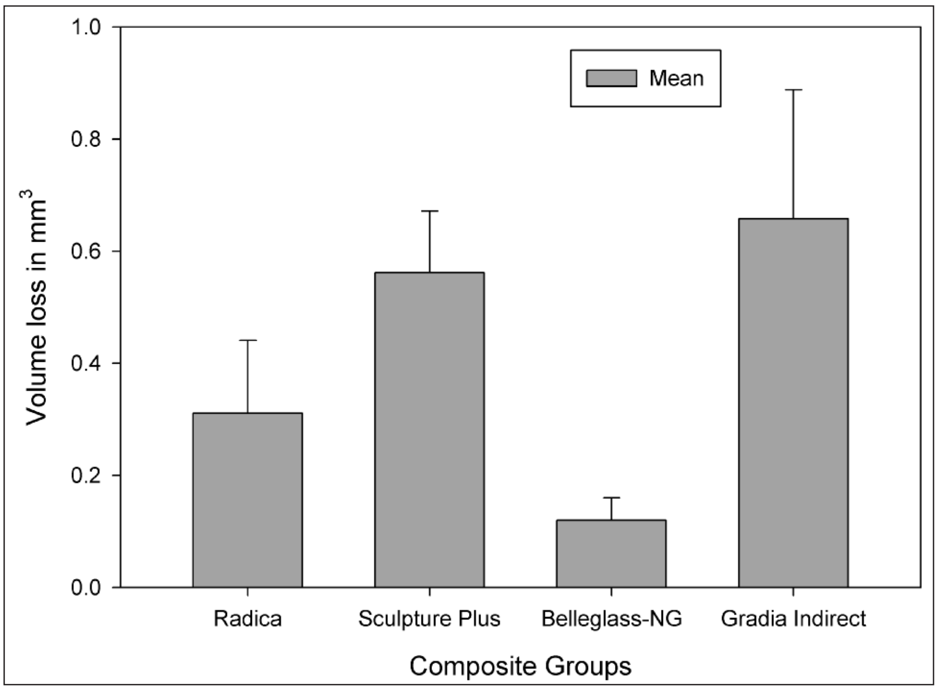

Figure 3. *Three-body Alabama wear (mean and std dev).*

significant low volume loss compared to Gradia Indirect and Sculpture, indicating that they were more wear resistant. Statistically, no significant difference was observed between Radica and Belleglass-NG (p=0.05).

Two-body Pin-on-disc Wear: The results are given in (Table 2 and Figure 4). Sculpture Plus showed the highest volume loss compared to the other test groups. Statistically, no significant difference was observed among Radica, Belleglass-NG and Gradia Indirect (p=0.05).

DISCUSSION

The null hypothesis was rejected, as statistically significant differences were observed in volume loss due to wear among the four indirect composites for each of the wear tests. Belleglass-NG had the least volume loss, while Sculpture Plus had the highest volume loss due to wear. Mandikos and others[19] reported Sculpture with a lower wear rate than Belleglass HP. The materials in the current study are Belleglass-NG and Sculpture Plus, which have different compositions and curing units. Sculpture Plus demonstrated high susceptibility to toothbrush wear. Post-curing with high temperature and under nitrogen pressure may result in improvement of surface properties and degree of conversion.[11-12,23] Although Sculpture Plus is cured under nitrogen pressure, the increased temperature, composition of resin and filler and their interaction may be possible factors in the low wear resistance. As the exact composition is unknown, the causative factors cannot be inferred.

Tooth abrasion occurs in a three-body wear mode and is generated by the sliding action of one tooth past another with force being transmitted through a layer of food that serves as a third-body medium.[18] To simulate this phenomenon in the laboratory, the current study used an orthodontic resin as a third body in a three-body Alabama wear testing machine. This mechanism is different from toothbrush abrasion, which is a much more complex wear phenomenon. The results obtained, however, were similar to results in toothbrush abrasion wear.

Attrition occurs in a two-body wear mode and results from the direct contact of opposing teeth where the

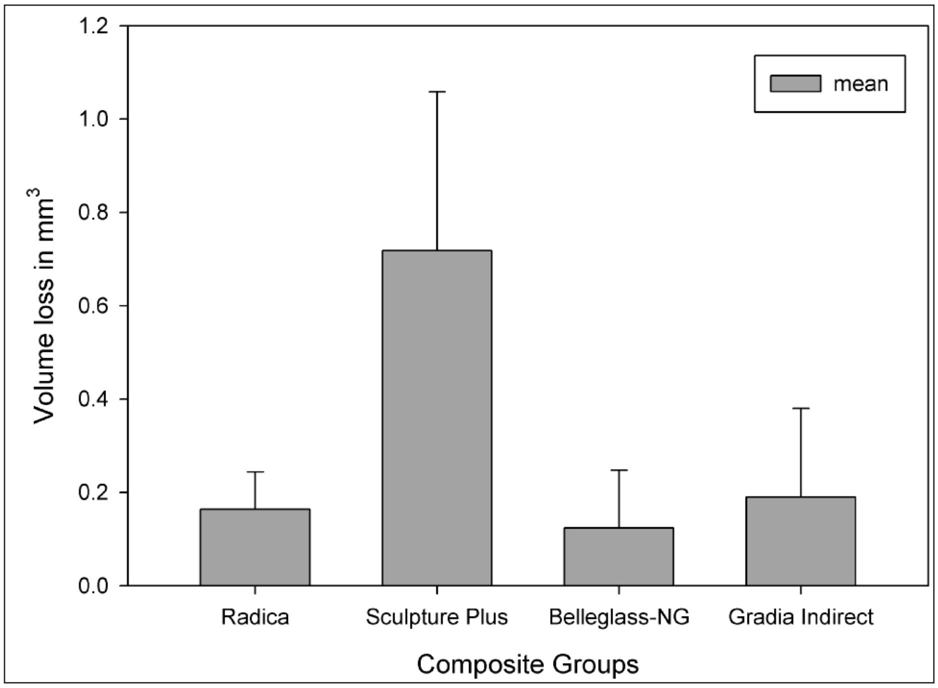

Figure 4. *Two-body pin-on-disc wear (mean and std dev).*

load level increases more than that which produces abrasion[24] to simulate the same pin-on-disc wear test. Statistically, only Sculpture Plus had significantly more wear than the other groups. No significant differences were observed among Belleglass-NG, Radica and Gradia Indirect. This may suggest that the material responded differently in the attrition and abrasion wear tests. Hence, no correlation can be established between the Alabama wear test and the Pin-on-disc test. This is consistent with a study conducted by Cha and others[25] in which Sculpture Plus showed the lowest attrition and abrasion wear resistance.

The diameter of the antagonist in the current study was 2 mm ± 0.1 mm. Others have reported an antagonist diameter of 5 mm and 10 mm.[25] Jaarda and others[26] reported that a reduced diameter resulted in higher attrition and had no significant influence on other forms of wear. Thus, a diameter of 2 mm would represent higher attrition and also be more clinically relevant. Marquis and others[27] reported that wear increased steadily under increasing loads. In the current study, a constant load of 2.8 kg-force was applied that produced contact stresses of 10 MPa, which is clinically relevant.[28]

Condon and Ferracane[29] observed a linear relation between wear and volume of filler. A decrease in volume of filler was associated with increased wear. Post curing with high temperature and nitrogen pressure may improve surface conditions and abrasion wear resistance. According to de Gee and others,[30] heat treatment will accelerate the relaxation of local stress conditions around filler particles into a more homogenized distribution, which is maintained after cooling. In addition, the resin matrix and filler-matrix coupling may also influence wear resistance.[31] As the exact composition of the commercial composites is unknown, no correlations could be made among the above factors.

CONCLUSIONS

Within the limited scope of the current study, it was concluded that indirect resin composites exhibited wear under different testing conditions. In general, Belleglass-NG and Radica demonstrated the lowest wear loss.

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References

1. Touati B & Aidan N (1997) Second-generation laboratory composite resins for indirect restorations *Journal of Esthetic Dentistry* **9(3)** 108-118.
2. Leinfelder KF (2005) Indirect posterior composite resins *Compendium of Continuing Education in Dentistry* **26(7)** 495-503 quiz 504, 527.
3. Touati B (1996) The evolution of aesthetic restorative materials for inlays and onlays: A review *Practical Periodontics in Aesthetic Dentistry* **8(7)** 657-666 quiz 668.
4. Wang JC, Charbeneau GT, Gregory WA & Dennison JB (1989) Quantitative evaluation of approximal contacts in Class 2 composite resin restorations: A clinical study *Operative Dentistry* **14(4)** 193-202.
5. Soderholm KJ & Richards ND (1998) Wear resistance of composites: A solved problem? *General Dentistry* **46(3)** 256-263 quiz 264-255.
6. Kern M, Strub JR & Lü XY (1999) Wear of composite resin veneering materials in a dual-axis chewing simulator *Journal of Oral Rehabilitation* **26(5)** 372-378.
7. Taylor DF, Bayne SC, Leinfelder KF, Davis S & Koch GG (1994) Pooling of long-term clinical wear data for posterior composites *American Journal of Dentistry* **7(3)** 167-174.

8. Kon M, Kakuta K & Ogura H (2006) Effects of occlusal and brushing forces on wear of composite resins *Dental Materials Journal* **25(1)** 183-194.

9. Suzuki S, Nagai E, Taira Y & Minesaki Y (2002) *In vitro* wear of indirect composite restoratives *Journal of Prosthetic Dentistry* **88(4)** 431-436.

10. Nihei T, Dabanoglu A, Teranaka T, Kurata S, Ohashi K, Kondo Y, Yoshino N, Hickel R & Kunzelmann KH (2007) Three-body-wear resistance of the experimental composites containing filler treated with hydrophobic silane coupling agents *Dental Materials* **24(6)** 760-764.

11. Wendt SL Jr (1987) The effect of heat used as secondary cure upon the physical properties of three composite resins. II. Wear, hardness, and color stability *Quintessence International* **18(5)** 351-356.

12. da Silva GR, Simamoto-Junior PC, da Mota AS & Soares CJ (2007) Mechanical properties of light-curing composites polymerized with different laboratory photo-curing units *Dental Materials Journal* **26(2)** 217-223.

13. Wendt SL Jr & Leinfelder KF (1990) The clinical evaluation of heat-treated composite resin inlays *Journal of the American Dental Association* **120(2)** 177-181.

14. Bartlett D & Sundaram G (2006) An up to 3-year randomized clinical study comparing indirect and direct resin composites used to restore worn posterior teeth *International Journal of Prosthodontics* **19(6)** 613-617.

15. Ziemiecki TL, Wendt SL & Leinfelder KF (1992) Methodology for proximal wear evaluation in posterior resin composites *American Journal of Dentistry* **5(4)** 203-207.

16. Jones DW, Jones PA & Wilson HJ (1972) A simple abrasion test for composites *Journal of Dentistry* **1(1)** 28-34.

17. Nagarajan VS, Jahanmir S & Thompson VP (2004) *In vitro* contact wear of dental composites *Dental Materials* **20(1)** 63-71.

18. Mair LH (1992) Wear in dentistry—current terminology *Journal of Dentistry* **20(3)** 140-144.

19. Mandikos MN, McGivney GP, Davis E, Bush PJ & Carter JM (2001) A comparison of the wear resistance and hardness of indirect composite resins *Journal of Prosthetic Dentistry* **85(4)** 386-395.

20. Momoi Y, Hirosaki K, Kohno A & McCabe JF (1997) *In vitro* toothbrush-dentifrice abrasion of resin-modified glass ionomers *Dental Materials* **13(2)** 82-88.

21. Ferracane JL (2006) Is the wear of dental composites still a clinical concern? Is there still a need for *in vitro* wear simulating devices? *Dental Materials* **22(8)** 689-692.

22. Beatty M (1991) Effect of changes in resin matrix chemistry and microfiller addition on composite resin properties Restorative Dentistry, Indiana University School of Dentistry, Indianapolis Master's thesis.

23. Wendt SL Jr (1987) The effect of heat used as a secondary cure upon the physical properties of three composite resins. I. Diametral tensile strength, compressive strength, and marginal dimensional stability *Quintessence International* **18(4)** 265-271.

24. Condon JR & Ferracane JL (1996) Evaluation of composite wear with a new multi-mode oral wear simulator *Dental Materials* **12(4)** 218-226.

25. Cha HS, Lee YK, Lim BS, Rhee SH & Yang HC (2004) Evaluation of wear resistance of dental resin composites with a 3D profilometer *Journal of Biomedical Materials Research Part B Applied Biomaterials* **71(2)** 414-420.

26. Jaarda MJ, Wang RF & Lang BR (1997) A regression analysis of filler particle content to predict composite wear *Journal of Prosthetic Dentistry* **77(1)** 57-67.

27. Marquis PM, Hu X & Shortall AC (2000) Two-body wear of dental composites under different loads *International Journal of Prosthodontics* **13(6)** 473-479.

28. Imanishi A, Nakamura T & Ohyama T (2003) 3-D Finite element analysis of all-ceramic posterior crowns *Journal of Oral Rehabilitation* **30(8)** 818-822.

29. Condon JR & Ferracane JL (1997) *In vitro* wear of composite with varied cure, filler level, and filler treatment *Journal of Dental Research* **76(7)** 1405-1411.

30. de Gee AJ, Pallav P, Werner A & Davidson CL (1990) Annealing as a mechanism of increasing wear resistance of composites *Dental Materials* **6(4)** 266-270.

31. Peutzfeldt A (1997) Resin composites in dentistry: The monomer systems *European Journal of Oral Science* **105(2)** 97-116.