

#2683 Evaluation of Seven Commercial Composites Using New In Vitro Wear Simulator

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ABSTRACT

Objective: The OHSU Oral Wear Simulator has been successful at modeling the major wear mechanisms of dental composite, which include three body abrasion, attrition, and wear of opposing dentition. However, operators found it to be time-consuming and technique sensitive. An improved version of the OHSU Oral Wear Simulator was developed which uses roller slides and solenoids to reproduce the oral mechanisms with similar precision while being easier to operate. **Methods:** The wear tester applied a 20N load through a polished enamel stylus while sliding across the composite specimen in the presence of a food simulating slurry to produce three-body abrasion. As the stylus reversed direction, a higher load of 90N was triggered to produce attrition wear. After 100,000 cycles, the average depth in each region was measured with a contact profiler. The wear of the enamel antagonist was measured with digital image analysis. Seven commercial composites were tested and the results were compared to published clinical wear results to validate the system. Six bar-shaped specimens of each composite were prepared using a steel mold in a light-curing oven (Triad II). The results were compared by ANOVA/Tukey's Test ($p < 0.05$). **Results:** ave(s.d.):

	Clearfil	Fulfil	Heliomolar	Herculite	Prisma	Silux Plus	Z100
Abrasion, μm	7(3) ^a	61(10) ^d	12(5) ^b	19(5) ^{ab}	45(9) ^c	24(10) ^b	9(2) ^a
Attrition, μm	20(4) ¹	77(7) ³	61(8) ^{3,4}	47(12) ^{2,3}	61(11) ^{3,4,5}	65(12) ^{4,5}	34(8) ^{1,2}
Enamel, mm2	2.5(1) ³	3.1(4) ²	1.3(3) ^a	2.6(4) ^{bc}	4.1(3) ^b	1.6(4) ^a	2.4(3) ³

Conclusions: The microfilled (Heliomolar and Silux) and mini-filled (Z100, Herculite and Clearfil) composites demonstrated low abrasive wear but were sensitive to attrition wear (except Clearfil). The midi-filled composites (Fulfil and Prisma) had high abrasion, attrition and enamel wear. A comparison of abrasion values with contact-free-wear values from three clinical studies produced an average correlation coefficient of $r^2 = 0.98$. The improved wear simulator provides meaningful, consistent results. Supported by NIH/NIDCR grant #DE07079.

INTRODUCTION

The sensitivity of composite restorative materials to intra-oral wear is a major problem in dentistry today. None of the direct composites currently in use have demonstrated the ability to withstand the forces of wear in the mouth as well as natural dentition does. The mechanisms by which intra-oral wear takes place have been classified into two types:

Three-Body Abrasion: The action of food particles during chewing in regions away from direct contact with opposing dentition causing contact-free wear. It is characterized by an even loss of material over large expanses of restorations.

Attrition: High forces transmitted through direct contact with opposing dentition causes occlusal contact wear, as evidenced by localized pitting and chipping.

Clinical studies of composite wear are an expensive and time consuming method of assessing intra-oral wear resistance. A variety of *in vitro* testing methods have been developed over the years to provide more convenient measures of composite wear resistance. A new testing method was developed at Oregon Health Sciences University (O.H.S.U.) which has the distinct advantage of being able to reproduce both the three-body abrasion and attrition wear mechanism, as well as simulating the wear action of the restorative upon the opposing enamel dentition. A number of publications have demonstrated that it yields results with a strong correlation to clinical wear studies¹. The system's usefulness in evaluating model composites², two-body wear³, and marginal wear resistance⁴ has also been reported.

However, a number of users found the system to be time consuming to set-up, and the results seemed to be sensitive to operator technique. A modified version of the Oral Wear Simulator (Figure 1) was developed to provide increased ease of use and more repeatable results.



Figure 1: The O.H.S.U. Oral Wear Simulator

This study tested the following hypothesis: the improved version of the O.H.S.U. Oral Wear Simulator provides clinically-realistic measures of composite wear resistance.

METHODS

The improved system used precision roller bearings and solenoids driven by all-electronic circuitry to produce the following wear routine (Figure 2):



Figure 2: An illustration of the wear cycle. The enamel-tipped antagonist moves across the composite specimen while imparting a 20N vertical load to produce three-body abrasion (slurry not shown). When it reaches the end of its 5mm path, the load is increased to 90N to produce attrition wear.

Three-body Abrasion: generated by the application of 20N of force through a 10mm diameter hemisphere of polished human enamel to a polished flat surface of composite. The enamel cusp was advanced across the composite at roughly 16mm/sec for 5mm in the presence of a food-simulating slurry composed of poppy seeds, acrylic powder and water.

Attrition: The force level was increased to 90N at the end of this path, as the enamel cusp reversed direction, much as happens during the natural chewing cycle.

The cusp was then lifted out of contact with the composite and returned to its original position. This cycle was repeated at 100 cycles per minute for 100,000 cycles.

The specimens were analyzed through contact profilometry. A diamond-tipped stylus attached to an eddy-current proximity sensor registered the height of the specimen surface as the stylus was moved across the width of the composite wear facet. (Figure 3). Among ten equally-spaced profile passes, the average depth from the fourth, fifth and sixth pass were combined to compute the abrasion wear depth (Figure 4). The passes which took place at the end of the wear facet, the eighth and ninth, made up the attrition wear depth. The wear of the enamel antagonist was measured through digital micro-photography and image analysis to compute the average area defined by the wear facet on the enamel cusp.

An *in vitro* comparison of the wear resistance of seven commercial composites was conducted. They were selected as representative of the broad range of composite types available today (Table 1). Six specimens of each material were

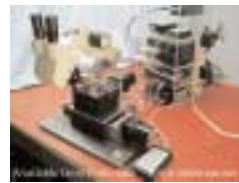


Figure 3: The Automated Profilometer.

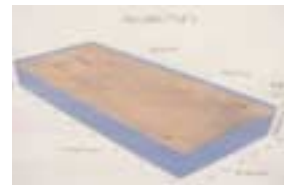


Figure 4: The profiling routine makes ten passes across the width of the specimen.

tested. The results of abrasion, attrition and enamel wear were compared by one-way ANOVA/Tukey's test ($p < 0.05$). Representative samples were examined under SEM to make a qualitative assessment of the wear facets.

Type	Name	Manufacturer
Nano-filled	Heliomolar	Vivadent, Leichtenstein
Nano-filled	Silux Plus	3M, St Paul, MN
Mini-filled	Herculite XR	Kerr, Orange, CA
Mini-filled	Z100	3M, St Paul, MN
Midi-filled	Clearfil	Tokuyama, Osaka, Japan
Midi-filled	Prisma TPH	Caulk/Dentsply, Milford, DE
Midi-filled	Fulfil	Caulk/Dentsply, Milford, DE

Table 1: Materials. Micro-filled composites have an average particle size of $< 100\text{nm}$, while mini-filled composites have particles $< 1\mu\text{m}$ and midi-filled have particles $< 10\mu\text{m}$.

RESULTS

The abrasion wear depths are reported in Figure 5. The midi-filled composites, except for Clearfil, demonstrated significantly higher abrasion wear than the mini- and nano-filled composites.

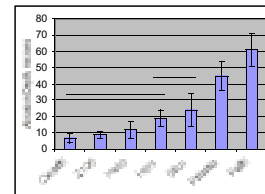


Figure 5: Abrasion wear of the seven commercial composites. Bars connected by a line are not significantly different.

The attrition wear results appear in Figure 6. The mini-filled composites tended to undergo less attrition wear than the nano- or midi-filled composites.

The enamel wear areas are reported in Figure 7. The results generally followed the particle size of the composite, i.e. nano-filled $<$ mini-filled $<$ midi-filled.

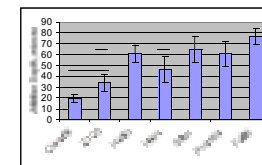


Figure 6: Attrition wear of the seven commercial composites. Bars connected by a line are not significantly different.

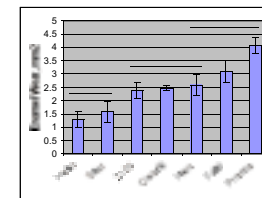


Figure 7: Wear of the enamel cusps opposing seven commercial composites. Bars connected by a line are not significantly different.

A comparison of this ranking with a ranking of the materials according to the results for abrasion wear we found was made (Table 3). A very strong agreement between this meta-analysis and our results was found.

Rank	OHSU abrasion	Taylor et al. 2 yr
1	Clearfil	Clearfil
2	Heliomolar	Heliomolar
3	Herculite	Silar
4	Silux	Herculite
5	Prisma	Prisma
6	Fulfil	Fulfil

Table 3: Comparison to meta-analysis. For purposes of this comparison, Silux Plus is considered equivalent to Silar, and Prisma TPH is equivalent to Prisma APH.



Figure 8: SEM of Fulfil in the abrasion wear region.



Figure 9: SEM of Heliomolar in the attrition wear region.

The results of the SEM analysis confirmed the realistic nature of the wear patterns produced by the Oral Wear Simulator. A gradual loss of material and preferential wear of the resin matrix was observed for the midi-filled composites in the abrasion region (Figure 8). This agrees with reports from microscopic evaluation of clinical wear⁵. The chipped and pitted appearance of the nano-filled composite in the attrition wear region (Figure 9) also agrees with observations from clinical studies.

DISCUSSION

The improved Oral Wear Simulator demonstrated its capability to distinguish between a wide variety of composite restoratives in terms of abrasion and attrition wear resistance, as well as wear of opposing enamel.

A comparison to the results of clinical studies would help validate the performance of the testing machine. Three clinical studies were found from a survey of the dental literature in which the loss of material was measured for two or more materials in common with this study. A summary of their results (Table 2) and comparison with our results by linear regression (no constant) was made, and an average regression coefficient for the three studies was found to be $r^2 = 0.98$.

Material	OHSU abrasion ave	Lundin et al, 5 3yr	Wendt et al, 6 2yr	Willems et al, 7 2yr
Clearfil	7			12
Z100	9			
Helio	12	22		16
Herc	19			20
Silux	24		30	
Prisma	45			
Fulfil	61	133	70	90
r2		0.99	0.95	0.97

Table 2: Comparison to clinical studies.

A meta-analysis which combined the results of a large number of clinical studies reported a ranking of dental composites by their reported wear values⁶.

CONCLUSIONS

The improved Oral Wear Simulator is capable of making clinically-realistic simulation of the abrasion and attrition wear resistance of dental composites, as well as their aggressiveness as a wear antagonist to opposing enamel dentition.

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John Condon is now the President of Proto-tech, offering a complete line of dental materials testing instruments, including the O.H.S.U. Oral Wear Simulator and Automated Profilometer on the web at www.oralwear.net.

- References**
- Condon JR and Ferracane JL. Evaluation of composite wear with a new multi-mode oral wear simulator. Dent Mater 12, 1996, 218-226.
 - Condon JR and Ferracane JL. In vitro wear of composite with varied cure, filler level and filler treatment. J Dent Res 76(7), 1997, 1405-1411.
 - Condon JR and Ferracane JL. Factors effecting composite wear in vitro. J Biomed Mater Res (Appl Biomater) 38, 1997, 303-313.
 - Ferracane JL and Condon JR. In vitro evaluation of the marginal degradation of dental composite under simulated occlusal loading. Dent Mater 15, 1999, 262-267.
 - Lundin SA, Andersson B, Koch G, Rasmussen CG. Class II composite resin restorations. Scand J Dent Res. 14, 1990, 105-114.
 - Wendt SL and Leinfelder KF. Clinical evaluation of a posterior resin composite. Am J Dent, 7, 1994, 207-211.
 - Willems G, Lambrechts P, Braem M, Celis JP, Vanherle G. Three year follow up of five posterior composites. J Dent, 21, 1993, 79-86.
 - Taylor DF, Bayne SC, Leinfelder KF, Davis S, Koch G. Pooling of long-term clinical wear data for posterior composites. Am J Dent, 7, 1994, 167-174.
 - Okamoto A, Sekiya K, Fukushima M, Kota K, Iwaku M. Direct observation of in vivo wear of composite resins. Dent Mater J 12, 1993, 54-61.