Comparative Evaluation of Wear of Indirect Resin Composites with Human Enamel
Devendra Pal Singh Chhonkar, Mahalakshmi Gujjalapudi, Himanshu Mishra, K S Akber Pasha, Srinivas J Bashetty, Brajesh G Dammani

Contributors:
1. Senior Lecturer, Department of Prosthodontics, Mahatma Gandhi Dental College and Hospital, Sitapur, Jaipur, Rajasthan, India;
2. Assistant Professor, Department of Prosthodontics, Government Dental College and Hospital, Vijayawada, Andhra Pradesh, India;
3. Senior Lecturer, Department of Oral Pathology, Azamgarh Dental College, Azamgarh, Uttar Pradesh, India;
4. Consultant Prosthodontist, Salmar, Karkala, Karnataka, India;
5. Reader, Department of Oral Pathology, Purvanchal Dental College, Gorakhpur, Uttar Pradesh, India;
6. Reader, Department of Prosthodontics, Rama Dental College, Kanpur, Uttar Pradesh, India.

Correspondence:
Dr. Chhonkar DP. Department of Prosthodontics, Mahatma Gandhi Dental College and Hospital, Itapur, Jaipur, Rajasthan, India. Email: devprostho@gmail.com

How to cite the article:

Abstract:
Background: Dental composite formulations have been continuously evolving ever since bisphenol A glycidyl methacrylate was introduced to dentistry by Bowen in 1962. Dental restorative composite materials can be divided into direct composite (directly placed into the oral cavity and cured) and indirect composite (externally fabricated and cured by means of light and/or heat). Indirect composites are also referred as prosthetic composites or laboratory composites.

Materials and Methods: Two commercially available indirect resin composite materials and human enamel (control). Human enamel specimen taken from buccal surface of extracted third molars was used as control in this study. Buccal cusp of maxillary premolars (extracted for orthodontic purpose) was used as an antagonist in this study. 10 samples of 15 mm diameter and 2 mm of thickness were prepared in the custom fabricated metal die. All the test and control specimens were stored in distilled water for 7 days before the wear test. After initial weight measurement, the specimens were subjected to wear simulation.

Results: All samples exhibited a loss of weight after wear simulation process. The value of ‘t’ in t-test for percentage weight loss of Ceramage and control was calculated to be −4.32, P < 0.001, indicating that there is statistically significant difference in percentage weight loss between Ceramage and control.

Conclusion: Within the limitations of this study, it was found that all samples exhibited a loss of weight and an increase in surface roughness after wear simulation process.

Key Words: Enamel, indirect composite, in vitro, wear, weight loss

Introduction
Dental composite formulations have been continuously evolving ever since bisphenol A glycidyl methacrylate was introduced to dentistry by Bowen in 1962. Recent developments in material science technology have considerably improved the physical properties of resin-based composites and expanded their clinical applications.

Dental restorative composite materials can be divided into direct composite (directly placed into the oral cavity and cured) and indirect composite (externally fabricated and cured by means of light and/or heat). Indirect composites are also referred as prosthetic composites or laboratory composites.

In an effort to offset the problems of marginal integrity and poor wear resistance associated with direct composites, the first generation of indirect composites were introduced in the 1980’s. These materials exhibited low mechanical properties owing to a low percentage of inorganic filler particles and a high percentage of exposed resin. In 1990’s, another generation of indirect composite resins was introduced into the market which had higher percentage of inorganic fillers (approximately 66%) and exhibited better mechanical properties. These materials are referred as second generation indirect composites.

Second generation indirect composites are indicated in several clinical applications such as inlays and on lays, laminated veneers and jacket crowns, implant-supported restorations, for progressive loading of implant-supported prostheses and for easier repair. When compared to the 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.

As ceramics exhibit a high modulus of elasticity and absorb little of the masticatory energy, considerable amount of the masticatory force is transmitted to the implant and the periosseous structure reducing the longevity. Polymers become the materials of choice.

Inspite of all these advantages there are two major issues of concern for indirect resin composites which are: Surface wear and color stability of indirect resin composites. Wear resistance of a given material is determined by its formulation, the quantity and the size of the reinforcing fillers and the degree of the cure of the polymer matrix.
The present study is an in vitro evaluation and comparison of wear of commercially available indirect resin composites and human enamel specimens to evaluate. Recently developed indirect resin composites which are considered to have improved mechanical properties including wear resistance.

**Aims and objectives**

The present in vitro study was taken up to evaluate and compare wear resistance of two commercially available indirect resin composites (Adoro and Ceramage) and human enamel (control). The main objectives of this study were as follows:

1. To evaluate the wear resistance of Adoro (Ivoclar) indirect resin composite, Ceramage (Shofu) indirect resin composite, and human enamel by determining percentage weight loss after wear simulation.
2. To compare the percentage weight loss after wear simulation of Adoro indirect resin composite, Ceramage indirect resin composite, and human enamel.

**Materials and Methods**

**Materials used**

Test materials: Figure 1 Indirect resin composite test materials used in this study were as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Manufacturer</th>
<th>Curing method</th>
<th>Lot. No.</th>
<th>Filler type</th>
<th>Filler %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoro</td>
<td>Ivoclar Vivadent</td>
<td>Light+heat</td>
<td>M 38937</td>
<td>Silica dioxide, copolymer</td>
<td>65</td>
</tr>
<tr>
<td>Ceramage</td>
<td>Shofu Inc., Japan</td>
<td>Light cured</td>
<td>OS0811</td>
<td>Zirconium silicate</td>
<td>73</td>
</tr>
</tbody>
</table>

**Control**

Human enamel specimen taken from buccal surface of extracted third molars was used as control in this study.

**Antagonist**

Buccal cusp of maxillary premolars (extracted for orthodontic purpose) was used as antagonist in this study.

Fabrication of samples:

Three groups of the samples were fabricated; each group containing 10 samples. These groups were as follows:

1. Adoro indirect resin composite (Ivoclar Vivadent)
2. Ceramage indirect resin composite (Shofu, Japan)
3. Enamel specimen taken from buccal surface of molars (control).

**Fabrication of indirect resin composite specimens**

10 samples of 15 mm diameter and 2 mm of thickness were prepared from each test material in the custom fabricated metal die. For the easy removal of specimen, the die was lubricated with a lubricating media before the specimen preparation. The composite was loaded in the die and then it was pressed between two flat glass plates for the removal of excess material.

**Fabrication of control specimens**

10 control enamel samples were prepared by slicing buccal surface of non-caries freshly extracted adult human molars. The enamel specimens were stored in 0.5% thymol solution for 48 h. The enamel surface was polished with 2000 grit carbide paper for the removal of enamel pellicle and then these enamel specimens were mounted in direct composite using the metal die and shaped according to the measurement of the test specimens.

All the test specimens and control specimens were stored in distilled water for 7 days before the wear test.

**Antagonist specimen**

Enamel specimen formed by buccal cusp of maxillary premolars was used as antagonists. The antagonist specimen was stabilized in auto-polymerizing acrylic resin block.

**Initial measurement of specimens**

**Weight measurement**

All the specimens were dried on blotting paper before weighing. The initial weight of the specimens before wear simulation was measured using precision weight balance (LWL Germany). The precision of the weight balance was 0.0001 g to facilitate its holding in horizontal arm of wear simulator (Figure 3).

**Wear simulation**

After initial measurement, the specimens were subjected to wear simulation. The specimens were mounted in the sample holder of the wear simulator with the help of auto-polymerizing resin block (Figure 4).
The horizontal or wearing arm consisted of antagonist tooth sample (buccal cusp of maxillary premolar). It was adjusted over the sample surface to produce a rotational sliding type of wear. The holding screw was adjusted and a load of 1.8 kg was applied over the arm and the rotation of the wear simulator was reduced to 120 rpm using a Dimmer stat. After these adjustments, the wear simulation procedure was performed for 20,000 cycles for each specimen.

**Final measurements**
After completion of wear simulation, the specimens were re-measured.

**Weight measurement**
Weight after the wear simulation process was measured for each specimen with precision weight balance.

**Calculation of wear**
The difference between weight before wear simulation and after wear simulation was calculated and wear percentage was calculated as follows. Calculation of wear was done using following formula:

\[
\text{Wear \%} = \frac{\text{Difference between weight}}{\text{Pre-weight}} \times 100
\]

**Results**
Weight of each specimen was calculated before and after the wear simulation process. Wear was calculated in terms of percentage weight loss. Data were tabulated and subjected to statistical analysis using one-way ANOVA test followed by *t*-test of difference of means.

Tables 1-3 show the weight of samples before and after wear simulation, difference of weight, and percentage weight loss for Adoro, Ceramage, and control groups, respectively. All samples exhibited a loss of weight after wear simulation process. Mean percentage weight loss was least for control (enamel) (0.157 ± 0.049%) followed by Ceramage (0.263 ± 0.060%) and most for Adoro (0.330 ± 0.112%). On subjecting the values of percentage weight loss to one-way ANOVA, *F* value was 12.161 and *P* value was 0.0002 indicating that there was a statistically significant difference in percentage weight loss among the groups tested (*P* < 0.05) (Table 4).
Table 2: Weight before and after wear simulation, difference in weight and percentage weight loss for Ceramage samples.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Weight before (g)</th>
<th>Weight after (g)</th>
<th>Difference of weight (g)</th>
<th>Percentage weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>0.4444</td>
<td>0.4333</td>
<td>0.0111</td>
<td>0.247</td>
</tr>
<tr>
<td>S2</td>
<td>0.4042</td>
<td>0.4030</td>
<td>0.0012</td>
<td>0.296</td>
</tr>
<tr>
<td>S3</td>
<td>0.4947</td>
<td>0.4933</td>
<td>0.0012</td>
<td>0.282</td>
</tr>
<tr>
<td>S4</td>
<td>0.4227</td>
<td>0.4212</td>
<td>0.0015</td>
<td>0.331</td>
</tr>
<tr>
<td>S5</td>
<td>0.3860</td>
<td>0.3849</td>
<td>0.0011</td>
<td>0.284</td>
</tr>
<tr>
<td>S6</td>
<td>0.3435</td>
<td>0.3432</td>
<td>0.0007</td>
<td>0.161</td>
</tr>
<tr>
<td>S7</td>
<td>0.3919</td>
<td>0.3912</td>
<td>0.0007</td>
<td>0.178</td>
</tr>
<tr>
<td>S8</td>
<td>0.4752</td>
<td>0.4739</td>
<td>0.0013</td>
<td>0.273</td>
</tr>
<tr>
<td>S10</td>
<td>0.4711</td>
<td>0.4700</td>
<td>0.0011</td>
<td>0.233</td>
</tr>
<tr>
<td>Mean±SD</td>
<td></td>
<td></td>
<td></td>
<td>0.26±0.060</td>
</tr>
</tbody>
</table>

SD: Standard deviation

Table 3: Weight before and after wear simulation, difference in weight and percentage weight loss for control samples.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Weight before (g)</th>
<th>Weight after (g)</th>
<th>Difference of weight (g)</th>
<th>Percentage weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.4425</td>
<td>0.4415</td>
<td>0.0010</td>
<td>0.225</td>
</tr>
<tr>
<td>C2</td>
<td>0.4987</td>
<td>0.4981</td>
<td>0.0006</td>
<td>0.120</td>
</tr>
<tr>
<td>C3</td>
<td>0.5089</td>
<td>0.5080</td>
<td>0.0009</td>
<td>0.176</td>
</tr>
<tr>
<td>C4</td>
<td>0.4379</td>
<td>0.4371</td>
<td>0.0008</td>
<td>0.182</td>
</tr>
<tr>
<td>C5</td>
<td>0.3647</td>
<td>0.3642</td>
<td>0.0005</td>
<td>0.137</td>
</tr>
<tr>
<td>C6</td>
<td>0.5256</td>
<td>0.5249</td>
<td>0.0007</td>
<td>0.133</td>
</tr>
<tr>
<td>C7</td>
<td>0.4800</td>
<td>0.4794</td>
<td>0.0006</td>
<td>0.125</td>
</tr>
<tr>
<td>C8</td>
<td>0.4018</td>
<td>0.4011</td>
<td>0.0007</td>
<td>0.174</td>
</tr>
<tr>
<td>C9</td>
<td>0.6093</td>
<td>0.6079</td>
<td>0.0014</td>
<td>0.229</td>
</tr>
<tr>
<td>C10</td>
<td>0.5680</td>
<td>0.5676</td>
<td>0.0004</td>
<td>0.070</td>
</tr>
<tr>
<td>Mean±SD</td>
<td></td>
<td></td>
<td></td>
<td>0.157±0.049</td>
</tr>
</tbody>
</table>

SD: Standard deviation

Table 4: One-way ANOVA results for percentage weight loss.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degree of freedom</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments (between columns)</td>
<td>2</td>
<td>0.1514</td>
<td>0.07569</td>
<td>12.161</td>
<td>0.0002</td>
</tr>
<tr>
<td>Residuals (within columns)</td>
<td>27</td>
<td>0.1680</td>
<td>0.006224</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>0.3194</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ANOVA: Analysis of variance

Table 5: Results of t-test for percentage weight loss and change in surface roughness between Adoro and control.

<table>
<thead>
<tr>
<th></th>
<th>Adoro (%)</th>
<th>Control (%)</th>
<th>t value</th>
<th>P value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage weight loss</td>
<td>0.330</td>
<td>0.157</td>
<td>±4.44</td>
<td>≤0.001</td>
<td>Significant</td>
</tr>
</tbody>
</table>

The value of t in t-test for percentage weight loss between Adoro and control was calculated to be –4.44, P < 0.001, indicating that there is statistically significant difference in percentage weight loss between Adoro and Control. The value of t in t-test for percentage weight loss of Ceramage and control was calculated to be –4.32, P < 0.001, indicating that there is a statistically significant difference in percentage weight loss between Ceramage and Control.

Discussion

Abrasive wear is probably the most common type of wear. It occurs when hard asperities plough into softer surfaces. These asperities may be an integral part of one surface (e.g., the filler particles protruding from a dental composite) or they may be separate particles which are enmeshed between the surfaces. 7-6

Wear is an important consequence of occlusal interactions. It is a complex phenomenon as it involves a number of factors. 10 Wear resistance is a prerequisite for a dental material to be accepted by both dentists and patients. Restorative materials play an important part in wear, and differ significantly with respects to wear. Materials may be worn by enamel or they may cause aggressive wear of enamel. Wear of restorations may involve systemic consequences via the ingestion or inhalation of worn material and, on the other hand, it may have biological consequences on the stomatognathic system via alterations of tissues and cells due to mechanical loading and change of vertical height between the lower and upper jaw. 11-14

In the present era, due to increased esthetic demands of patients, ceramics and dental composites are the most widely used material for the restorative procedures in dentistry ceramic can be considered the benchmark material and gold standard for full-coverage crowns due to its excellent esthetics and color stability. Characteristics such as high abrasion to opposing natural dentition, tendency to catastrophic failure, and repair limitations are the potential limitations for the use of ceramics. 6

The present study is an in vitro study to evaluate and compare the wear resistance of two commercially available indirect resin composites (Adoro and Ceramage) and human enamel, which is considered as a control in this study. This study was taken up to provide information about the wear resistance of indirect resin composites which would be helpful in predicting their durability in the oral environment. In the present study, wear is measured in terms of percentage weight loss after a predefined wear simulation process.

Test materials used in this study were SR Adoro indirect resin composite (Ivoclar Vivadent) and Ceramage indirect resin composite (Shofu, Japan). Both these materials are second generation indirect resin composite, 10 specimens of each test material and the control, which was human enamel, was prepared and stored in water for 7 days and subjected to a predefined wear simulation, weight of specimens was measured before and after wear simulation.
The results showed a statistically significant wear rate of both the test materials when compared to the human enamel specimen's wear. When both the materials were compared for wear rate, it showed that the wear rates for both the materials were almost same.

The Kanter et al. conducted a study to check the relationship of weight loss to surface roughness of composite resins from simulated tooth brushing and found that the composite resins with a micro-sized filler and a soft filler had the greatest resistance to abrasion and retained the smoothest surface.  

Mandikos et al. conducted a study to compare the wear resistance and hardness of indirect composite resins. And found that the differences in wear, hardness, and average surface roughness may have been due to the differences in the chemistry or the method of polymerization of the composites. Indicated that under simulated conditions of tooth brushing, the second generation indirect composites have not improved on the wear and hardness properties.  

Suzuki et al. conducted an in vitro wear study of indirect composite restoratives and found that some indirect composite restoratives have similar wear resistance to Type III gold alloy. Antagonistic enamel was abraded more by composite materials with high filler content.  

Mehl et al. conducted a study to measure the wear of composite resin veneering materials and enamel in a chewing simulator, and resulted that the wear of the ultrafine compact filled composite resins was not statistically significantly different from that of human enamel. The other composite resins and bovine enamel showed a wear statistically significantly higher than human enamel.  

Results indicated that the indirect resin composites have an inferior wear resistance to the human enamel.

**Summary and Conclusion**  
Indirect resin composites have been developed in order to overcome the inherent limitations of direct composites such as incomplete polymerization and poor mechanical properties. The present study was conducted to evaluate and compare the wear resistance of two commercially available indirect resin composites - SR Adoro (Ivoclar Vivadent) and Ceramage (Shofu, Japan) and human enamel, which was considered as a control in this study.

Within the limitations of this study, it was found that all samples exhibited a loss of weight and an increase in surface roughness after wear simulation process. Enamel exhibited a mean wear rate that was significantly lower than the composites tested. When Adoro and Ceramage were statistically compared for percentage weight loss, it was seen that there was no statistically significant difference of wear between both the materials. Hence, the wear resistance of both the indirect resin composite materials was similar.

**References**

12. DeLong R. Intra-oral restorative materials wear:

<table>
<thead>
<tr>
<th>Table 6: Results of t-test for percentage weight loss and change in surface roughness between Ceramage and control.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramage (%)</td>
</tr>
<tr>
<td>0.263</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 7: Results of t-test for percentage weight loss and change in surface roughness between Adoro and Ceramage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoro (%)</td>
</tr>
<tr>
<td>0.330</td>
</tr>
</tbody>
</table>
Rethinking the current approaches: How to measure wear.
