The effect of toothbrushing on surface gloss of resin composites

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ABSTRACT: Purpose: To determine the changes in surface gloss of different composite materials after laboratory toothbrushing simulation. Methods: 36 specimens were fabricated for each material and polished with 120-, 220-, 500-, 1200-, 2400- and 4000-grit SiC abrasive paper, respectively. Gloss measurements were made with a glossmeter (Novocure) prior to testing procedures and then subjected to simulated toothbrushing for 5, 15, 30 and 60 minutes by means of an electric toothbrush with a pressure of 2N while being immersed in a 50 RDA toothpaste slurry. Four supplementary samples per group were analyzed under SEM immediately after polishing procedures and four samples after 60 minutes simulated toothbrushing in order to evaluate the causes of the gloss decrease. The tested resin composite materials were Filtek Supreme XTE, Durafill, HRi Enamel Plus, Miris 2, Empress Direct, Venus Diamond, Gradia Direct, Clearfil Photo Posterior and G-aenial. Natural enamel represented the control group. Statistical analysis was performed using Kruskal Wallis and Tukey post-hoc test, with a level of significance set at 0.05. Results: Resin composite initial gloss values ranged from 68.9 to 100.5 at baseline to 10.6 to 62.6 after 1 hour of brushing. Highest gloss values were obtained by Filtek Supreme XTE, followed by Empress Direct and Durafill. Lowest values were obtained by Clearfil Photoposterior, Miris 2, Enamel HRi and Venus Diamond. Natural enamel was the only substrate to maintain its gloss throughout the brushing procedure (110.4 after 60 minutes). SEM analysis revealed different patterns of surface degradation depending on the composite material. (Am J Dent 2012;25:54-58).

CLINICAL SIGNIFICANCE: None of the resin composites performed as well as natural enamel. Some restorative materials exhibited a decreased gloss due to toothbrushing, which might result in an esthetic problem.

Introduction

The esthetic restoration of the anterior dentition represents one of the greatest challenges in current daily practice. Continuous improvements regarding the esthetic properties of resin composites such as color match, translucency and opalescence have led to natural looking restorations. As a consequence, these resin composites are increasingly used as an alternative to porcelain-fused-to-metal (PFM) crowns and ceramic veneers for the restoration of severely compromised anterior teeth. In this indication, not only color match, translucency and opalescence, but also surface gloss is of paramount importance.

Surface quality of restorations is in fact one of the important factors that determine their clinical success. A smooth surface can improve longevity and esthetics of restorations by reducing plaque accumulation and surface staining, allowing successful mimicking of the tooth’s natural appearance. Directly related to surface quality is also the ability of the material to reflect direct light. This optical phenomenon is defined as gloss or reflective capacity. Differences in gloss between a restoration and surrounding enamel are clinically relevant as the human eye can easily detect differences in gloss even if their colors are matched. On the other hand, high gloss reduces the effect of a color difference, since the color of reflected light is more predominant than the color of the underlying composite material.

Modern resin composites can achieve a high luster if appropriate polishing procedures are used. Gloss is an attribute of visual appearance that originates from the geometrical distribution of light reflected by the surface, and is directly influenced by the surface roughness. However, the high gloss level obtained immediately after polishing procedures is not clinically stable over time, leading to a matte surface. Previous studies that investigated the influence of toothbrushing on surface gloss and surface roughness of resin composites showed a decrease in gloss and increase in roughness of various resin composites, as well as differences between the observed materials. This decrease in gloss is the result of degradation due to mechanical and/or chemical interaction with the oral environment, resulting in changes in surface gloss and therefore deteriorated esthetics at long term. This surface degradation may be due to several factors: wear of fillers, degradation of the resin matrix or weakening of resin-filler bonding. These three factors lead to a roughening of the surface which is the main cause of a gloss decrease. Clinically, this kind of superficial degradation can cause esthetic problems especially in patients who present a high lip line. In this case, the different refraction index between natural tooth and resin composite on upper anterior teeth free of saliva can cause a severe esthetic problem.

Newly developed resin composites have no information available on their surface gloss. Therefore, the present study evaluated the gloss behavior of newly developed resin composites with different filler range and mechanical characteristics such as Enamel HRi, Gradia Direct, Empress Direct and G-aenial, (Table 1) immediately after polishing and after toothbrushing simulation, compared to natural enamel and reference materials. The null hypothesis was that surface gloss of resin composites was not influenced by laboratory toothbrushing simulation.

Material and Methods

Nine resin composites were selected, i.e. eight indicated by the manufacturer as anterior restorative materials and one for posterior restorations (negative control) (Table 1). Natural enamel was added as a positive control.
Specimen preparation - Thirty-six disc-shaped specimens measuring 10 mm in diameter were made of each of nine composites (Table 1), resulting in a total of 324 samples, by covering the resin composite with a transparent matrix strip and gently pressing it with a glass slide to the thickness of 1 mm. The resin composites were light cured for 40 seconds from a distance of 1 mm by using a curing light (L.E.Demerton II) at a light intensity of 1100 mW/cm² as measured with a radiometer (L.E.D.radiometer). One additional group, made of 36 slices of natural tooth enamel (ENML) obtained from freshly extracted human anterior teeth, was added to the restorative material groups as a positive control. This enamel extracted human anterior teeth was added to the restoration material groups for the SEM evaluation.

Gloss measurements - Surface gloss was measured by means of a glossmeter (Novo-Curve) according to Heintze et al. This device measures the amount of light reflected from the surface of an object, which is then translated into a numerical scale. The measuring principle of this device is based on a light beam that strikes the object at a 60° angle. The intensity of the reflected light is measured and compared to the reference value. The device has a measuring window of 2 mm x 8 mm over which the specimen is placed and then covered with a black film container to avoid external light exposure during the measurement. Each time before a new measurement was made, the glossmeter was calibrated by comparing the results with a calibration plate provided by the manufacturer, which has a reference value of 94.0 and by checking the zero point to exclude negative values.

Simulated toothbrushing - After baseline gloss measurements, each specimen (n=36 per material) was then subjected to consecutively 5, 15, 30 and 60 minutes of brushing with an electric toothbrush (Triumph Professional Care) fixed on a custom-made holder, applying a standardized force of 2 N. The specimens were immersed in a toothpaste slurry consisting of 3 g 50 RDA toothpaste (Signal) mixed with 0.3 mL of distilled water. After each treatment the slurry was renewed and specimens were thoroughly cleaned of any treatment material residue due both manually and in an ultrasonic bath with distilled water for 10 minutes in order to remove eventual smear layer created on their surface. Surface gloss measurements were made subsequently using the NovoCurve device as described above.

SEM evaluation - Four specimens of each material before and four samples after 1 hour of simulated toothbrushing were gold sputtered and then analyzed by scanning electron microscopy (SEM Phillips XL 20) in order to investigate possible surface changes.

Statistical analysis - Statistical analysis was performed with SPSS 17.0 software. As the distribution of data was not normal (Kolmogorov-Smirnov test) non parametric methods were used. A Wilcoxon signed-rank test was run for each paired group, i.e. before vs. after treatment (P= 0.05). Furthermore, to detect whether the results were material dependent, a Kruskal-Wallis test was run. Tukey post-hoc test was used to detect differences among group means.

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**Table 1. Description of the tested materials.**

<table>
<thead>
<tr>
<th>Product</th>
<th>Composite classification</th>
<th>Filler type</th>
<th>Filler mean particle, size and range</th>
<th>Matrix composition</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empress Direct</td>
<td>Inhomogeneous microhybrid with homologous splinters</td>
<td>Ba-Al-fluorosilicate glass; barium glass filler (0.4 µm), mixed oxide (150 nm)</td>
<td>Mean 550 nm range 150 nm-0.4µm</td>
<td>Dimethacrylate</td>
<td>EMP</td>
</tr>
<tr>
<td>Miris 2®</td>
<td>Inhomogeneous microhybrid with homologous splinters</td>
<td>Silanized barium glass, amorphous silica splinters 15-20 µm (mean 1 µm)</td>
<td>Mean 0.6 µm Range 0.02 µm-2.5 µm</td>
<td>Methacrylate</td>
<td>MIR</td>
</tr>
<tr>
<td>G-aenial</td>
<td>Inhomogeneous microhybrid with homologous splinters</td>
<td>Strontium and lanthanoid fluoride pre-polymerized fillers (16-17 µm)</td>
<td>Range 16 nm-17 µm</td>
<td>UDMA Dimethacrylate co-monomer</td>
<td>GAE</td>
</tr>
<tr>
<td>Gradia Direct</td>
<td>Inhomogeneous microhybrid with heterologous splinters</td>
<td>Silica 0.85 µm Prepolymerized filler</td>
<td>Mean 850 nm Range 20 nm-20 µm</td>
<td>UDMA</td>
<td>GRA</td>
</tr>
<tr>
<td>Filtek Supreme XTE®</td>
<td>Inhomogeneous microhybrid with aggregated particles</td>
<td>Silica filler (20 nm) Zirconia filler 4-11 nm Aggregated zirconia/silica cluster filler (0.6-10 µm)</td>
<td>Mean 0.6 µm Range 20 nm-10 µm</td>
<td>bisGMA, UDMA, TEGDMA, bis-EMA</td>
<td>SUP</td>
</tr>
<tr>
<td>Enamel HRi</td>
<td>Homogeneous microhybrid</td>
<td>Glass filler (mean 1.0 µm) nano zirconium oxide particles 20 nm</td>
<td>Mean 0.9 µm Range 20 nm-2 µm</td>
<td>Diurethandimethacrylate bisGMA 1,4-butanoldimethacrylate</td>
<td>HRI</td>
</tr>
<tr>
<td>Durafile®</td>
<td>Microfilled inhomogeneous</td>
<td>Silicon dioxide (0.02-0.07µm) splinter polymer (2-20 µm)</td>
<td>Mean 0.04 µm Range 0.02-0.2 µm</td>
<td>UDMA</td>
<td>DUR</td>
</tr>
<tr>
<td>Venus Diamond®</td>
<td>Fine hybrid</td>
<td>Ba-Al fluoride glass nano-particles 5 nm-20 µm</td>
<td>Mean 0.6 µm Range 5 nm-20 µm</td>
<td>TCD-DI-HEA, UDMA</td>
<td>DIA</td>
</tr>
<tr>
<td>Clearfil Photo Posterior®</td>
<td>Coarse hybrid</td>
<td>Silanated silica Silanated barium glass silanated colloidal silica</td>
<td>Mean 1-2 µm</td>
<td>bisGMA TEGDMA urethane tetramethacrylate</td>
<td>CPP</td>
</tr>
</tbody>
</table>
Table 2. Mean gloss values at baseline and after each brushing cycle of 5, 15, 30 and 60 minutes (GU), ΔGU and the group of statistical significance of each material.

<table>
<thead>
<tr>
<th>Material</th>
<th>Baseline (± SD)</th>
<th>After 5 minutes (± SD)</th>
<th>After 15 minutes (± SD)</th>
<th>After 30 minutes (± SD)</th>
<th>After 60 minutes (± SD)</th>
<th>ΔGU</th>
<th>Statistical significance (after 60 minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRI</td>
<td>88.2 (±7.1)</td>
<td>29.0 (±12.3)</td>
<td>15.9 (± 5.6)</td>
<td>12.8 (±2.9)</td>
<td>10.6 (±2.2)</td>
<td>77.7</td>
<td>F</td>
</tr>
<tr>
<td>DIA</td>
<td>82.5 (±4.3)</td>
<td>53.3 (±12.8)</td>
<td>17.2 (± 8.7)</td>
<td>12.1 (±5.7)</td>
<td>12.5 (±5.5)</td>
<td>70.1</td>
<td>FE</td>
</tr>
<tr>
<td>GAE</td>
<td>79.5 (±4.1)</td>
<td>26.7 (± 7.9)</td>
<td>18.4 (± 7.4)</td>
<td>16.5 (±5.1)</td>
<td>13.4 (±4.8)</td>
<td>66.1</td>
<td>FE</td>
</tr>
<tr>
<td>CPP</td>
<td>68.9 (±6.2)</td>
<td>33.1 (± 9.6)</td>
<td>22.1 (± 6.9)</td>
<td>19.0 (±8.2)</td>
<td>14.8 (±5.7)</td>
<td>54.2</td>
<td>E</td>
</tr>
<tr>
<td>MIR</td>
<td>81.1 (±4.7)</td>
<td>53.3 (±11.7)</td>
<td>42.6 (± 9.0)</td>
<td>29.6 (±9.0)</td>
<td>18.9 (±5.9)</td>
<td>62.2</td>
<td>D</td>
</tr>
<tr>
<td>GRA</td>
<td>78.7 (±2.9)</td>
<td>30.0 (±12.3)</td>
<td>31.8 (±11.1)</td>
<td>21.6 (±6.5)</td>
<td>20.8 (±7.2)</td>
<td>58.0</td>
<td>D</td>
</tr>
<tr>
<td>DUR</td>
<td>84.2 (±5.8)</td>
<td>77.5 (± 6.0)</td>
<td>67.9 (± 6.9)</td>
<td>56.8 (±7.6)</td>
<td>48.0 (±5.5)</td>
<td>36.2</td>
<td>C</td>
</tr>
<tr>
<td>EMP</td>
<td>86.7 (±3.8)</td>
<td>83.6 (± 5.3)</td>
<td>73.1 (± 7.9)</td>
<td>65.1 (±7.3)</td>
<td>51.1 (±7.4)</td>
<td>35.6</td>
<td>C</td>
</tr>
<tr>
<td>SUP</td>
<td>100.5 (±4.2)</td>
<td>83.2 (± 6.3)</td>
<td>74.0 (± 7.1)</td>
<td>68.2 (±8.9)</td>
<td>62.6 (±7.5)</td>
<td>37.9</td>
<td>B</td>
</tr>
<tr>
<td>ENML</td>
<td>113.2 (±4.0)</td>
<td>111.3 (± 6.3)</td>
<td>116.6 (± 2.1)</td>
<td>111.9 (±5.8)</td>
<td>110.4 (±1.4)</td>
<td>2.8</td>
<td>A</td>
</tr>
</tbody>
</table>

*ΔGU is the difference in gloss values between the initial and the final values. It is calculated according to the following formula: GUinit - GUfin where init and fin are the respective values at the baseline and at the end of the experimental phase.

Results

Initial gloss values of each composite material and changes from baseline after each cycle of brushing are shown in Table 2. Resin composite gloss at baseline ranged from 68.9 (CPP) to 100.5 (SUP) GU (gloss units). After 1 hour of toothbrushing simulation gloss values ranged from to 10.6 to 62.6 (SUP) GU.

The highest ΔGU was detected for HRi, followed by DIA, GAE and CPP. EMP showed the lowest ΔGU.

Natural enamel provided the best baseline and post-treatment gloss values, resulting in the lowest ΔGU when compared to the tested resin composite materials (Figs. 1, 2).

SEM images of the tested materials before and after 60 minutes of simulated toothbrushing are shown in Figs. 3A-D.

Discussion

A visual gloss evaluation may include many errors due to subjectivity. Therefore, a numeric quantitative approach such as a glossmeter device is mandatory to achieve an objective evaluation. Furthermore, the glossmeter used in this study (Novo-Curve) was specifically chosen because it is able to measure surface gloss of a restricted area.

The composites evaluated in this study were chosen according to the influence of the composition of the resin composite on the surface gloss. Natural enamel was chosen as positive control because it is supposed to be the ideal natural substrate. Clearfil PhotoPosterior on the other hand was considered as negative control due to its mean filler size which suggests indication for posterior restorations only. 13

The samples were prepared under standardized conditions. Pre-roughening of the specimens was found necessary to eliminate voids in the external layer of the composite samples. In most studies 14-18 pre-roughening was performed either with diamond or tungsten carbide burs to mimic clinical procedures. However, Heintze et al 13 claimed that pre-roughening with diamond burs resulted in an inhomogeneous surface texture and consequently in increased scattering of the results. In order to obtain a standardized force, a calibration session was initiated prior to the application of the polishing system, using an electronic laboratory scale to measure the force applied (2 N) during the polishing steps. 19 To overcome the possible influence of the type of illumination and angle of the observer, a glossmeter with 60° angle of illumination was used for all measurements. 20

As previously reported, 7,21 toothbrush abrasion of composite materials varied according to the type of composite, type of toothpaste 22 and the nature of the toothbrush employed. 23 There-
Fig. 3A-D. SEM images of Clearfil PhotoPosterior and Filtek Supreme XTE before and after 60 minutes of simulated toothbrushing. A. Filtek Supreme XTE before simulated toothbrushing. B. Filtek Supreme XTE after 60 minutes toothbrushing. C. Clearfil PhotoPosterior before simulated toothbrushing; D. Clearfil PhotoPosterior after 60 minutes of toothbrushing. The surface integrity was substantially maintained. Only small superficial defects are present, which might be due to loss of hard zirconium particles. Decrease in surface quality with resin loss and appearance of macrofillers can be observed.

Therefore, absolute values of the results of this study cannot be compared with other reports.

In the present study, the specimens were brushed during 60 minutes, which may correspond to the amount of toothbrushing that is carried out over a period of 2 years, if it is assumed that the ideal brushing time is 120 seconds three times a day which is equal to a tooth surface brushing of 6 seconds a day. However, various studies showed that the actual mean brushing, even if variable, is about 120 seconds per day, which corresponds to 2 seconds per day per tooth surface. Therefore, our brushing simulation may correspond to a clinical simulation of 6 years.

After polishing procedures at baseline, natural tooth showed the highest gloss. This highlights the fact that, so far, no resin composite is able to mimic reflectivity of the natural tooth. However, Filtek Supreme XTE, a micro-hybrid with aggregated clusters of SiO₂ and ZrO nano particles, showed the highest luster among the tested materials (Fig. 3A). This could be due to the fact that only microfillers are present in this material. Enamel HRi, Empress Direct and Durafill showed all a higher reflectivity than the coarse hybrid but lower than Filtek Supreme XTE. All three restorative materials contained small filler particles (20 nm-0.4 µm). According to Lee et al not only the filler size, but the resin matrix system as well as the shape of the fillers influence initial gloss of materials. Light reflectivity seems, therefore, to be related to mean filler size and to the homogeneity of the filler-matrix complex. Higher filler size and lower homogeneity of the filler-matrix complex result in less light reflectivity.

The present study clearly showed that, except for the natural tooth group, the surface gloss of all the materials was significantly reduced by simulated toothbrushing. This phenomenon, as reported in other studies, was material dependent. Gloss decrease is influenced by the resin matrix, filler particles and the silanization between both. Whenever fillers are much harder than the surrounding resin, this may result in a rough surface after toothbrushing simulation. The abrasion of the softer resin might cause a lack of support of the filler, which finally detaches from the matrix, resulting in a concavity in the surface (Photohole effect). This phenomenon may be the cause of the poor gloss values observed for Clearfil PhotoPosterior (Fig. 3D) and Venus Diamond. On the other hand, when the material consists of softer fillers, such as Filtek Supreme XTE, the abrasion will occur in a more uniform way, therefore resulting in a smoother surface and thus a higher gloss (Fig. 3B).

Silanization, on the other hand, is another factor of paramount importance. A higher quality of silanization might explain the lower ΔGU for Empress Direct when compared to other materials of the same family (inhomogeneous microhybrid resin composite with homologous splinters), as claimed by the manufacturer.

Within the limitation of this study, natural enamel demonstrated to be the best substrate in respect to gloss stability and behavior throughout toothbrushing simulation. In fact, no artificial material showed comparable behavior. The null hypothesis was therefore rejected.

In future studies, the influence of specific parameters and parameter combinations should be evaluated in order to determine their exact influence on gloss.

a. Micerium, Avegno, Italy.
b. GC, Leuven, Belgium.


