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Laboratory evaluation of the effect of toothbrushing on surface gloss of resin composites

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ABSTRACT: Purpose: To determine changes in surface gloss of different composite materials after laboratory toothbrushing simulation. Methods: 40 specimens were fabricated for each material (Filtek Supreme XTE, Renamel, Empress Direct, Gradia Direct, Edelweiss, G-aenial, Venus Pearl and Venus Diamond) and polished with 120-, 220-, 500-, 1200-, 2400- and 4000- grit SiC abrasive paper, respectively. Gloss measurements were made with a glossmeter prior to testing procedures and then subjected to simulated toothbrushing for 5, 15, 30 and 60 minutes by means of an electrical toothbrush with a pressure of 2N while being immersed in a 50 RDA toothpaste slurry. Four 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. Human enamel was the control group. Statistical analysis was performed using Kruskal Wallis and Tukey’s post-hoc test (P< 0.05). Results: Resin composite initial gloss values ranged from 78.2 to 100.5 at baseline to 13.8 to 62.4 after 1 hour of brushing. Highest gloss values were obtained by Filtek Supreme XTE and Renamel (P< 0.05), followed by Empress Direct. Lowest values were obtained with Venus Diamond, Venus Pearl, G-aenial and Edelweiss. Human enamel was the only material which maintained its gloss throughout the brushing procedure (110.4 after 60 minutes). SEM analysis revealed different patterns of surface degradation dependant on the material. (Am J Dent 2014;27:42-46).

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

Introduction

The esthetic restoration of the anterior dentition is 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 incisors. Therefore, not only color match, translucency and opalescence, but also durable surface gloss is of paramount importance.1

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 a successful mimic of natural tooth appearance.2,3 Directly related to surface quality is also the ability of the material to reflect 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 predominant to the color of the underlying composite material.4

Current resin composites can achieve a high gloss.2 Being an attribute of visual appearance that originates from the geometrical distribution of light reflected by the surface, gloss is directly influenced by the surface roughness.2 However, the high gloss level obtained immediately after polishing procedures is not clinically stable over time, leading to a matte surface. Previous studies5,6 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 investigated resin composites, as well as differences between the materials evaluated.

This decrease in gloss was the result of degradation due to mechanical and/or chemical interaction with the oral environment, and therefore deteriorated esthetics in the 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 factors lead to a roughening of the surface which is the main cause of decrease in gloss. Clinically, this superficial degradation can cause esthetic problems.

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 (Renamel,a Gradia Direct,b Empress Direct,c G-aenial,d Filtek Supreme XTE,d Gradia Direct,b Edelweiss,e and Venus Pearl,f) with different filler range and mechanical characteristics. Their gloss was quantified immediately after polishing and after toothbrushing simulation and compared to the gloss of human enamel. The null hypothesis was that surface gloss of the resin composites was not significantly influenced by a laboratory toothbrushing simulation.

Materials and Methods

Eight resin composites were selected, indicated by the manufacturer as anterior restorative materials (Table 1). Human enamel was used as the positive control.

Specimen preparation - Forty disc-shaped samples measuring 10 mm in diameter were made of each of eight composites (Table 1), resulting in a total of 320 samples, by covering the...
resin composite with a transparent matrix strip and gently pressing it with a glass slide to a 1 mm thickness. The resin composites were light cured for 40 seconds from a distance of 1 mm with a L.E.D., Demetron II curing light at a light intensity of 1,100 mW/cm² as measured with a L.E.D. radiometer. One additional group, made of 36 slices (10 mm diameter, 1 mm thick) of natural enamel obtained from freshly extracted human incisors, was used as the positive control. This enamel was subjected to the same polishing protocol and the same testing procedures as the composite materials. The surface of all samples was then polished with 120-, 220-, 500-, 1200-, 2400- and 4000-grit SiC abrasive paper. Polishing was performed for 60 seconds for each grit of abrasive paper under water cooling at a constant force of 2 N as in a previous study. A new abrasive paper was used for every sample. After storage in artificial saliva (Glandosan, HUG) at 37°C for 24 hours, initial surface gloss measurements were made for each sample.

Gloss measurements - Surface gloss was measured with a glossmeter (Novo-Curve) according to Heintze et al. This device measured 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 an angle of 60°. The intensity of the reflected light is measured and compared to the reference value. The device has a measuring window of 2 × 8 mm over which the sample 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 subjected consecutively to 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. One toothbrush head per sample was used throughout the experimental time of 60 minutes in order to assure standardized conditions for all materials. The samples were immersed in a toothpaste slurry consisting of 3 g of a 50 RDA toothpaste (Signal™), mixed with 0.3 ml of distilled water. After each brushing section the slurry was renewed and specimens were thoroughly cleaned from any treatment material residue both manually and in an ultrasonic bath filled up with distilled water for 10 minutes. Surface gloss measurements were made subsequently using the NovoCurve device as described above, immediately after polishing and after 5, 15, 30 and 60 minutes of simulated toothbrushing.

SEM evaluation - Four polished specimens of each material after 60 minutes of simulated toothbrushing were gold-sputtered and analyzed by scanning electron microscopy (Philips XL 20) at different magnifications 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, Shapiro-Wilk 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’s post-hoc test was used to detect differences among group medians.
Table 2. Gloss unit (GU) values before and after 60 minutes of simulated toothbrushing (medians and 25th and 75th percentiles), with the respective group of statistical significance and ΔGU being the difference in GU after 60 minutes of simulated toothbrushing and baseline GU values.

<table>
<thead>
<tr>
<th>Material</th>
<th>Before simulated toothbrushing (GU)</th>
<th>60 minutes simulated toothbrushing (GU)</th>
<th>Statistical significance*</th>
<th>ΔGU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>Human enamel</td>
<td>109.9</td>
<td>111.9</td>
<td>117.9</td>
<td>109.0</td>
</tr>
<tr>
<td>Filtek Supreme XTE (SUP)</td>
<td>97.4</td>
<td>100.5</td>
<td>104.7</td>
<td>58.5</td>
</tr>
<tr>
<td>Renamel (REN)</td>
<td>84.1</td>
<td>88.0</td>
<td>91.7</td>
<td>57.8</td>
</tr>
<tr>
<td>Empress Direct (EMD)</td>
<td>83.9</td>
<td>86.6</td>
<td>89.4</td>
<td>48.2</td>
</tr>
<tr>
<td>Gradia Direct (GRA)</td>
<td>75.8</td>
<td>78.3</td>
<td>80.7</td>
<td>17.5</td>
</tr>
<tr>
<td>Edelweiss (EDE)</td>
<td>81.0</td>
<td>83.9</td>
<td>87.9</td>
<td>13.1</td>
</tr>
<tr>
<td>G-aenial (GAE)</td>
<td>74.8</td>
<td>80.2</td>
<td>83.2</td>
<td>10.4</td>
</tr>
<tr>
<td>Venus Pearl (PEA)</td>
<td>78.0</td>
<td>79.3</td>
<td>81.4</td>
<td>11.4</td>
</tr>
<tr>
<td>Venus Diamond (DIA)</td>
<td>81.0</td>
<td>84.6</td>
<td>87.7</td>
<td>8.2</td>
</tr>
</tbody>
</table>

*Group of statistical significance after 60 minutes of simulated toothbrushing.

Results

Initial gloss values of each composite material and changes from baseline after each cycle of brushing are shown in Fig. 1. Resin composite gloss at baseline ranged from 78.3 (GRA) to 100.5 (SUP) GU (gloss units). After 1 hour of toothbrushing simulation, gloss values ranged from to 13.8 (DIA) to 62.4 (SUP) GU (Table 2), all significantly different from baseline values (P< 0.001). Boxplots of data before and after 60 minutes of simulated toothbrushing are presented in Figs. 2 and 3.

The highest ΔGU was detected for DIA, followed by EDE, GAE, PEA and GRA. EMP and SUP showed the lowest ΔGU.

Human enamel provided the best baseline and post-treatment gloss values, resulting in the lowest ΔGU when compared to the tested resin composites (Fig. 1 and Table 2). Statistical differences were observed between the different materials after 60 minutes of simulated toothbrushing (P< 0.001), as represented by the groups of statistical significance in Table 2.

SEM images of the tested materials before and after 60 minutes of simulated toothbrushing are shown in Figs. 4A-D.

Discussion

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. The glossmeter used in this study (Novo-Curve) was specifically chosen because it is able to measure surface gloss of a restricted area.

The resin composites evaluated in this study were chosen as they represented a group of materials relatively recently introduced onto the market. They were compared to human enamel (positive control) because it is supposed to be the ideal natural
Fig. 4. Figs. 4A-D. SEM images of Filtek Supreme XTE and Venus Diamond before and after 60 minutes of simulated toothbrushing. For Filtek Supreme XTE, the surface integrity was substantially maintained. Only small superficial defects are present, which might be due to loss of hard zirconium particles. For Venus Diamond, decrease in surface quality with resin loss and appearance of macro-fillers (large Al Ba fluoride particles) can be observed.

A. Filtek Supreme XTE before simulated toothbrushing.
B. Filtek Supreme XTE after 60 minutes toothbrushing.
C. Venus Diamond before 60 minutes toothbrushing.
D. Venus Diamond after 60 minutes toothbrushing.

As previously reported, the investigated materials represented different composite types, in order to investigate the possible influence of the composition of the resin composite on the surface gloss. The samples were prepared under standardized conditions. Pre-roughening of the specimens was done in order to eliminate voids in the external layer of the composite samples. In most studies, pre-roughening was performed either with diamond or tungsten carbide burs to mimic clinical procedures. However, Heintze et al. 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. 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.

As previously reported, toothbrush abrasion of composite materials varied according to the type of composite, type of toothpaste and the nature of the toothbrush employed. Therefore, absolute values of the results of this study cannot be compared with other reports.

In the present study, the samples were brushed for 60 minutes, which may correspond to the amount of toothbrushing carried out over a 2-year period, if 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 about 6 years.

After the polishing procedures at baseline, human enamel showed the highest gloss. This highlights the fact that, so far, no resin composite is able to mimic the reflectivity of the natural tooth. However, Filtek Supreme XTE, a micro-hybrid with aggregated clusters of SiO$_2$ and ZrO nanoparticles, showed the highest gloss among the tested materials (Fig. 4A). This could be due to the fact that only microfillers are present in this material. Empress Direct and Renamel showed both a higher gloss than the other microhybrids, but significantly lower than that of 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 may result in less light reflectivity.

The present study clearly showed that, except for the natural enamel group, the surface gloss of all the materials was significantly reduced by simulated toothbrushing. This phenomenon, as previously reported, 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 (photo-Hall effect). This phenomenon could be the cause of the
poor gloss values observed for Venus Diamond and Venus Pearl, which have fillers of up to 20 µm (Fig. 4D). On the other hand, when the material consists of smaller and 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. 4A). Renamel consists of particles smaller than the wavelength of the visible light, resulting in a higher reflectivity. Some of these small fillers form prepolymerized particles up to 64 µm (Table 1).

Silanization of the filler particles is another factor of paramount importance.27 A higher quality of silanization, as claimed by the manufacturer, might explain the lower △GU 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 limitations of this study, human enamel demonstrated to be the best substrate in respect to gloss stability and behavior throughout toothbrushing simulation. In fact, no artificial material tested in the present study showed comparable results. The null hypothesis was therefore rejected. These results showed that when choosing a resin composite material for an adhesive reconstruction these results may have an impact on esthetics as well as periodontal and bacterial implications caused by a rough surface.

In future studies, the influence of specific parameters such as filler size, form and nature as well as the exact composition of the resin matrix should be evaluated in order to determine their exact influence on gloss. Furthermore, results from resin composite materials should be compared to results obtained from ceramic materials in order to evaluate their different behaviors.

References