Influence of mechanical and chemical degradation on surface gloss of direct and CAD-CAM resin composite materials

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Influence of mechanical and chemical degradation on surface gloss of direct and CAD-CAM resin composite materials

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Abstract: Purpose: To compare the gloss retention of four resin based materials, two direct resin composites (Tetric EvoCeram and Filtek Supreme) and two indirect resin composite CAD-CAM blocks (Tetric CAD and Lava Ultimate). **Methods:** 36 samples of 1 mm thickness were readied of each test material and manually polished with polishing discs (Sof-Lex) up to the finest grit size. Three gloss measurements per sample were taken (one every 120 degrees of sample rotation) by means of a glossmeter (Novo-Curve) for a total of 60 values obtained per tested material. Samples of each material were then randomly divided into three equal groups and aged with 75% alcohol (Group 1), amine fluoride gel (Elmex gelée) (Group 2) or mechanical brushing (Group 3). Another set of gloss measurements was performed on all samples after 1 hour of aging. Gloss values were statistically evaluated by means of repeated measures ANOVA and Fisher's LSD post-hoc tests. **Results:** Gloss retention values ranged from 59.0 (Tetric EvoCeram) to 70.9 (Lava Ultimate) for alcohol, from 59.3 (Filtek Supreme) to 67.5 (Lava Ultimate) for Elmex gelée and from 33.3 (Tetric EvoCeram) to 53.4 (Lava Ultimate) for mechanical brushing. Statistical analysis revealed: (1) significant difference between intial and final gloss values for all materials and groups; (2) significant difference between final gloss values of all the materials in the alcohol group; (3) significant difference between final gloss values of Lava Ultimate and all the other materials in the Elmex gelée group; (4) significant difference between final gloss values of Lava Ultimate and Tetric CAD with the other tested materials in the brushing group. (*Am J Dent* 2020;33:157-160).

Clinical significance: Direct resin composites in general are widely used, and CAD-CAM resin composite materials are becoming progressively more accessible. Making the choice between direct and indirect techniques is still a challenge, and understanding the advantages of CAD-CAM resin composites in the form of higher gloss retention, which translates into higher durability of esthetics, may be one the parameters facilitating the decision.

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Introduction

Resin composites are the most commonly used materials in adhesive dentistry today, combining esthetic properties with mechanical resistance, and are user-friendly for dentists.[1] Furthermore, their relatively low cost allows for a large variety of treatments and problem solving in general dentistry even for highly demanding patients. Along with form, color match, translucency and opalescence, gloss represents one of the pillars on which esthetic dentistry is based,[2-6] and it is of paramount importance especially in anterior tooth restorations on patients with high lip line position. Due to limited saliva coverage, the different refraction index between natural tooth and resin composite may pose a problem at the esthetic level for these patients.[7]

All resin composites can be polished to a high luster if appropriate procedures are employed.[8] However, gloss does not last forever due to mechanical wear, brushing habits, acidic and alcoholic attacks as well as the continuous enzymatic attacks from enzymes in saliva which tend to leave a rough and matte surface. Gloss is related to the geometrical distribution of light reflected by the surface,[9] gloss is thus directly influenced by the surface roughness. Loss of surface gloss can be due to several factors such as wear of fillers, degradation of the resin matrix or weakening of resin-filler bonding. In order to increase mechanical properties of resin composites and to extend their clinical indication into large cavities, indirect resin composite materials can be submitted to additional curing procedures, like heat and pressure, for example, before being sent to dentists. Such indirect resin composite restorations maintain the advantages of easy reparability, favorable flexural modulus and convenient handling, but as a disadvantage require the involvement of a dental lab technician. With the evolution of optical scanners and chairside indirect restorative treatments, resin composite CAD-CAM blocks have been introduced into the market. They are often made out of similar components of their corresponding direct resin composite products, but fabricated in blocks where higher conversion rate is achieved due to the specific fabrication method, which theoretically should deliver better clinical performance.

Another trend in composite manufacturing is to include nanofillers in the resin matrix. As nanofillers are smaller than the wavelength of visible light, they enhance the material's gloss retention.

This in vitro study compared the gloss retention of two direct composite materials (Tetric EvoCeram[a] and Filtek Supreme[b]) and two respective indirect CAD-CAM blocks (Tetric CAD[a] and Lava Ultimate[b]). The first null hypothesis was that mechanical and chemical agents do not have a direct effect on surface gloss of direct or CAD-CAM resin composites. The second null hypothesis was that no difference in respect to surface gloss exists between gloss retention of direct and CAD-CAM resin composites.

Materials and Methods

Sample preparation - A total of 144 samples of 1 mm thickness were made of the four tested materials (n= 36). For

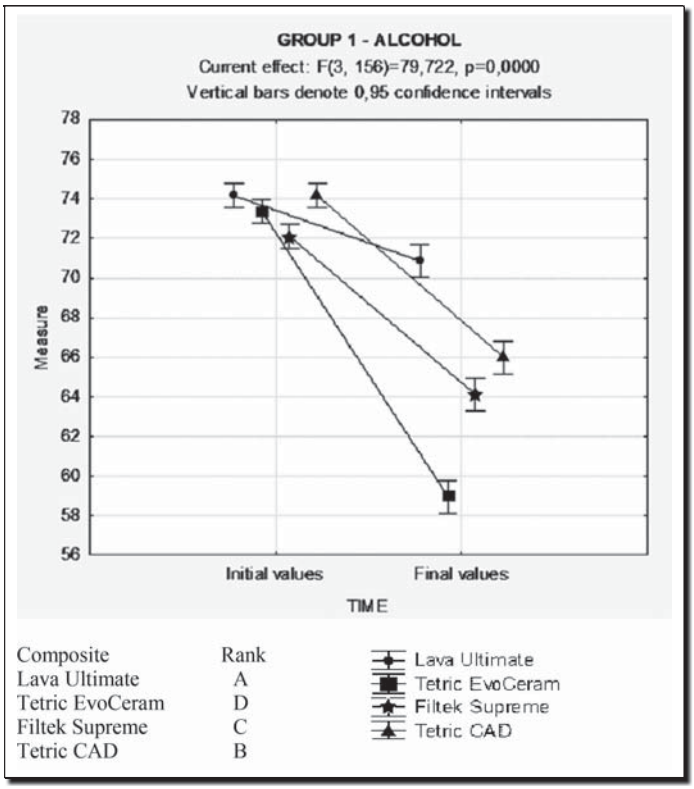

Fig. 1. Graphical representation of composites' gloss retention for the alcohol test as well as their ranking, where A is the best and D is the worst.

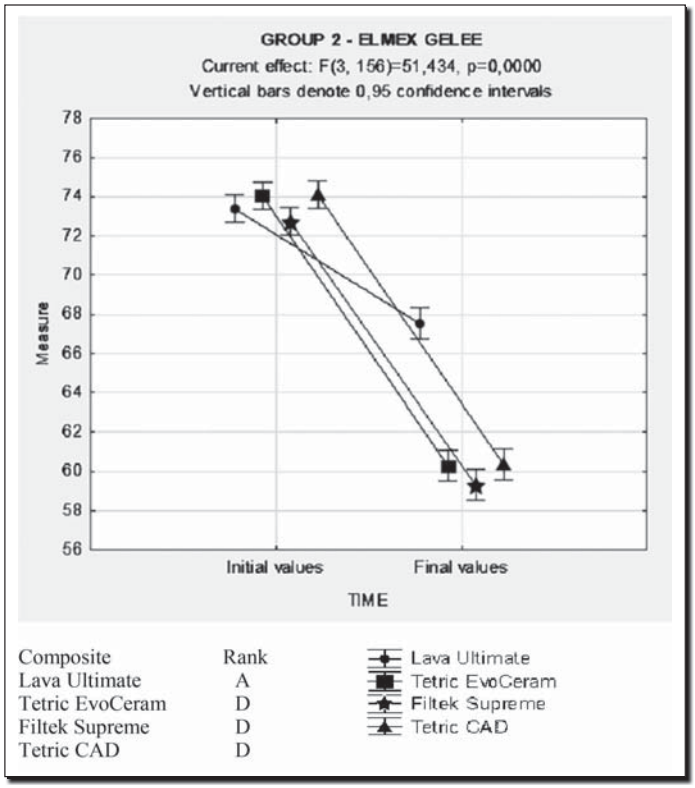

Fig. 2. Graphical representation of composites' gloss retention for the Elmex gelée test, as well as their ranking where A is the best and D is the worst.

the two tested direct resin composites [Filtek Supreme XTE[b] (A1 shade) and Tetric EvoCeram[a] (A1 shade)] specimens measuring 8 mm in diameter were prepared by covering the resin composite with a transparent polyester strip (Hawe Transparent Strips[c]) and gently pressing it with a glass slide to the thickness of 1.1 mm. The resin composite was light-cured for 20 seconds (according to manufacturer's suggestion) from a distance of 1 mm by using a high power LED light curing unit[c] (LCU) at a light intensity of 1,200 mW/cm^2 as measured with a LED radiometer (L.E.Demetron II[c]). Specimens were then manually reduced and polished with polishing discs (Sof-Lex[b]) starting from coarse, medium, fine up to superfine in order to achieve a standardized 1 mm thickness. For CAD-CAM blocks, Lava Ultimate[b] (A1 shade) and Tetric CAD[a] (A1 shade) slices of 1.1 mm were cut by means of a diamond coated wheel (Miniton Fuse 2.5At[d]) and manually reduced and polished by the same sequence of polishing discs up to 1 mm thickness.

Measurements - Three gloss measurements were made per sample (one every 120 degrees of sample rotation) according to the method proposed by Heintze et al[10] by means of a glossmeter (Novo-Curve[e]) for a total of 118 values obtained per tested material. This device measures the amount of light reflected from the surface of an object by translating the reflected light into numerical values. The measuring principle of this device is based on a light beam that strikes the surface at an angle of 60°. The intensity of the reflected light is measured and compared to the reference value. In order to achieve reproducible results and to avoid bias, the glossmeter was recalibrated before each new measurement by comparing the results with a calibration plate provided by the manufacturer.

Sample aging - All samples within each of the tested materials were then randomly divided into three equal groups and aged either for 1 hour in a 75% ethanol aqueous solution (Group 1/alcohol), or covered for 1 hour by amine fluoride gel (Elmex gelée,[f] amine fluoride gel) (Group 2/Elmex gelée) or mechanically brushed for 1 hour by means of a toothbrush (Curaprox 1560 Soft[g]) and a toothpaste (Signal Anti-Caries[h]) (Group 3/brushing) in a brushing machine (Zahnburst-simulator ZM 3.12[i]). Another set of gloss measurements was taken after each of the three aforementioned aging tests. Gloss values were statistically evaluated by means of repeated measures ANOVA and Fisher's LSD post-hoc tests after testing data by means of Kolmogorov-Smirnov test for normality.

In addition to the quantitative measurements of gloss values, samples were then gold sputtered to be qualitatively analyzed by scanning electron microscopy (SEM) (Sigma 300 VP Gemini[j]) in order to investigate possible changes in surface morphology and to better understand gloss variations.

Results

For statistical analysis, 144 samples were evaluated, 36 samples per each group of composite material. The average of the three gloss values per sample was calculated before and after aging. Gloss retention values varied from 59.0±3.4 (Tetric EvoCeram) to 70.9±2.6 (Lava Ultimate) for the alcohol, from 59.3±3.4 (Filtek Supreme) to 67.5±3.2 (Lava Ultimate) for Elmex gelée and from 33.3±2.6 (Tetric EvoCeram) to 53.4±4.5 (Lava Ultimate) for brushing.

Gloss retention data were statistically evaluated by means of repeated measures ANOVA and Fisher's LSD post-hoc tests, which revealed statistically significant differences: (1) significant difference between values of initial and final measurements for all composites and for all groups; (2) significant difference between final values of all the materials in the alcohol group; (3) significant difference between mate-

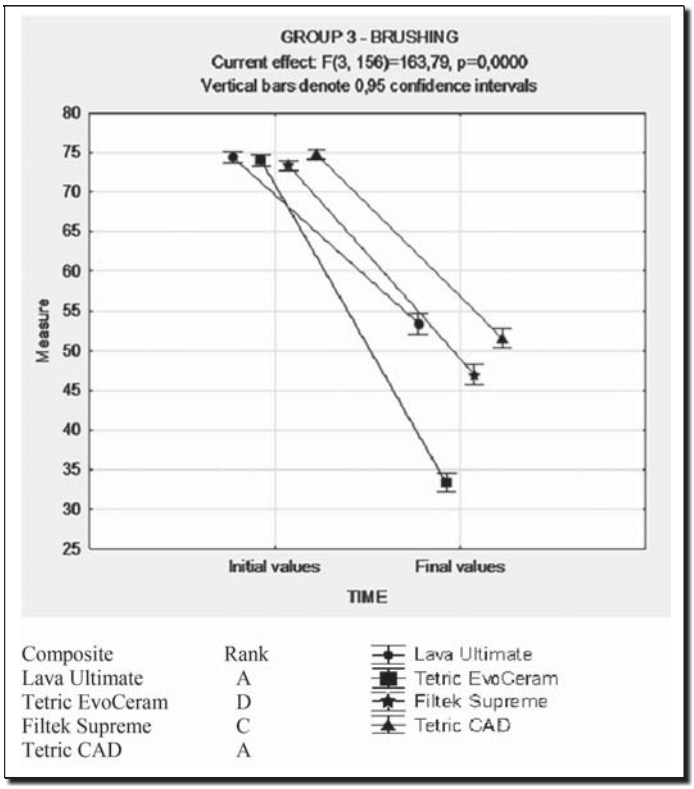

Fig. 3. Graphic representation of composites' gloss retention for the brushing test, as well as their ranking where A is the best and D is the worst.

rials in the Elmex gelée group; (4) significant difference of final values between the tested materials in the brushing group. Figures 1-3 show the results as well as their rankings.

Discussion

The quality of the restoration's surface is one of the key factors for long-term clinical success of resin composites. From a biological point of view, plaque and bacterial accumulation, as well as increased staining susceptibility are enhanced whenever the surface is not smooth.[8,9] From the esthetic point of view, a glossy surface of the restoration may lower the effect of color mismatch with the surrounding tooth structure.[11] In this study, in order to avoid bias imminent to the subjective observation by human eyes, a numeric approach was introduced by means of a glossmeter device (Novo-Curve), which has the capacity to quantify the surface reflectance of composite materials. The construction of this device allows for the elimination of two possible confounding factors such as illumination and angle of the observer,[12] which was set at 60° of illumination for all measurements, following the publication of Da Costa et al.[13]

The choice of the tested materials was made in order to evaluate possible clinical advantages of CAD-CAM blocks compared to their respective direct resin composite materials. This is why Filtek Supreme XTE and Tetric EvoCeram were chosen as direct composite references (the first one nano-filled and the latter a micro-hybrid with pre-polymerized particles) together with Lava Ultimate and Tetric CAD blocks. As this experiment was intended to test the materials under clinically relevant conditions, they were all submitted to common agents such as toothpaste and toothbrush effect (brushing test), acidic challenge (Elmex gelée test) and alcoholic beverages (Alcohol test). In order to be as clinically relevant as possible, all samples were manually polished up to the finest Sof-Lex polishing disk by the same trained operator. This polishing method led to lower gloss numbers at baseline as well as at the end of the experiment compared to other studies where resin composites were machine polished with disks up to a 4,000 grit size.[7,14] This difference is explained by the sub-optimal polishing that can be achieved manually, and furthermore the small irregularities that may be present on the surface polished by hand, but the hand polishing comes much closer to the clinical reality than machine polishing.

Aging by alcohol was simulated by using 75% ethanol as recommended by previous studies.[15,16] According to Condon & Ferracane,[17] simulated aging through ethanol storage (75% ethanol aqueous solution, 37°C) produced an increase in subsequent wear only in resin composite materials that were undercured, while no effect could be detected in well polymerized samples. A possible explanation of the findings that all materials in this study were affected by alcoholic aging may be that direct resin composite materials can only achieve a rather low level of conversion and that the manual polishing may have created some flaws at the surface. When the results after alcohol challenge are analyzed, Lava Ultimate blocks performed the best followed by Tetric CAD blocks, Filtek Supreme and Tetric EvoCeram. This ranking clearly shows the advantages of blocks that are supposed to be better polymerized and thus present a higher degree of polymerization. Alcohol, being an amphiphilic solution, acts by enhancing water sorption of the hydrophilic part of resin composites, more specifically the resin fraction. The increase in volume can alter micromorphology of the surface resulting in lower gloss reflection, as witnessed in this in vitro experiment.

Amine fluoride gels are widely employed as caries-preventive agents. Nevertheless, they are highly acidic due to the formation of hydrofluoric (HF) acid in contact with water. HF acid is known to be very aggressive against glass and ceramics,[18] which are often used as filler particles of resin composites. Acidic food and beverages as well as acidic caries preventive substances may thus etch resin composite surfaces. In order to quantify the extent of this effect on surface gloss, Elmex gelée was tested as previously proposed by Ardu et al.[16] In general, all the composite materials tested were severely affected by the amine fluoride gel. However, the results revealed a clear advantage of Lava Ultimate over the other materials. It seems that the nano-fillers in this CAD-CAM material are more acid-resistant, maybe due to a better silanization of the nanofiller aggregates or due to a better protection by resin. Another possible explanation is that, even if a certain amount of nanoparticles leaks out, the remaining ones still allow for a glossy appearance.

Toothbrush abrasion is a test which is widely discussed and employed in the literature where it has been established that type of resin composite material, toothpaste and toothbrush as well as the brushing force applied on the samples have an influence on results.[6,7,14,19-21] In the present setup, a medium abrasive toothpaste (75 RDA) (Signal Anti-Caries) together with a soft toothbrush (Curaprox Soft 1560) with a standardized brushing force of 1.5 N[22,23] was used in a commercial mechanical brushing device. This methodology limited the variables to only one, the type of composite material. Results

showed that the decrease of gloss, as reported in other studies,[24,25] was material dependent. The tooth brushing test highlighted the advantage of CAD-CAM blocks against direct resin composites as well as the better performance of the direct nano composite in comparison to the hybrid one. Concerning this last point, a possible bias of our study may be related to the renewal of the toothpaste slurry every 5 minutes. Containing only rounded nano particles, Lava Ultimate could have performed slightly better due to possible detachments of fillers which could have then acted as a polishing medium of the surface. In contrast, detached hard polygonal glass particles of the micro hybrid composite Tetric CAD could have worsened the roughness of the surface, thus decreasing gloss values.

Tessarin et al[26] showed that a variation of 17.6 gloss units (ΔGU) is the limit of perceptibility in gloss variation, which was defined as the probability that more than 50% of observers will detect a gloss difference. Therefore, when considering the clinical relevance of gloss variation in our three aging media, only the brushing test caused clinically perceptible changes in the four tested materials.

The first null hypothesis was thus rejected since mechanical and chemical agents had a negative effect on surface gloss of direct resin composite materials as well as of indirect CAD-CAM blocks, which was statistically significant. The second null hypothesis was partially rejected since gloss retention of both CAD-CAM blocks was significantly higher than that of their direct resin composite counterparts in the alcohol and in the brushing tests, while in the Elmex gelée test, only Lava Ultimate CAD-CAM block performed better than its direct resin composite counterpart.

One of the limitations of this study was that no saliva or physiological biofilm were used, which may have led to different results.

Within the limitations of this study, it is concluded that CAD-CAM blocks had a better gloss retention under the different aging protocols applied in this study, maybe due to their higher conversion rate, in respect to direct resin composite materials. Nano-charged resin composites appeared to perform better in regards to gloss retention than the hybrid resin composites.

a. Ivoclar Vivadent, Schaan, Liechtenstein.
b. 3M, St. Paul, MN, USA.
c. Kerr Corporation, Orange, CA, USA.
d. Struers, Ballerup, Denmark.
e. Rhopoint Instrumentation Ltd., Bexhill on Sea, UK.
f. GABA International AG, Therwil, Switzerland.
g. Curaprox, Kriens, Switzerland.
h. Unilever Schweiz GmbH, Thayngen, Switzerland.
i. SD Mechatronik GmbH, Rosenheim, Germany.
j. Zeiss, Oberkochen, Germany.

Acknowledgements: To the manufacturers who generously provided the products tested in this study.

Disclosure statement: The authors declared no conflict of interest.

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