The effect of surface preparation techniques on the color of dental composite resins immersed in different solutions

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The use of dental composites materials requires their finishing and polishing of the composite materials in the final preparation step. We studied the modifications of color of the dental composites when immersed in different solutions on both matte and glossy surfaces. The values of ΔE show that the color modifications of dental composite samples between different roughness surfaces depend on time, solution and material. This knowledge is important to the clinician for the selection of restorative material for the management of patients who have the habit of drinking of wine or other colored drinks.

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1. Introduction

Composite resins are used successfully for restoring all cavity classes in anterior and posterior teeth (1) Performing fillings with composite materials requires several preparation steps. The finishing and polishing are the final steps in realizing a filling with composite materials. They are important from an aesthetical point of view but also in the longevity of composite resin restorations. (1, 2, 3) The finishing refers to the first contour line of the filling and aims to reproduce the anatomical form of the tooth, and the polishing refers to the removing of irregularities created by the finishing instruments.(1, 4) The final form of the fillings is given either by the application of the matrix for compliance or by the finishing and polishing to adjust the anatomic form and the occlusion, and, finally, to obtain a smooth surface. A smooth surface of restoration ensures patient comfort and facilitates oral hygiene. (5) The smoothest surfaces of dental composite materials were produced when the materials were allowed to polymerize against a polyester matrix. (1, 2, 6, 7, 8, 9, 10)

The surface roughness of the composite fillings influences the color of the dental composites.(11, 12, 13) The coloring food and liquids determine modifications of color in the composite materials and require the replacement of the fillings. Among these, the red wine is famous for causing the most important modifications. (14, 15)

The purpose of the study is to determine whether the color difference (ΔE) between a glossy dental composite surface and a matte one is changing in time and if these changes are dependent on the solution of immersion. The analysis of the color parameters and of the coloring differences can be performed by means of the CIE L*a*b* system, and the differences in color by means of ΔE. Regarding the matching of the colors of the composite materials, the ΔE value of 3.5 or smaller value is considered to be clinically acceptable (16). Easy Shade spectrophotometer is able to measure color variations of the composite materials introduced in anthocyanin based food dyes. (17, 18, 19, 20)

Null hypotheses:

1. The first null hypothesis is that ΔE matte/glossy does not depend on the immersion time in solutions.
2. A second null hypothesis is that the solution of immersion has no influence on ΔE.

2. Material and method

Dental composites from three different classes were taken into this study- a composite with micro filling Valux Plus shade A2, a nanocomposite Filtek Ultimate A2 Body Shade and an experimental nanohybrid composite A2. The composition of the dental materials is presented in Table 1.

Table 1. Composition of materials used in the study. BIS-GMA – 2,2 bis(4-(2-hydroxy-3methacryloyloxypropoxy)phenyl)propane, TEGDMA-triethylene glycol dimethacrylate, UDMA- urethane dimethacrylate, PEGDMA- poly(ethylene glycol) dimethacrylate, Bis-EMA- ethoxylated bisphenol A glycol dimethacrylate.

Brand Name	Resin composition	Fillller composition	Filler content (vol%)	Filler content (wt%)	Averages filler size	Manufacturer
Composite	Bis-GMA, UDMA, TEGDMA	Glasses with BaO, coloidal silica, HAP with Zr O2, quartz	67	80-82	Between 2.5 and 0.04 microns	Raluca Ripan Chemistry Research Institute
Filtek Ultimate	Bis-GMA, UDMA Bis-EMA, TEGDMA, PEGDMA	SiO2, ZrO2,SiO2/Zr O2 aggregates	78.5	63.3	20nm (silica) 4-11nm zirconia) 0.6–10 μm nanoclusters	3M ESPE
Valux Plus	Bis-GMA,TEG DMA	Basic component zirconia/silica	66	80-90	Between 3.5 and 0.01 microns.	3M ESPE

For each group 20 samples were realized by means of a plastic mold. The composite samples were created with a height of 2mm, and a diameter of 8 mm. They were covered with a smooth polyester matrix surface on a ground that was to be polymerized. The 2mm sample thickness allows a single sided polymerization. (21) The polymerization was performed for 20 seconds with the LED curing light Elipar Freelight 2, 3M ESPE, Ø 8 mm guide, 1000mW/cm2, 20 sec. The opposite side was finished with abrasive paper with increasing granulation up to 1600 grits. The specimens were further rinsed with water and dried with a paper tissue. Then all prepared specimens were stored in distilled water at 37°C for 24 hours for rehydration and completion of the polymerization.(15, 22, 23)

The immersion at 37 C was performed in water, wine, alcohol and tartaric acid solution. Water was used as reference. To obtain the maximum number of color modifications we used red wine (Cabernet Sauvignon 2011, Recas Winery). We prepared an ethanol solution with a concentration equal to that of the wine used in the experiment (13% as stated on the label) and a tartaric acid solution in distilled water with a pH equal to that of the wine (3.45). (6, 24) After 24 h, 7 days, 28 days the samples were subsequently removed from the solutions, rinsed with water and dried, and then measured with Vita Easyshade, Advance, Vita, Zahnfabrik Germany. Throughout the experiment color measurements were performed by positioning the specimens on a white background. During the experiment measurements of the parameters CIE L*a*b were performed. Two readings were done at each sample on matt surface and then two readings on glossy surface.(15, 22, 25,17,18)

In order to determine the color difference between the matt/glossy surfaces we calculated ΔE between the surfaces at the same moment in time and with the same solution. We pair the first matt surface reading with the first glossy surface reading and the second mat surface reading with the second glossy surface reading and we calculate two ΔE values between the surfaces of the sample. The calculated ΔE values for the same sample group (material/time/solution) will be used in the statistical analysis. Mean ΔE values will be calculated as arithmetic mean of values from the same sample group (material/solution/time).

The color differences were calculated based on the formula:

$$\Delta E = \sqrt{(L_g - L_m)^2 + (a_g - a_m)^2 + (b_g - b_m)^2}$$

whereby L, a, b are the values measured CIE L*a*b for the surface g=glossy and m=matte.

The statistical analysis has been realized by means of the SPSS 21 (IBM Corp) program. The statistical test used was the General Linear Model Repeated Measures. The dependent variable, ΔE matte/glossy is calculated. The independent variables are the solution of immersion and the moment in time of the measurement. The material is a constant.

3. Results

The mean values for ΔE can be viewed in Table 2. One can observe that for all materials studied occur visible modifications (over ΔE 3.5) when immersed in wine after 7 days.

Table 2. Mean ΔE matte/glossy, different time intervals and different solution of immersion.

Material	Solution	Mean ΔE matte/glossy at		
		24h	7days	28days
Valux	Water	1.0807	1.0528	1.4078
	Acid	1.7465	2.3187	2.0274
	Alcohol	1.1316	1.0794	2.0947
	Wine	2.0166	4.6975	4.5246
Filtek	Water	1.4547	1.4620	1.1513
	Acid	.9711	1.4889	1.1985
	Alcohol	1.1476	1.4549	1.5642
	Wine	11.1869	19.7105	25.2098
Composite	Water	5.7641	6.3484	5.1134
	Acid	5.3277	4.9730	4.1279
	Alcohol	6.1941	4.7673	4.1733
	Wine	4.0283	7.6715	13.3370

The modifications of ΔE observed in our study systematically exceed the reference value of 3.5 at which the replacement of the fillings is recommend, only at the immersion in wine. For the experimental composite values of ΔE were observed which exceed 3.5 between the matt surface and the glossy one no matter of the solution of immersion or of the moment in time when the measurement was performed.

Table 3. Statistical analysis of within and between subjects effect.

Material		Time	Solution	Time&Solution
	Mauchly's test of sphericity	Test of within-subjects Effects	Test of between-subjects effects	Test of within-subjects Effects
	Sig. (95%)	Sig. (95%)	Sig. (95%)	Sig. (95%)
Valux	0.010	0.007 (0.897 Greenhouse-Geyser)	0.000	0.031
Filtek	0.785	0.000	0.000	0.000
Composite	0.985	0.047	0.000	0.000

For the statistical analysis we used a linear model with repeated measures. The within-subjects factor was time at 24h, 7days and 28 days. The between-subjects factor is the solution of immersion. The dependent variable was ΔE between matte/glossy surfaces of samples. We ran a statistical test for each of the studied material. No direct comparison between materials was made.

For the microfilled composite material Valux we observed in Table 3 that Mauchly's test of sphericity has a statistically significant value. Accordingly we chose to

report the statistical results corresponding to the Greenhouse-Geyser values from the test of within-subjects effects (Table 3). The other two materials passed the Mauchly's test of sphericity and we reported the values for assumed sphericity from the test of within-subjects effects (Table 3). The test of within-subjects effects presents relations between data groups at different moments in time. Taking into consideration just the time as a factor we can conclude that ΔE matte/glossy is changing significantly from one measurement time to another for the studied materials. A detailed pairwise comparison is available in Table 4. The pairwise comparisons using time as partition factor shows that for Valux the observed values are significantly different after 7 days. No difference was observed between 7 days and 28 days. For Filtek we observed that for every time interval the values differed significantly. For the experimental composite material the observed differences between different moments in time are less relevant. The results point out only a difference between 24h and 28 days. Regarding the influence of time and immersion solution we observed that at different moments in time the solution of immersion induce statistically significant differences of ΔE within the same moment in time data group.

Table 4. Statistically significat time pairwise comparison, adjustment for multiple comparisons Bonferroni (test of within-subjects effects).

Material	Pairwise Comparisons	Measure: ΔE
	Significant time pairs	Adjustment for multiple comparisons Bonferroni Sig. (95%)
Valux	day 1 – day 7	0.019
	day 1 – day 28	0.004
Filtek	day 1 – day 7	0.000
	day 1 – day 28	0.000
	day 7 – day 28	0.001
Composite	day 1 – day 28	0.045

The test of between-subjects effects compares the evolution in time of ΔE for different solution of immersion. Results show that for all the studied dental composite materials the effect of the solution of immersion is statistically significant (Table 3). A pairwise comparison shows that wine as solution of immersion is the only one that causes a different pattern of ΔE changes in time. Water, acid and alcohol generate similar changes in time unconcerned about the studied material. (Table 5).

Table 5. Statistically significant solution of immersion pairwise comparison, adjustment for multiple comparisons Bonferroni (test of between - subjects effects).

Material	Pairwise Comparisons	Measure: ΔE
	Significant pairs solution	Adjustment for multiple comparisons Bonferroni Sig. (95%)
Valux	water – wine	0.000
	acid – wine	0.000
	alcohol – wine	0.000
Filtek	water – wine	0.000
	acid – wine	0.000
	alcohol – wine	0.000
Composite	water – wine	0.000
	acid – wine	0.000
	alcohol – wine	0.000

The graphic representation of ΔE evolution in time shows a different path only for the samples immersed in wine. This means that for all materials, water, alcoholic solution and tartaric acid solution there is a similar effect in time (Fig. 1, Fig. 2, Fig. 3).

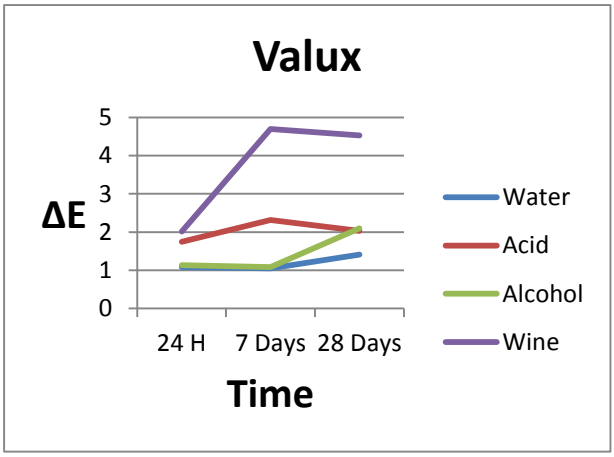

Fig. 1. Representation of Valux ΔE mean values in time.

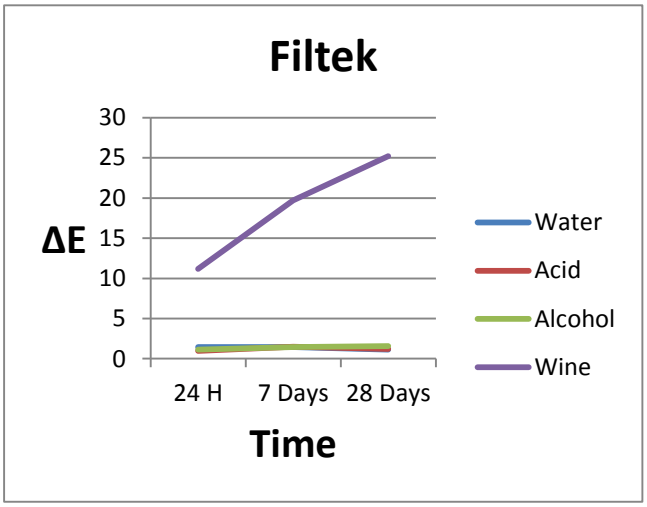

Fig. 2. Representation of Filtek ΔE mean values in time.

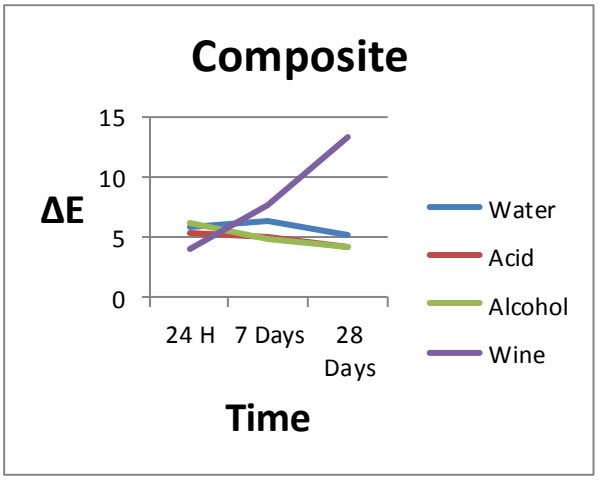

Fig. 3. Representation of experimental dental composite ΔE values in time.

4. Discussions

The color changes of the composite materials are given by the values of ΔE, and the values of ΔE are directly affected by surface roughness. (26, 10) In general, polished composite resins tend to appear lighter, whiter, and less glossy than the corresponding matrix covered surfaces (26). In our study the samples were not submitted to a wear treatment during the experiment. We intend to estimate only the effect of the initial finishing treatment of the dental composite surface. Further studies are needed to explore the effect of normal wear (due to brushing, mastication) of dental composite surfaces on the ΔE variation between the different initial finishing surface treatments.

An effective finishing system for dental composite resin requires that the abrading particles must have hardness greater than the filler materials. Otherwise, the polishing agent will only remove the soft resin matrix and leave the filler particles protruding from the surface.(27, 7)

Studies showed that an increased particle size results in lower color changes. This fact was explained by a reduced fluid absorption due to a decrease in the proportion of organic filler matrix.(28)

Knowing that TEGDMA is color sensitive we chose composites which contain TEGDMA to obtain greater modifications of the color.(11) TEGDMA is more susceptible to enzymatic hydrolysis than other monomers like Bis-GMA or Bis-EMA. (29)

The modifications of ΔE observed in our study have systematically exceeded the reference value of 3,5 at all materials for which the replacing of the fillings was recommended only at the immersion in wine. The commercial materials studied revealed that for non-pigmented immersion solutions (water, acid, alcohol) the color differences between the two surfaces are at an acceptable clinical level. This means that the degree of surface finishing will affect less the color of the composite when the immersion solutions have no pigments. Regarding the immersion in wine (water-acid alcohol solution with natural pigments) we can observe that the smallest effect was obtained at the microcomposite Valux and the greatest effect at the nanocomposite Filtek Ultimate. Why these differences occurred must still be explored. Regarding the experimental composite one can observe, that between the matt and the glossy surfaces there are significant differences in ΔE (larger than 3.5) for all solutions of immersion, no matter of the moment in time. This shows that in the present formulation (at the current composition) the material is sensitive regarding the degree of finishing of the surface. Encouraging is the fact that the distribution interval of the ΔE values is rather reduced, similar to that of the commercial materials studied. Some researchers stated that using nanoparticles in the resin composite formulation is not sufficient to improve their surface texture after polishing. (30) The conclusion of a study which evaluated the surface roughness and color change of a hybrid, a microhybrid, and a nanohybrid composite, is that the nanohybrid composite resin shows the lowest surface roughness values compared to the other composite resins in the control groups.(10) A possible explanation could be that the craters are often formed around hard quartz particles of conventional composite resins after polishing. (27)

Staining solutions and immersion time are significant factors that affect color stability of the composite resins. (31) A low pH and alcoholic drinks can produce erosion of resin composites (32,33) Our study reveals modifications in color triggered by acid and alcohol but these are kept below the critical value of 3,5 of ΔE, at the Valux and Filtek material, while at the experimental composite material the critical value is exceeded.

The wine constantly causes significant color changes constant at all composites used in our study unlike the other immersion solutions. The values significant in time vary according to the composite used. The nanocomposite material Filtek was the most predisposed material of our study to time related ΔE changes after the immersion in wine but the color stability in non-colored immersing solutions was among the best of our study (Table 2). We chose to use the red wine in our study for his renowned power to induce color changes to dental composite materials. We observed that all the studied materials have a ΔE bigger than 3.5 after just 7 days of exposure to red wine. The main natural pigment of wine (malvidin, an anthocyanin) is representative for the natural pigments existing in our colored food or drinks. Further studies are required to estimate the effects of other natural pigments from beverages and foods.

5. Conclusions

The color differences between different roughness surfaces of dental composite samples are time, solution and material dependent. This is important to the clinician for the selection of restorative material for the management of patients who have the habit of drinking wine or other colored drinks.

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