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The effect of red and white wine on color changes of nanofilled and nanohybrid resin composites

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Objectives: This study investigated the effect of red and white wine on color changes of nanofilled and nanohybrid resin composite. ***Materials and Methods:*** Sixty specimens of each resin composite were prepared. Baseline data color values were recorded using a spectrophotometer. Three groups of discs (n = 20) were then alternately immersed in red, white wine, and deionized water (as a control) for twenty five minutes and artificial saliva for five minutes for four cycles. Specimens were then stored in artificial saliva for twenty two hours. This process was repeated for five days following immersion in artificial saliva for two days. Subsequently, the process was repeated again. Data were analyzed by two-way repeated ANOVA, one-way ANOVA, and Tukey's HSD. ***Results:*** Red wine caused significantly higher color change ($\Delta E^* > 3.3$) than did white wine and deionized water ($p < 0.05$). Nanohybrid resin composites had significantly more color changes than nanofilled resin composite ($p < 0.05$). ***Conclusions:*** The effect of red and white wine on the color changes of resin composite restorative materials depended upon the physical and chemical composition of the restorative materials and the types of wine. (*Restor Dent Endod* 2016;41(2):130-136)

Key words: Resin composite; Stainability; Wine

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Introduction

Resin-based composites (RBCs) have been used in restorative dentistry since the 1960s.[1] New classes of RBCs, so-called nanocomposites (known as nanofilled and nanohybrid resin composites), have been developed during recent years. Nanocomposites are becoming popular in esthetic restorative dentistry. They are widely used in restoring both anterior and posterior teeth because of the great advantages in the material compositions and the physical and mechanical properties.[2,3] Nanocomposites compose of two types, nanofilled and nanohybrid RBCs. Nanofilled RBCs contain nanomers and nanoclusters. The particle size of nanomers are 5 to 75 nm. Nanoclusters are 0.6 to 1.4 µm and they are agglomerates of primary zirconia/silica nanoparticles (5 to 20 nm in size) fused together at points of contact, and the resulting porous structure is infiltrated with silane.[3] Nanohybrid types contain milled glass fillers and discrete nanoparticles (40 - 50 nm).[2] Although nanocomposites are used in both direct and indirect restorations at present and several studies have shown that nanofilled and nanohybrid resin composites have high color stability and can retain high surface luster,[4,5] problems of color changes of nanofilled and nanohybrid resin composites have been found after a long time.[6]

One of the main factors that affect the longevity of esthetic restorations is the discoloration of restorations. Esthetic restoration with an unacceptable color match with other teeth is a main factor for replacement restoration.[7] Color change in RBCs may be caused by extrinsic and intrinsic factors.[8,9] The intrinsic factors involve the discoloration of the esthetic restorative material by itself. Chemical discoloration has been attributed to a change or oxidation in the amine accelerator for polymerization of resin.[10,11] The extrinsic factors, such as adsorption or absorption of stains, may cause discoloration of esthetic restorative materials.[12] Previous studies reported that coffee, Coca-Cola, red wine, and tea may affect the color stability of resin composite and giomer.[13-16] At present, wine is frequently consumed with food, between meals, or at social gatherings, thereby predisposing RBCs for discoloration.[15] Consumption of wine has demonstrated color change in RBCs.[17,18]

Previous studies have evaluated the color stability of RBCs after immersion in wine.[7,17,18] However, a comparative study on the effect of both red and white wine on color stability of nanofilled and nanohybrid resin composites has not yet been documented. Therefore, the objective of this study was to evaluate the effect of red and white wine on color changes of nanofilled and nanohybrid resin composites. The null hypothesis of this study were that there was no difference in color change between the two types of wines (red and white wines), and types of resin composites (nanofilled and nanohybrid RBCs) would not affect the color changes after being immersed in wine.

Materials and Methods

Specimen preparations

Sixty disc-shaped specimens of nanofilled and nanohybrid resin composites (shade A2, Table 1) were prepared in a polytetrafluoroethylene cylindrical mold (10.0 mm in diameter and 2.0 mm in thickness) on a glass plate. The cylindrical mold was covered with a mylar matrix strip. A second glass plate was placed over the mylar strip. A static load of approximately 200 g was applied to extrude excess resin composites and to obtain a smooth and flat surface on each specimen. The specimens were then polymerized for 40 seconds with a light-activated polymerization unit (Elipar 2500, 3M ESPE, St. Paul, MN, USA). The light intensity (452.1 ± 7.2 mW/cm^2) was verified with a measuring device (Cure Rite, L.D. Caulk, Milford, DE, USA). After polymerization, the mylar strip and the glass plate on the top and bottom of the mold were removed, and the specimen was removed from the cylindrical mold. No mechanical preparation or abrasions of the specimens were performed.

Table 1. Resin composites used in this study

Material	Trade name	Manufacturer	Composition		Average particle size (μm)
			Matrix	Filler	
Nanofilled resin composite	Filtek Z350 XT	3M ESPE, St. Paul, MN, USA	Bis-EMA, UDMA, PEGDMA	Zirconia, silica	Silica 0.02, Zirconia 0.004 - 0.011
Nanohybrid resin composite	Estelite Sigma Quick	Tokuyama Corp., Taitou-ku, Tokyo, Japan	Bis-GMA, TEGDMA	Prepolymerized filler, barium glass, silica	Super-nano spherical fillers 0.2
	Premise	Kerr Corp., Orange, CA, USA	Bis-EMA, UDMA, TEGDMA	Prepolymerized filler, barium glass	Prepolymerized filler, barium glass filler 0.4
	Herculite Ultra	Kerr Corp., Orange, CA, USA	Bis-EMA, UDMA, TEGDMA	Prepolymerized filler, barium glass, silica	Prepolymerized filler, barium glass filler 0.4, silica filler 0.02 - 0.05

Bis-EMA, Ethoxylated bisphenol A dimethacrylate; UDMA, Urethane dimethacrylate; PEGDMA, Polyethylene glycol dimethacrylate; Bis-GMA, Bisphenol A glycidyl methacrylate; TEGDMA, Triethyleneglycol dimethacrylate.

The pH and titratable acidity measurements

Red and white wine were used in this study and their compositions are shown in Table 2. The pH of each wine was determined using a pH meter (Orion 900A, Orion Research, Boston, MA, USA). Ten pH readings of each beverage were obtained so as to give a mean pH measurement for each wine.

To verify titratable acidity (buffering capacity),[19] 20 mL of each wine was added by 0.05 mL increments of 1 mol/L sodium hydroxide (NaOH). The amount of NaOH required to reach pH levels of 5.5, 7.0, and 10.0 were recorded. The titrations for each beverage were also repeated ten times to achieve a mean value.

Storage agent immersions and color measurements

Sixty discs of nanofilled and nanohybrid resin composites were divided into 3 groups of 20 specimens for immersion in red, white wine, and deionized water (served as a control). For baseline color measurement, each group was subjected to a spectrophotometer (ColorQuest XE, Hunter Associates Laboratory Inc., Reston, VA, USA) for assessing the Commission Internationale de l'Eclairege L*a*b* (CIELAB) color. L* indicates the lightness of the color measured from black ($L^* = 0$) to white ($L^* = 100$), a* determines the color in the red ($a^* > 0$) and green ($a^* < 0$) dimension, and b* determines the color in the yellow ($b^* > 0$) and blue ($b^* < 0$) dimension. Three measurements were obtained from each disc and the mean L*, a*, and b* values were used for the final analyses.

The specimens were then alternately immersed in 25 mL of a storage agent for 25 minutes and in 25 mL of artificial saliva for 5 minutes conducted over 4 cycles at room temperature (about 25℃).[20] After the cyclic immersion, specimens were returned to the artificial saliva (daily changed) and kept overnight at 37℃. This process was repeated for five days following immersion in artificial saliva for two days. Subsequently, the process was repeated again. After immersion, specimens were evaluated on day 7 and 14. The same protocol was used with the different storage agents in this study. In order to maintain the original pH level of the storage agents, they were refreshed daily throughout the experiment. For blinding the evaluators to reduce the bias in color measurement, one author immersed the specimens throughout the experiment and the other author evaluated the color measurement of the specimens that were not labeled the storage agent immersed. After the immersion sequence was completed, the specimens were rinsed with deionized water, blotted dry against filter paper and subjected to post-immersion color measurement.

Overall color change (ΔE^*) was calculated using the following equation: $\Delta E^* = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{1/2}$. Mean ΔE^* values for the experimental groups were calculated between baseline and after immersion at day 7 and 14.

Statistical analysis

The ΔE^* values were subjected to two-way ANOVA, one-way ANOVA and Tukey's Honestly Significant Difference (HSD) for multiple comparisons (at $\alpha = 0.05$).

Results

The mean pH, standard deviations (SD) and titratable acidity of beverages with 1 mol/L NaOH are shown in Table 3. White wine had the lowest pH (2.97 ± 0.02) and red wine had the highest pH (3.32 ± 0.02). The titratable acidity was lowest for red wine (1.55 ± 0.05 mL) and highest for white wine (1.64 ± 0.07 mL). The ΔE^* values of the materials used before and after immersion are presented in Table 4. Overall, red wine which had the highest pH caused significantly higher color change ($\Delta E^* > 3.3$) than did white wine and deionized water ($p < 0.05$). Nanohybrid resin composites had significantly more color changes than nanofilled resin composite ($p < 0.05$).

Table 2. Red and white wine used in this study

Beverage	Trade name	Manufacturer	Composition	Percent alcohol
Red wine	Mouton Cadet Rouge 2011	Baron Philippe De Rothschild, S.A. (1902 - 1988), Bordeaux, France	Merlot (65%), Cabernet Suvignon (20%), Cabernet France (15%)	13.5
White wine	Mouton Cadet Blanc 2011	Baron Philippe De Rothschild, S.A. (1902 - 1988), Bordeaux, France	Sauvignon Blanc (65%), brings fresh, fruity, floral aroma, flavor, and semillon (30%), roundness, refinement, and muscadelle (5%)	12.5

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Table 3. The mean pH and standard deviation (SD) and titratable acidity (volume of NaOH [mL]) to bring the pH to 5.5, 7.0, and 10.0) in red and white wine

Beverage	Mean	Cumulative volume of NaOH solution used to titrate to each pH (mL)		
	pH ± SD	5.5	7.0	10.0
Red wine	3.32 ± 0.02	1.01 ± 0.05	1.19 ± 0.06	1.55 ± 0.05
White wine	2.97 ± 0.02	1.23 ± 0.04	1.43 ± 0.05	1.64 ± 0.07

Table 4. Overall color changes (ΔE*) of nano-filled and nanohybrid resin composites from baseline to after immersion

Storage agent	Material	ΔE*	
		Baseline to first wk	First to second wk
Red wine	Filtek Z350 XT	6.98 ± 2.33[b,B]	2.91 ± 0.97[*,b,B]
	Estelite Sigma Quick	11.50 ± 0.14[a,A]	3.74 ± 1.72[*,a,A]
	Premise	8.63 ± 1.03[a,A]	3.73 ± 1.73[*,a,A]
	Herculite Ultra	10.88 ± 1.29[a,A]	3.73 ± 1.95[*,a,A]
White wine	Filtek Z350 XT	2.28 ± 0.66[b,D]	1.82 ± 0.90[*,b,D]
	Estelite Sigma Quick	3.20 ± 0.62[a,C]	2.61 ± 0.82[*,a,C]
	Premise	3.13 ± 0.67[a,C]	2.53 ± 1.34[*,a,C]
	Herculite Ultra	3.16 ± 0.74[a,C]	2.56 ± 0.75[*,a,C]
Deionized water	Filtek Z350 XT	1.24 ± 0.75[E]	1.28 ± 0.41E
	Estelite Sigma Quick	1.36 ± 0.11[E]	1.37 ± 0.54E
	Premise	1.25 ± 0.17[E]	1.28 ± 0.60E
	Herculite Ultra	1.33 ± 0.19[E]	1.34 ± 0.19E

*Indicates statistically significant difference (in rows) between baseline to the first week and from the first week until the second week ($p < 0.05$).
[a,b] Indicates statistically significant difference (in columns) among materials for each storage agents ($p < 0.05$).
[A - E] Indicates statistically significant difference (in columns) among materials and storage agents ($p < 0.05$).

Discussion

On the basis of the data, the null hypothesis tested in the present study is rejected. This study showed that types of wines, red and white wine, significantly affected the color changes of resin composite materials ($p < 0.05$). Types of resin composites, nanofilled and nanohybrid RBCs, also significantly affected the color changes after immersion in wine ($p < 0.05$).

With the improvement of RBCs and demand for esthetic restorations, nanofilled and nanohybrid RBCs have become popular restorations. However, the success and failure of any esthetic restoration depends on the color match and color stability of the material.[21] Color change determination in dentistry can be evaluated by visual and instrumental techniques.[22] A spectrophotometer is more exact than the naked eye in repeatedly measuring slight ΔE* in objects on flat surfaces, providing better sensitivity and objectivity. This present study used a spectrophotometer and the CIE L*a*b* coordinates system, one of the most common color measurement systems in dentistry with precise results for several color parameters.[23] Any ΔE* greater than 3.3 was taken as clinically perceptible color differences.[24,25]

The results of this study showed that after soaking in red wine from baseline until the first week that ΔE* greater than 3.3 was seen in all groups of resin composites. However, after soaking in red wine from the first week until the second week, ΔE* greater than 3.3 was found only in nanohybrid groups of resin composite (Estelite Sigma Quick, Premise, Herculite Ultra), except the nanofilled group of resin composite (Filtek Z350 XT). Likewise after soaking in white wine, the results showed that from baseline until the first week, ΔE* greater than 3.3 was found in nanohybrid groups of resin composite (Estelite Sigma Quick, Premise, Herculite Ultra) except nanofilled group of resin composite (Filtek Z350 XT). While after soaking in white wine from the first week until the second week, ΔE* less than 3.3 was found in all groups of resin composite.

Moreover, the staining ability of RBCs is related to resin matrix, the percentage of filler[8] and size of the filler. Stain susceptibility of RBCs can be a result of the type of resin matrix and water absorption of the resin matrix,[26] which TEGDMA absorbs the highest amount of water. Bis- GMA leads to the formation of the most rigid network, which absorbs less water than the resin made by TEGDMA but it absorbs more water than the resins made by UDMA and Bis-EMA.[27] Excessive water sorption could decrease the longevity of RBCs by expanding and plasticizing the resin matrix, hydrolyzing the silane coupling agent, and producing microcrack formations. Consequently, the microcracks at the interface between filler particles and the resin matrix permit surface degradation acid, staining solution penetration and increase surface roughness (Ra).[28] In addition, surface roughness is related to the size of the filler particles, as larger filler particles will produce a rougher surface.[29] Surface roughness results from penetration and adsorption of staining agents to the RBCs surface. RBCs used in this study were Filtek Z350 XT (nanofilled RBCs), which have an average filler particle size of 0.005 - 0.02 µm and are even smaller than nanohybrid RBCs (Estelite Sigma Quick, 0.2 µm; Premise, 0.4 µm; Herculite Ultra, 0.4 µm). This is related to the results of this study as it found that nanofilled RBCs had color changes less than nanohybrid RBCs after immersion in wine.

This study result indicates that wine's acidity has a pH ranging from 2.97 - 3.32, which is close to an earlier study.[30] In the present study, wine had low pH compared to other alcoholic beverages. Wine composed of main acid constituents which are 1 - 4 g/L maleic acid, 1 - 5 g/L tartaric acid and other acids comprising succinic acid, citric acid, acetic acid, and lactic acid.[31] The pH of the beverage reproduces the strength of acidity, while titratable acidity indicates the amount of acid present in a solution and is measured by titration against a standard solution of sodium hydroxide. Red wine had the highest pH (3.32 ± 0.02) but had the lowest titratable acidity (1.55 ± 0.05 mL). However, red wine caused significantly higher color change (ΔE* > 3.3) than did white wine and deionized water ($p < 0.05$). The pH and titratable acidity value are not the only factor to affect color changes.

Color change in RBCs usually occurs due to three factors. The first factor for color change is that external discolorations form accumulation of plaque and stains. The second factor is that alterations on the surface of RBCs promote surface roughness, slight penetration and adsorption staining agents on the RBCs surfaces. The last factor is intrinsic discolorations from physiochemical reactions of RBCs.[25] The stain susceptibility of RBCs depends on the type of stain solution. The red wine promoted a marked color change of RBCs, probably because the red wine has higher concentration of pigments than white wine.[32] Tannin, anthocyanin and its pigments in red wine may have a significant effect on the color change of RBCs during aging, resulting in more color change of RBCs in red wine than white wine. Deionized water served as a control in this study. Consistent in this study, was that after soaking in deionized water from baseline until the first week and from the first week until the second week, ΔE* less than 3.3 was found in all groups of resin composite. In addition, alcohol is also thought to act as a plasticizer of the polymer matrix.[32] The softening effect of alcohol on the RBCs may be due to the susceptibility of Bis-GMA and UDMA based polymers.[33] Red wine has a higher ethanol concentration (13.5 vol%) than white wine (12.5 vol%) which might be a cause of color change. However, further investigation is required. All of the above, result in red wine more than white wine promoting surface roughness, slight penetration and adsorption of staining agents on RBCs surfaces after specimen immersion.

The results of the present study provided information of the stain susceptibility on direct esthetic restorations in some people who commonly consume wine in daily life. However, the present study evaluated only the *in vitro* effects with some limitations. The dilution effects of saliva and other fluids including pH change in the oral cavity should also be considered. Therefore, further studies are required to examine the effects of wines *in vivo*. Finally, the authors suggest that the management of color changes of resin composite restorations in people who commonly drink wine was polishing external discolorations to remove accumulations of plaque and stains. However, if slight penetration and adsorption of staining agents on the RBCs surfaces or intrinsic discolorations from physiochemical reactions of RBCs have been found, refilling of resin composite restorations may be needed.

Conclusions

Within the limitations of this study, the following conclusions could be drawn. Red wine significantly affected the color change of nanofilled and nanohybrid RBCs after evaluation at the end of the 14 days immersion period. The effect of red and white wine on the color changes of resin composite restorative materials depended upon the physical and chemical composition of the restorative materials and the types of wine.

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Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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