Original Article

Stainability of Esthetic Restorative Materials after Cyclic Immersion in Various Beverages

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Abstract

The objective of this study was to investigate the stainability effects of five beverages (apple cider, orange juice, Coca-Cola, coffee, and beer) on nanohybrid resin composite and giomer. Fifty specimens of each resin composite and giomer were prepared. Before immersion, baseline data of the color values were recorded. Five groups of discs (N = 10) were alternately immersed in 25 mL of each beverage for 5 seconds and in 25 mL of artificial saliva for 5 seconds for 10 cycles. Specimens were then stored in artificial saliva for 24 hours. This process was repeated everyday for 28 days. After immersion, specimens were evaluated and data were analyzed by two-way repeated ANOVA and Tukey's HSD (α = 0.05). Color changes ($\Delta E^* > 3.3$) in both materials were significantly found after being immersed in the Coca-Cola, coffee, and orange juice groups ($p < 0.05$). In conclusion, the stainability effect of these beverages on both of the restorative materials also depended upon the chemical composition of the restorative materials and beverages.

Key words: Beverage; Giomer; Resin composite; Stainability

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Introduction

New classes of resin-based composites, so-called nanocomposites, have been developed and marketed during recent years. They are becoming popular because they combine physical, mechanical and esthetic properties.[1-3] Nano particles were inserted into resin-based composites in order to provide high wear resistance, reduce polymerization shrinkage and to improve esthetic value to the restorations with a superior polish.[1,2] Nanohybrid resin composites are used routinely for restoring both anterior and posterior teeth because of their ease of handling, esthetic qualities, superior polish, and the improved optical characteristics are suitable for anterior restorations. Their agglomerated nanoclusters interspersed with microsized particles also give it a very acceptable wear characteristic and good mechanical strength suitable for posterior restorations.[1-3]

Giomer is the latest type of glass ionomer-composite hybrid material, in which the chemical composition includes pre-reacted glass filler and an organic-resin matrix.[4,5] The giomer composed of pre-reacted glass fillers (ranges between 0.01 - 5 µm) is derived from the complete or partial reaction of ion-leachable fluoroaluminosilicate glasses with polyalkenoic acids in water before being interfaced with the organic matrix.[4,5] The pre-action can involve only the surface of the glass particles (called surface pre-reacted glass ionomer or S-PRG) or almost the entire particle (termed fully pre-reacted glass ionomer or F-PRG).[6] Coupling agents bond the inorganic fillers to the resin matrix and catalysts are added to initiate a polymerized material, thus the giomer is light-activated with a blue light wavelength of 470 nm. The giomer is easy to handle, releases and recharges fluoride,[7] and has better polishability than conventional glass ionomers,[8] yet cannot chemically bond to the tooth structure.

Esthetic failure is one of the most common reasons for replacement of a restoration. One of the main factors that affect the longevity of esthetic restorations is the discoloration of restorations. Discoloration of esthetic restorative materials may be caused by intrinsic or extrinsic factors.[9,10] 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 of the polymerization of resin.[11,12] Extrinsic factors, such as adsorption or absorption of stains, may cause discoloration of esthetic restorative materials.[13] Previous studies reported that coffee, Coca-Cola, red wine, and tea may affect the color stability of resin composites and giomers.[14-17] Moreover, consumption of acidic food, fruit juices, soft drinks, coffee, tea or wine can result in surface damage and a decrease in hardness, and a decrease in esthetic quality and other properties of resin composites and giomers.[18-20]

Esthetic color stability and discoloration properties of nanohybrid resin composite and giomer restoratives employing PRG technology are still not widely available in dental literature. Only a few studies have reported effects of apple cider, orange juice, Coca-Cola, coffee, and beer on stains of nanohybrid resin composites and giomers. In addition, previous studies[15-17] presented continuous immersion of the resin composite in the selected beverages. This study was thus designed to alternate immersion of nanohybrid resin composites and giomers in various beverages over a longer time period. Therefore, the objectives of this study were to compare the stainability effects and titratable acidity of various beverages (apple cider, orange juice, Coca-Cola, coffee, and beer) on nanohybrid resin composites and giomers. The null hypothesis was that there would be no stainability difference in the nanohybrid resin composites and giomers after the immersion period in the different beverages tested.

Materials and Methods

Specimen preparations

The materials evaluated in this present study and their compositions are shown in Table 1. Fifty disc-shaped specimens of each nanohybrid resin composite and giomer (shade A2) 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 composite (and giomer) and to obtain a smooth and flat surface on each specimen. The specimens were then polymerized for 40 s with a light-activated polymerization unit (Elipar 2500, 3M ESPE, St. Paul, MN, USA). The light intensity 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** Materials used in this study*

Material	Product	Manufacturer	Composition		Average particle size (μm)
			Matrix	Filler	
Nanohybrid resin composite	Premise	Kerr Corp., Orange, CA, USA	Bis-EMA, UDMA, TEGDMA	Prepolymerized filler, barium glass, silica	0.4
Giomer	Beautifil II	Shofu Inc., Kyoto, Japan	Bis-GMA, TEGDMA, catalyst	S-PRG, Fluoroboroalumino -silicate glass	1.0

Bis-EMA: Ethoxylated bisphenol A dimethacrylate; UDMA: Urethane dimethacrylate;
TEGDMA: Triethyleneglycol dimethacrylate; Bis-GMA: Bisphenol-A glycidyl methacrylate;
S-PRG: Surface pre-reacted glass ionomer

The pH and titratable acidity measurements

Five beverages were used in this study including apple cider, orange juice, Coca-Cola, coffee, and beer (Table 2). The pH of each beverage 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 beverage.

To verify titratable acidity (buffering capacity),[21] 20 mL of each beverage was added by 0.5 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.

Beverage immersion and color measurement

Fifty discs of each nanohybrid resin composite and giomer were divided into 5 groups of 10 specimens. 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.

Table 2 *Tested beverages used in the present study*

Beverage	Product	Composition	Manufacturer
Apple cider	Heinz	100 % Apple juice diluted with water to 5% acidity	H.J. Heinz company, Sharpsburg, PA, USA
Orange juice	Harvey Fresh	100 % Orange juice	Harvey Fresh (1994) Ltd., Western Australia
Coca-Cola	Coke	Carbonated water, 10 % sugar, flavors	Thainamtip, Bangkok, Thailand
Coffee	Nescafe	7.5 % Sugar, 4.4 % coffee extract, 1.9 % skimmed milk powder	Nestle (Thailand) Co., Ltd., Bangkok, Thailand
Beer	Heineken	5 % Alcohol by volume, water, malted barley, hops, yeast	Heineken N.V. Global Corporate Relations, Amsterdam, Netherlands

The specimens were then alternately immersed in 25 mL of a beverage for 5 seconds and in 25 mL of artificial saliva for 5 seconds for 10 cycles at room temperature (about 25 °C).[18] After the cyclic immersion, specimens were returned to the artificial saliva (daily changed) and kept overnight at 37 °C. The same protocol was used with the different beverages in this study everyday for 28 days consecutively. In order to maintain the original pH level of the beverages, they were refreshed daily throughout the experiment. The specimen immersion protocol simulated an individual eating acidic food, sour fruits and drinks.[18] 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.

Statistical analysis

The color change values (ΔE^*) were subjected to two-way ANOVA and Tukey's Honestly Significant Difference (HSD) for multiple comparisons (at α = 0.05).

Results

The mean pH, standard deviations (SD) and titratable acidity of beverages with 1 mol/L NaOH are shown in Table 3. Coca-Cola had the lowest pH (2.88 ± 0.03) and coffee had the highest pH (6.82 ± 0.05). The titratable acidity was lowest for Coca-Cola (10.02 ± 0.06 mL) and highest for apple cider (99.35 ± 0.06 mL). The color change values of the materials used before and after immersion are presented in Table 4. Overall, giomer had more significant color change than nanohybrid resin composite ($p < 0.05$). Coca-Cola caused the highest color change but there was no statistically significant difference in comparison with coffee and orange juice.

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 beverages tested*

Beverage	Mean pH ± SD	Cumulative volume of NaOH solution used to titrate to each pH (mL)		
		5.5	7.0	10.0
Apple cider	3.08 ± 0.02	91.20 ± 0.20	98.42 ± 0.09	99.35 ± 0.06
Orange juice	3.82 ± 0.03	12.79 ± 0.20	21.12 ± 0.07	24.56 ± 0.08
Coca-Cola	2.88 ± 0.03	2.69 ± 0.03	6.53 ± 0.08	10.02 ± 0.06
Coffee	6.82 ± 0.05	0	0.78 ± 0.09	10.78 ± 0.07
Beer	4.37 ± 0.04	2.82 ± 0.05	5.69 ± 0.07	12.09 ± 0.11

Table 4 *Changes in overall color (ΔE*) from baseline of nanohybrid resin composite and giomer*

Material and beverage	Nanohybrid resin composite	Giomer
Apple cider	2.5 ± 0.2[b]	2.9 ± 0.3*,[b]
Orange juice	4.3 ± 0.2[a]	4.7 ± 0.3*,[a]
Coffee	4.1 ± 0.3[a]	4.5 ± 0.2*,[a]
Coca-Cola	4.4 ± 0.2[a]	4.9 ± 0.3*,[a]
Beer	2.4 ± 0.3[b]	2.8 ± 0.2*,[b]

* indicate statistically significant difference (in column) between nanohybrid resin composite and giomer.

[a,b] Different superscript letters (in row) state statistically significant difference between various beverages ($p < 0.05$).

Discussion

From the data results, the null hypothesis of this present study should be rejected. This study showed that soaking in tested beverages significantly increased stainability on nanohybrid resin composites and giomers ($p < 0.05$), which is similar to previous studies.[22,23]

Color change determination in dentistry can be evaluated by visual and instrumental techniques.[24] This present study used a spectrophotometer and the CIE L*a*b* coordinates system. It can potentially eliminate subjective errors in color assessment. The spectrophotometer is more reliable than the naked eye in measuring slight color change (ΔE) in objects on flat surfaces with repeatability, sensitivity, and objectivity. When ΔE is greater than 3.3 the results are clinically unacceptable.[25,26] The results showed that Coca-cola, coffee, and orange juice caused a ΔE greater than 3.3 for both resin composite and giomer.

Giomer was more susceptible to staining than resin composite. There are many factors for discoloration of esthetic restorative materials including the pH, titratable acidity, degree of conversion of resin polymerization, and also food colorant absorption/penetration may contribute to the amount of staining observed.[9,10] Under acidic conditions over time, the esthetic restorative materials presented a surface roughness with voids due to the softening of the resin matrix or hydrolysis of the silane coupling agent that would cause dislodgement of filler particles, resulting in facilitating adsorption of stains.[23] However, the result of this present study showed that color changes after immersion in the various beverages did not relate to the pH of the beverages alone. Coca-cola had the lowest pH (pH 2.88), but produced less color change than coffee, which was mildly acidic (pH 6.82). The pH of the beverage reflects the strength of acidity, while titratable acidity shows the total amount of acid present (total acidity) and is measured by titration against a standard solution of sodium hydroxide. There is no direct relation between pH and total acidity. Coca-Cola is composed of carbonic acid. Although Coca-Cola had the lowest pH which might damage the surface integrity of the materials, it did not produce as much discoloration as coffee, which may have been due to a lack of a yellow colorant in Coca-Cola. In contrast, coffee contains yellow colorants which caused discoloration of the materials by adsorption and absorption. The absorption and penetration of colorants into the organic phase of the materials were probably due to compatibility of the polymer phase with the yellow colorants of coffee.[9,27] Orange juice and apple cider is composed of citric acid, while beer is composed of alcohol. The presence of alcohol may have softened the resin and consequently may have promoted an irreversible degradation of the material.[19]

Moreover, staining ability of resin composites and giomers might be attributed to the degree of water sorption and hydrophilicity of their resin matrix. The resin composite can direct absorbed water and other fluids in the resin matrix by expanding and plasticizing the resin component, hydrolyzing the silane, and causing a microcrack formation.[23,28] The microcracks or the interfacial gaps at the interface between the filler and matrix allow stain penetration and discoloration.[23,28] Hydrophilic materials have a higher degree of water sorption and a relatively higher staining ability than hydrophobic materials.[9] In this study, resin matrixes of resin composite (Premise, Kerr Corp.) and giomer (Beatifil II, Shofu Dental Corp.) containing Bis-GMA and TEGDMA are considered to be susceptible to staining due to their increased hydrophilicity.[29] Giomer provides more water absorption than resin composite because of the presence of pre-reacted glasspolyacid zone, which are also responsible for generating water sorption,[30] resulting in more ΔE values than resin composite in this present study.

Additionally, color stainability of resin composites and giomers has also been related to the degree of conversion of resin monomers. Incomplete polymerized resin composites and giomers have greater susceptibility to discoloration due to the larger amounts of residual mononers available to form colored degraded products.[31] The degree of conversion is influenced by Bis-GMA content and co-monomer types with TEGDMA mixtures resulting in higher conversion than BisEMA (Ethoxylated Bisphenol-A Dimethacrylate).[32] Also the roughened surfaces are easily stained by mechanical absorption.[23]

However, it must be noted that there are some limitations in this present study. Actual staining of esthetic restorative materials in the oral cavity would very likely require a longer period of time due to the intermittent nature of stain exposure and the dilution effects of saliva and other fluids. The specimens in this study were not also polished as in clinical situations where the restorations have to be polished afterward. In addition, the present study evaluated only *in vitro* effects. Further studies are required to examine the effects of these beverages *in vivo.*

Conclusion

Within the limitations of this study, the following conclusions could be drawn. Coca-Cola, coffee, and orange juices significantly affected the stainability of both materials by the end of the 28 days immersion period. In addition, giomer showed significantly greater color change than nanohybrid resin composite. The effect of these beverages on the color changes of both restorative materials also depended upon the chemical composition of the restorative materials and beverages.

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