Original Article

Spectrophotometric evaluation of color stability of composite resin after exposure to cold drinks: An *in vitro* study

J. Noor Fathima, M. Mohamed Jubair Hashir, Kadambari Padmanabhan

Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

Abstract

Objectives: The aim of this study was to evaluate the color stability of two composite resins after exposure to beverages such as Cola, Pepsi, Red Bull, and distilled water after 15 days.

Materials and Methods: The color stability of a microhybrid and nanohybrid composite was evaluated after storage in distilled water, Coca-Cola, Pepsi, and Red Bull for 15 days. Color measurement was done using a reflectance spectrophotometer based on the CIE L*a*b* color scale.

Results: All tested resin composites showed color change after a period of 15 days. One-way analysis of variance and Tukey *post hoc* were done to assess the significance of color change within the group and an independent *t*-test was done to assess the change between micro and nanohybrid composite. Among the resin composites studied, microhybrid composite was found to be more color stable. The microhybrid and nanohybrid composite discolored most in Coca-Cola and Pepsi. In both groups, distilled water showed very less color change.

Conclusion: Every endeavor should be undertaken to minimize the potential for discoloration in composite restorations by employing meticulous polishing techniques and also to use newer composite material with submicron particles. Furthermore, it is imperative to educate patients about the likelihood of the restoration being susceptible to staining from various beverages.

Keywords: Color stability; microhybrid; nanohybrid; spectrophotometer

INTRODUCTION

In recent years, dentists have increasingly turned to resin-containing restorative materials to fulfill the esthetic preferences of patients, as they seamlessly blend with natural tooth color. These materials are versatile and can be applied in both direct and indirect dental restorations.[1]

In contemporary dentistry, a paramount emphasis is placed on esthetics, with prostheses and restorations crafted meticulously to harmonize seamlessly with the surrounding oral structures. Among the crucial attributes of an esthetic restorative material, color stability stands out. Ensuring that the matched color endures throughout its service life can be pivotal in determining the success or failure of the material. Various factors can influence the color stability of dental materials. Discoloration may stem from either intrinsic or extrinsic sources. Intrinsic factors involve chemical alterations within the material, such as the oxidation of amine accelerators. These tertiary amines can lead to discoloration, shifting the hue from a whitish to a yellowish appearance. Extrinsic factors contributing to discoloration

Address for correspondence:
Dr. M. Mohamed Jubair Hashir,
Department of Conservative Dentistry and Endodontics,
Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.
E-mail: jubairhashir@gmail.com

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encompass staining through the adhesion or infiltration of colorants from external sources such as coffee, tea, and nicotine. It is worth noting that one or a combination of these factors can be accountable for visibly noticeable or esthetically unsatisfactory color alterations in dental materials. Therefore, it is imperative that the restorative material exhibits resistance to intrinsic color changes.[2] Previous studies have concluded that the color stability of composite resin depends on composition and properties.[3-5]

Dental fillings such as composite materials undergo continuous exposure to various detrimental influences within the oral environment, potentially leading to alterations in their fundamental characteristics. These influences can be categorized as mechanical, thermal, and chemical. Chemical factors such as acids from dietary products and gastric acids have the potential to induce erosive damage not only to the hard tissues of the tooth but also to the composite materials employed in dental restorations.[6]

The success of composite resin restorations hinges on a spectrum of mechanical and physical attributes. These encompass durability, hardness, resistance to abrasion, surface smoothness, capacity to thwart secondary caries, susceptibility to microleakage, propensity for plaque accumulation, overall esthetic appearance of the restoration, and patient contentment. Each of these factors collectively plays a pivotal role in determining the long-term efficacy and satisfaction derived from these restorative procedures.[6,7]

One method that can be used to evaluate the color stability of composite is using a spectrophotometer and then comparing their respective values. A spectrophotometer indicates values of L^*, a^*, and b^* in the CIELAB color system. The L^* parameter corresponds to the luminosity, whereas a^* and b^* correspond to the hue. The a^* axis represents the red-green axis saturation and b^* the blue-yellow saturation. The color difference (ΔE) is obtained from the individual changes in each parameter and is expressed as a single value.[8]

Few studies have demonstrated that composite resins are prone to experiencing color changes when subjected to staining agents such as coffee, tea, Cola, and wine. The regular consumption of beverages such as coffee and tea can potentially impact both the visual appeal and structural integrity of composite resins, potentially compromising the overall quality of the dental restoration. In addition, the high consumption of carbonated beverages, particularly among young adults and children, raises concerns about the potential deleterious effects of their acidity on the properties of restorative resins.[9,10]

Given the prevalent use of tooth-colored restorative materials, it becomes crucial to ascertain which among these materials are prone to undergoing alterations in color. Thus, the purpose of this study was to evaluate the color stability of a commercially available nanohybrid resin composite and microhybrid resin composite after exposure to beverages such as distilled water, Coca-Cola, Red Bull, and Pepsi after a period of 15 days.

MATERIALS AND METHODS

Eighty composite disc-shaped samples (40 microhybrid and 40 nanohybrid) were prepared using a stainless steel mold with dimensions of 10 mm in diameter and 2 mm in thickness. The resin composite was placed into the mold and sandwiched between the translucent Mylar Strips and two thin glass slides. The samples were then light-cured for 40 s using a light-emitting diode unit (2300 mW/cmÂ^2, Woodpecker O-Light 1 s Curing Light Unit, DTE Woodpecker, China). Following that, the samples were polished using the Super-Snap polishing system (Shofu Inc., Kyoto, Japan) and polishing discs as per the manufacturer's instructions. After sample preparation, they were stored in distilled water for 24 h to complete their polymerization process and rehydration.

The resin-based composite material samples were divided into four group

- Group 1: Distilled water
- Group 2: Coca-Cola
- Group 3: Pepsi
- Group 4: Red Bull

Restorative materials to be evaluated for their color stability were Spectrum Composite (Dentsply DeTrey GmbH, Germany) and IPS Empress Direct (Ivoclar Vivadent, Schaan, Liechtenstein).

Sample immersion protocol

The immersion protocol was followed for 15 days, based on the assessment by Barve *et al*.[11] The beverage sample was changed every time, and each group's samples were submerged in their respective beverage for 15 min daily.

Color change measurement

Konica Minolta – Spectrophotometer CM5 was used to assess the color change in the microhybrid and nanohybrid composites. The surfaces of the discs were measured after drying them gently with tissue paper. The CIE $L^*a^*b^*$ values were recorded for the disc samples before immersion and after 15 days of immersion in different drinks. Color change value (ΔE) was calculated using the following equation:

$$\Delta E\ (L^*\ a^*b^*) = ½[(\Delta L^*)\ 2 + (\Delta a^*)\ 2 + (\Delta b^*)\ 2].$$

In the equation, ΔL^*, Δa^*, and Δb^* are the differences in L^*, a^*, and b^* values before and after immersion for 15 days in the drinks.

Statistical analysis

The statistical analysis was performed using the IBM Statistical Package for Social Sciences software (SPSS Statistics; version 23, IBM Corp., Armonk, New York, USA). One-way analysis of variance (ANOVA) and Tukey *post hoc* were done to assess the significance of color change within the group and an independent *t*-test was done to assess the change between micro- and nanohybrid composite. All the statistical tests used in the present study consider a $P < 0.05$ to be significant.

RESULTS

In this study, 40 microhybrid composite blocks and 40 nanohybrid composite blocks were used to assess the color difference after immersing them into carbonated beverages such as Coca-Cola, Pepsi, and Red Bull while distilled water was used as a control.

IPS Empress Direct

In the nanohybrid composite blocks, distilled water had the minimal color change and Coca-Cola had the maximum change, followed by Pepsi [Table 1]. Coca-Cola and Pepsi had ΔE of more than 3.3 which was clinically not acceptable. One-way ANOVA was done to assess if the color change parameter had any difference within the group. Tukey *post hoc* was done to assess if the difference is significant with each other within the group. It was revealed that there was a significant difference between the groups. Furthermore, distilled water had a significant difference from Coca-Cola and Pepsi but not Red Bull. Similarly, Coca-Cola had a significant difference with water and Red Bull but the difference was not statistically significant with Pepsi.

Spectrum Composite

In the microhybrid composite blocks, distilled water had the minimal color change and Coca-Cola had the maximum change, followed by Pepsi [Table 2]. One-way ANOVA was done to assess if the color change parameter had any difference within the group. Tukey *post hoc* was done to assess if the difference is significant with each other within the group. It was revealed that there was a significant difference between the groups. Furthermore, distilled water had a significant difference from Coca-Cola, Red Bull, and Pepsi. Similarly, Coca-Cola had a significant difference with water but the difference was not statistically significant with Red Bull and Pepsi. Furthermore, Pepsi had significant differences only with control groups but not with any other groups.

Spectrum and IPS Empress Direct

An independent *t*-test was done to assess the difference from micro and nanohybrid composite. Among the two, the microhybrid composite was more stable than the nanohybrid composite and the difference was statistically significant. In both composite, color differences were noted but the microhybrid showed ΔE value <3.3 which was clinically acceptable.

Table 1: Descriptive statistics - IPS empress direct

	n	Minimum	Maximum	Mean	SD
Distilled	10	0.79	0.90	0.8440	0.03921
Coca-Cola	10	3.03	5.89	4.2780	0.88376
Pepsi	10	1.67	4.98	3.6240	1.04855
Red Bull	10	0.56	3.33	1.4840	0.92140
Valid N (listwise)	10				

SD: Standard deviation

Table 2: Descriptive statistics - Spectrum composite

	n	Minimum	Maximum	Mean	SD
Distilled water	10	0.44	0.67	0.5330	0.08301
Coca-Cola	10	1.34	3.05	2.3500	0.59558
Pepsi	10	1.34	3.89	2.1880	0.75095
Red Bull	10	0.67	2.78	1.7060	0.68357
Valid N (listwise)	10				

SD: Standard deviation

DISCUSSION

Ensuring the long-term color stability of tooth-colored restorative materials is crucial for both esthetic appeal and cost-effectiveness in dental treatment. It not only enhances the visual appeal of the restoration but also minimizes the expenses associated with frequent replacements. The ability of restorations to maintain their color throughout their functional lifespan is pivotal in determining their overall acceptability and effectiveness. Discoloration in dental composites arises from various factors, influenced by both inherent and external elements. These include inherent factors such as chemical alterations in the materials, encompassing the resin matrix and filler particles, as well as the interfaces between these components. In addition, external factors play a significant role, such as the adsorption or absorption of stains, dietary habits, smoking, and the water absorption of resin monomers.[12]

Resin composites featuring smaller filler particles, such as nanohybrid and nanofilled composite resins, have traditionally been assumed to yield superior surface finish and gloss, thereby potentially providing enhanced color stability.[13] However, this study has uncovered a different outcome, with microhybrid composite resin exhibiting the least amount of absorbed stain, indicating superior color stability compared to nanohybrid resin. This finding aligns with the conclusions reached by Mahajan *et al*. and Al Kheraif *et al*.[14,15]

The presence of triethylene glycol dimethacrylate (TEGDMA) in the resin matrix has been identified as a contributing factor to the discoloration of the resin matrix. TEGDMA, a diluent monomer added to the bisphenol A-glycidyl dimethacrylate resin matrix, is known for its hydrophilicity, leading to increased water sorption. In studies conducted by Alberton Da Silva *et al*.,[16] it was observed that the nanohybrid composite resins examined in this study contained TEGDMA in their composition, potentially accounting for their higher staining capacity compared to microhybrid composite resin, which lacks TEGDMA and predominantly comprises UDMA, a component shown to reduce water uptake and minimize color changes.

Al-Haj Ali *et al*. conducted a study investigating the impact of various soft drinks (including iced tea, sports drinks, orange juice, Cola, and distilled water) on the color stability of microhybrid composites and nanocomposites. Their findings indicated that microhybrid composites demonstrated superior color stability across all soft drinks.[17]

Al Kheraif *et al*. conducted a similar study, examining the effects of coffee, tea, Cola, and distilled water on both the color stability and conversion degree of nano- and microhybrid composites. They observed that nanohybrid composites with a higher conversion degree exhibited lower color stability and experienced significant discoloration when compared to microhybrid composites.[15]

In addition, Bansal *et al*. conducted a study assessing the impact of alcoholic and nonalcoholic beverages on the color stability of nanofield and microhybrid composites. Their results aligned with the previous studies indicating that microhybrid composites displayed greater color stability across different beverages.[18] Various studies have also evaluated the color change of composite respective to composition, curing depth and light, and surface roughness.[19-22] Collectively, these studies, including the current one, consistently affirm that microhybrid composites tend to exhibit higher color stability compared to nanohybrid composites.

Several factors significantly influence the susceptibility of composites to discoloration, including the type of filler, the resin composition, and the nature of the staining agent. Microhybrid composite, a glass-ceramic composite, incorporates a range of filler particles with varying sizes and distributions. Notably, this composite consists of 77% microfillers by weight, encompassing very fine particles approximately 0.05 μm in size. This glass-based structure is designed to provide optimal stability. Interestingly, studies have indicated that increasing particle size can lead to reduced discoloration due to a lower matrix–filler ratio.[23]

In contrast, nanohybrid composites feature agglomerate particles known as nanoclusters. These particles are generally less resistant to discoloration compared to the silicon-zirconia micron-sized fillers present in microhybrid composites. This discrepancy in discoloration resistance may be attributed to the higher water absorption properties of nanoclusters.[24]

The assessment of composite resin sample discoloration was conducted using a spectrophotometer, a highly reliable tool known for its precision in detecting color variations. This makes spectrophotometers the preferred choice for ensuring accurate and consistent color measurements.[25] Consequently, they were employed in this study to evaluate any instances of discoloration. However, this cannot be used in clinical situations as it is mainly designed for laboratory studies. In *in vivo* conditions, VITA Easyshade spectrophotometer can be employed, as demonstrated in numerous studies. This advanced device offers exceptional capabilities for precise color measurement and has been utilized effectively in a range of research investigations.[8,26] The scientific spectrophotometer calculated the parameters L, a, and b for both composites from which the values of ΔE, ΔL, Δa, and Δb resulted. A color difference above ΔE 3.3 is said to be clinically unacceptable and the color difference was easily noticeable.[27] In our study, the ΔE value was above 3.3 for nanohybrid composite and it was below 3.3 for microhybrid composite.

A notably higher level of discoloration was observed in IPS Empress Direct following a 15-day storage period. The composition and dimensions of filler particles play a pivotal role in determining surface smoothness and susceptibility to external staining. Consequently, it would be reasonable to anticipate that a nanohybrid composite with smaller particle sizes would exhibit a smoother surface and be less prone to retaining surface stains. However, in this particular investigation, IPS Empress Direct, classified as a nanohybrid composite resin, demonstrated lower color stability. This could potentially be attributed to specific characteristics of the resin matrix and the potential presence of porosity within aggregated filler particles, along with potential porosity in the glass fillers themselves.[28,29] These findings align with previous studies, which have consistently demonstrated that composites with lower filler contents tend to exhibit inferior color stability.[30,31]

Reports suggest that in nanohybrid composites, smaller filler particles are more prone to removal during the polishing and finishing processes, leaving small voids on the material's surface compared to microhybrid. Interestingly, this characteristic advantage of nanohybrids does not necessarily translate into heightened resistance to staining. It is worth noting, however, that some studies present conflicting results compared to the findings of the current study.[32,33] This suggests that the factors influencing stain resistance in composites may vary and require further investigation.

While extrapolating the findings of this study to *in vivo* conditions may pose challenges, the results nonetheless provide valuable insights into the potential behavior of various resin composites under diverse beverage exposure. This information can significantly influence the material choices made by clinicians and empower patients to exercise better control over their dietary habits for optimal outcomes.[18]

CONCLUSION

Under the conditions of the present *in vitro* study, it can be concluded that the microhybrid composite was more stable than the nanohybrid composite. Coca-Cola discolored more in both composite, followed by Pepsi, Red Bull, and distilled water. The color changes were within the clinically acceptable range ($\Delta E < 3.3$) for Spectrum Composite (microhybrid composite). Further, *in vivo* studies with longer follow-ups may be necessary for better understanding of the color stability of resin composites exposed to various beverages.

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Conflicts of interest
There are no conflicts of interest.

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