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Do Sugary Drinks Color Bulk-Fill Composite More?

Şekerli İçecekler Bulk-fill Kompoziti Daha Fazla Renklendirir Mi?

ABSTRACT

Objectives

This *in vitro* study evaluated the color stability of a bulk-fill resin composite (Filtek One Bulk Fill) after immersion in five media: distilled water, tea, coffee, tea with added sugar, and coffee with added sugar.

Material and Methods

Fifty disc-shaped specimens were prepared and randomly assigned to 5 groups (n = 10). All specimens were kept in distilled water at 37 °C for 24 h to ensure hydration. Baseline color measurements were recorded using a spectrophotometer. The groups were immersed for 14 days in solutions, refreshed daily: distilled water (control); tea (T), made by Yellow Label Tea (Lipton, Rize, Türkiye), filtered; coffee (C), Nescafé Classic (Nestlé, Switzerland); tea with sugar (TS), as100 mL tea with 5 gr sugar dissolved; coffee with sugar (CS), as 100 mL coffee with 5 gr sugar dissolved. Color changes (ΔE00) were measured using a spectrophotometer. Data normality was tested with the Shapiro-Wilk test, followed by One-Way ANOVA and Tukey's Post-Hoc test ($P < 0.05$).

Results

All test groups showed significantly greater discoloration than the control group ($P < 0.05$). The TS group exhibited the highest color change (ΔE00 = 12.35 ± 2.03), significantly different from other groups ($P < 0.05$). The T group (ΔE00 = 9.28 ± 2.34) displayed more staining than the C group (ΔE00 = 6.93 ± 2.04), while C and CS groups (ΔE00 = 8.82 ± 3.26) showed statistically similar staining levels ($P > 0.05$).

Conclusion

The addition of sugar to tea significantly increased discoloration of Filtek One Bulk Fill resin composite, with the tea with sugar group showing the highest color change. In contrast, sugar addition to coffee had no significant effect on staining. These findings indicate that sweetened tea consumption may notably compromise the esthetic longevity of bulk-fill composite restorations, suggesting the need for dietary considerations in patients with such restorations to maintain their color stability.

Key Words

Bulk-fill composite resin, Color stability, CIEDE2000.

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ÖZ

Amaç

Bu *in vitro* çalışmada, bir bulk-fill rezin kompozitin (Filtek One Bulk Fill) distile su, çay, kahve, şeker ilaveli çay ve şeker ilaveli kahve olmak üzere beş solustona daldırıldıktan sonraki renk stabilitesi değerlendirilmiştir.

Gereç ve Yöntemler

Disk şeklinde elli örnek hazırlandı ve rastgele beş gruba ayrıldı (n = 10). Tüm örnekler hidrasyonun sağlanması için 24 saat boyunca 37 °C'de distile su içinde bekletildi. Başlangıç renk ölçümleri bir spektrofotometre kullanılarak kaydedildi. Gruplar 14 gün boyunca her gün yenilenen solüsyonlara daldırıldı: distile su (kontrol); çay (T), Yellow Label Çay (Lipton, Rize, Türkiye) , filtre kahve (C), (Nescafé Classic Nestlé, İsviçre); şekerli çay (TS), içerisinde 5 mg şeker çözülmüş 100 mL çay ; şekerli kahve (CS), içerisinde 5 mg şeker çözülmüş 100 mL kahve. Renk değişiklikleri (ΔE00) bir spektrofotometre kullanılarak ölçüldü. Verilerin normalliği Shapiro-Wilk testi ile test edildi, ardından One-Way ANOVA ve Tukey's Post-Hoc testi uygulandı ($P < 0.05$).

Bulgular

Tüm test grupları kontrol grubuna göre önemli ölçüde daha fazla renk değişikliği göstermiştir ($P < 0.05$). TS grubu diğer gruplardan önemli ölçüde farklı ve en yüksek renk değişimini sergiledi (ΔE00 = 12.35 ± 2.03) ve ($P < 0.05$). T grubu (ΔE00 = 9.28 ± 2.34) C grubundan (ΔE00 = 6.93 ± 2.04) daha fazla renklenme gösterirken, C ve CS grupları (ΔE00 = 8.82 ± 3.26) istatistiksel olarak benzer renklenme seviyeleri gösterdi ($P > 0.05$).

Sonuç

Çaya şeker eklenmesi Filtek One Bulk Fill rezin kompozitin renklenmesini önemli ölçüde artırmış ve şekerli çay grubu en yüksek renk değişimini göstermiştir. Buna karşın, kahveye şeker ilavesinin lekelenme üzerinde anlamlı bir etkisi olmamıştır. Bu bulgular, şekerli çay tüketiminin bulk-fill kompozit restorasyonların estetik uzun ömürlülüğünü önemli ölçüde tehlikeye atabileceğini göstermekte ve bu tür restorasyonlara sahip hastalarda renk stabilitesini korumak için diyete dikkat edilmesi gerektiğini düşündürmektedir.

INTRODUCTION

The utilization of composite resins in daily clinical practice is predominantly attributed to their ease of use, cost-effectiveness in comparison to ceramics, satisfactory aesthetic properties, adequate mechanical strength, and their capacity to bond to the tooth structure (1). Since their introduction to the dental market, there has been continuous improvement in the physico-chemical properties of monomer chemistry, filler technology and structure (2). A recent development in composite resins is the bulk-fill technique. In order to ensure effective light transmission and adequate polymerization, it is recommended to apply composite resins in layers with thicknesses not exceeding 2 mm (3). However, layered application of composite resin has several disadvantages, such as the need for separate light polymerization of each layer, the formation of air bubbles, moisture contamination between layers and the requirement for a greater investment of time.

Recently, according to the manufacturers of bulk-fill composite resins, it is claimed that a single layer can be sufficiently light polymerized up to 4-5 mm thickness. Therefore, it is suggested that the bulk-fill technique overcomes the shortcomings of layered placement of the composite resin. One of the most important advantages of this technique is that it simplifies restorative procedure, saving clinical time for dentists, especially in deep and wide preparations. Furthermore, bulk-fill composite resins can be applied without compromising issues such as polymerization shrinkage, degree of conversion and cavity adaptability (4).

The varying properties acquired by composite resins during the development process have the potential to induce alterations in the surface structure of the material, thereby engendering divergent responses to ageing factors. Color change is one of the most common aging factors in composite resins and may be due to intrinsic and extrinsic causes (5-7). Intrinsic color change is mostly related to the chemical properties of the composite, such as the structure of the resin matrix, the matrix-particle interface, the size and volume of the filler particles. External coloration is related to physical factors such as oral hygiene, occupational factors, smoking, and contact with food and beverages (8,9) In various studies examining the color stability of composite resins, it has been reported that different beverages (coffee, tea, wine, cola, fruit juice, etc.) and mouthwash solutions have different degrees of staining effect (10,11) According to these studies, the highest color change was observed in samples immersed in coffee, followed by tea, red wine, and cola (12)

A review of the extant literature reveals numerous studies on the coloration of tea and coffee. However, the present study, in which sugar was added, represents a novel contribution to the field. The hypotheses of this study are;

H01: Storage in beverages (tea, coffee, sweetened tea, sweetened coffee) will not affect its color stability compared to storage in distilled water.

H02: Adding sugar to beverages (tea or coffee) will not influence the color change of Filtek One Bulk Fill resin composite compared to unsweetened beverages.

Table 1. Composition of the composite resin

Composite (manufacturer)	Resin Matrix	Filler	Filler amount (W/V)
Filtek One Bulk Fill (3M Espe, St.Paul, MN, USA)	AFM (dynamic stress-relieving monomer), AUDMA(Aromatic urethane dimethacrylate), UDMA(UDMA: urethane dimethacrylate) and 1,12-dodecane-DMA	Non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles) and a ytterbium trifluoride filler agglomerate 100 nm particles	76.5%/58.5%

MATERIAL and METHODS

Preparation and grouping of composite samples

Fifty composite samples (Filtek One Bulk Fill) were prepared with a diameter of 5 mm and a thickness of 2 mm (Tab. 1).

During the preparation of the specimens, the Teflon mould was fixed on a translucent polyester strip (Mylar Type D, DuPont, DE, USA) using a piece of double-faced adhesive tape. The resin composite was placed in the Teflon mould. The top of the Teflon mould was protected with another translucent polyester strip. The resin composite was polymerized from the top surface for 20 sec using an LED light device (Valo Ultradent Products, UT, USA) at an intensity setting of 1200 mW/cm^2. The head of the light device was kept in direct contact with the mylar strip to standardize the distance to the specimen surface during curing. The curing device was calibrated after every five polymerization.

Composite specimens were randomly divided into 5 groups (n = 10). Five different beverages used in this experiment were instant coffee, black tea, and the same groups with sugar addition.

Control Group: In this group, the composite specimens were kept in distilled water only.

Tea Group: The tea solution was prepared by immersing 2 prefabricated doses (2 x 2 gr) of tea (Yellow Label Tea; Lipton, Rize, Türkiye) in 200 mL of boiling water at 100 °C for one minute. After removing the tea waste, the final volume of the solution reached 200 mL.

Coffee Group: To make coffee solution, 6 gr of ground coffee powder (Nescafe Classic, Nestle, Switzerland) was poured in coffee filter and 200 mL of water at 100 °C was added. The obtained solution was passed through another filter and the final volume reached 200 mL

Tea Group + 5 gr sugar added: The tea solution was prepared as described above. After this step, 5 gr of sugar was added and mixed until dissolved.

Coffee Group + 5 gr sugar added: The coffee solution, was prepared as described above. After this step, 5 gr of sugar was added and mixed until dissolved.

Color measurement

A clinical spectrophotometer (VITA Easyshade V, VITA Zahnfabrik, Bad Säckingen, Germany) was used for color measurement. Composite discs were placed on a standard background. Single tooth mode of the spectrophotometer was selected for color measurement and all measurements were made from the middle region of the upper surfaces of the discs. The measurements were based on the International Commission on Illumination (CIE) L*a*b* System. The spectrophotometer was standardized according to the manufacturer's instructions. Three repeated readings were made for each sample and average L*, a* and b* values were obtained. The first color measurements were made after the samples were kept in distilled water for 24. (T0) Color measurements were repeated on the 14th of the study and the values obtained were recorded. (T1) The measurements were made after the samples were removed from the solutions, rinsed with distilled water and dried slightly with blotting paper. After the measurements, color change values were calculated using the formula ΔE00:

$$\Delta E_{oo} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'_{ab}}{K_S S_C}\right)^2 + \left(\frac{\Delta H'_{ab}}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'_{ab}}{K_S S_C}\right)\left(\frac{\Delta H'_{ab}}{K_H S_H}\right)}$$

ΔL*, ΔC* and ΔH* give the brightness, saturation and hue values, respectively. Rt gives the interaction between saturation and hue values. KL, KC and KH are parametric values and set to 1. 50%: The 50% clinically acceptable threshold value was taken as ΔE00 ≥ 1.8

Statistical analysis

The ΔE2000 values were analyzed using the Shapiro Wilk test and the data were analyzed using repeated measures analysis of variance (ANOVA). Tukey tests were used for post-hoc comparisons. All tests were performed using IBM SPSS Statistics 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, USA) package program. The significance level for statistical analyses was set as $P < 0.05$.

RESULTS

The color stability of Filtek One Bulk Fill resin composite was assessed by measuring color changes (ΔE00) after 14 days of immersion in 5 solutions: distilled water (control), tea (T), coffee (C), tea with sugar (TS), and coffee with sugar (CS). Data normality was confirmed using the Shapiro-Wilk test ($P > 0.05$ for all groups), allowing the use of parametric tests. One-Way ANOVA revealed significant differences in ΔE00 values among the groups ($F(4, 45) = 32,18$, $P < 0,001$. Post-hoc comparisons were performed using Tukey's test to identify specific group differences.

All test groups exhibited significantly greater discoloration than the control group (distilled water, ΔE00 = 3.33 ± 1.18) ($P < 0.05$). The tea with sugar (TS) group demonstrated the most pronounced color change (ΔE00 = 12.35 ± 2.03), which was significantly higher than all other groups ($P < 0.05$ for TS vs. T, C, CS, and control).

The tea (T) group (ΔE00 = 9.28 ± 2.34) showed significantly greater staining than the coffee (C) group (ΔE00 = 6.93 ± 2.04) (p = 0.009), confirming that tea induces more discoloration than coffee. The coffee (C) and coffee with sugar (CS) groups (ΔE00 = 8.82 ± 3.26 for CS) exhibited statistically similar levels of discoloration (p = 0.569), supporting H02 for coffee, as sugar addition did not significantly alter staining in coffee.

The ΔE00 values for all test groups exceeded the clinically acceptable threshold (ΔE00 ≤ 1.8), indicating noticeable color changes, particularly in the TS and T groups. [13]

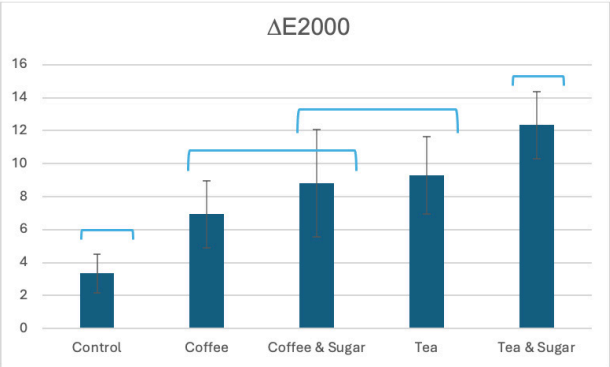

Figure 1. Comparison of 14-day ΔE00 values.

DISCUSSION

The present study revealed a marked, beverage-specific influence on the color stability of Filtek One Bulk Fill resin composite. Immersion in tea, coffee, sweetened tea, or sweetened coffee for fourteen days produced statistically and clinically greater ΔE_{00} values than storage in distilled water, indicating a high susceptibility of this bulk-fill material to dietary staining within short time frames. Tea acted as the most chromogenic solution, and sucrose addition amplified its staining potential, whereas the inclusion of sugar did not significantly intensify the discoloration caused by coffee. The large effect size obtained from the one-way ANOVA confirms that beverage composition accounts for the majority of the variance in color change across experimental groups, all of which exceeded the 1.8 ΔE_{00} clinical acceptability threshold.

Accordingly, the null hypothesis H_{01}-stating that beverage storage would not affect color stability relative to distilled water-is rejected. The second null hypothesis, H_{01}-asserting that sugar addition would not influence color change compared with unsweetened beverages-is only partially accepted: sucrose increased staining in tea but exerted no statistically additional effect in coffee.

Unexpectedly, the control specimens kept in distilled water also showed a perceptible color shift (ΔE_{00} = 3.33 ± 1.18), nearly twice the 1.8 clinical acceptability threshold. This finding suggests that water sorption and associated matrix changes alone can generate aesthetically relevant discoloration, even in the absence of external chromogens. Composite resin is now the most common aesthetic restorative material. Long-term success depends not only on mechanical integrity but also on the restoration maintaining color harmony with adjacent tooth structures (14,15). Despite their popularity, composite restorations remain prone to discoloration, a frequent reason for replacement (16). Although periodic repolishing can remove superficial stains, the primary goal is to minimize new discoloration and preserve esthetics even after frequent consumption of highly pigmented beverages (17,18).

Bulk-fill composites have attracted interest because of their enhanced polymerization kinetics and favorable mechanical properties (19,22) However, color stability varies with beverage exposure time and resin thickness. A lower depth of cure or incomplete conversion can increase residual monomer, elevate water sorption and, in turn, accelerate color change (23). Flury *et al.* (24) reported that 4 mm bulk-fill specimens exhibited a cure depth below the manufacturers' claims Consequently, the present study evaluated the color stability of 2 mm-thick Filtek One Bulk Fill specimens after immersion in sugar-sweetened and unsweetened tea and coffee.

Previous research (25,27) has largely focused on staining produced by individual chromogenic solutions such as coffee, tea, or red wine. Discolouration stems principally from water uptake and the hydrophilic nature of matrix

monomers (28). Pigments diffuse into the organic phase through bisphenol-A glycidyl methacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA), which readily absorb water (29). In coffee, caramelized compounds formed during roasting react with chlorogenic acids to yield dark pigments, (30) whereas tannins in tea adsorb strongly to resin surfaces and exacerbate staining (31). Sucrose may also leave a thin, viscous film on the composite surface, increasing its tackiness and surface free energy; this sticky residue can trap chromogenic molecules more readily and thus intensify stain adsorption and water-related sorption.

To mirror general consumption patterns, sucrose was incorporated into both beverages. All experimental solutions caused statistically significant and clinically perceptible color shifts compared with the distilled-water control, with sweetened tea producing the most pronounced change. These observations align with Shamszadeh *et al.* (20) who found bulk-fill composites more prone to staining than conventional materials, and support the proposal of Korać *et al.* (32) that interactions between TEGDMA and beverage constituents drive discoloration.

Polymerization depth varies with composite shade; darker tones cure less thoroughly, compromising surface finish and mechanical integrity. To minimize shade-related variability, all specimens were prepared in the widely used A2 hue (33,34) which exhibits intermediate translucency and reliable depth of cure under standard chairside conditions. The extent of staining depends on the duration of contact with chromogenic solutions. A typical cup of coffee is consumed in ≈15 min, and the average daily intake is 3.2 cups; one week of continuous immersion therefore approximates seven months of clinical exposure (35,36). In the present protocol, 14 days of storage in beverage solutions were chosen to simulate roughly one year of habitual tea or coffee consumption.

Color stability is influenced by matrix composition, filler loading, pigment sorption/adsorption, and the physicochemical properties of the staining medium (37) Although the CIELAB color-difference metric (ΔEab) is widely used, it assigns equal weight to L, a*, and b* coordinates, a simplification that over- or under-estimates visual perception (38,40). The CIEDE2000 formula (ΔE_{00}) incorporates weighting functions and correlates more closely with human vision (38,41,42) Accordingly, ΔE_{00} was selected to quantify color change. All experimental groups exhibited perceptible shifts, with ΔE_{00} values ranging from (6.93) to (12.35).

Certain limitations must be acknowledged. The *in vitro* design excludes oral variables such as thermal cycling, salivary clearance, and biofilm formation. Finally, only one bulk-fill composite was investigated; future studies should evaluate multiple materials and longer ageing regimens to confirm the generalizability of these findings.

CONCLUSION

Filtek One Bulk Fill showed clinically unacceptable color shifts after a 14-day immersion that simulated 1-year of beverage exposure. Sweetened tea produced the greatest ΔE_{00}, whereas adding sugar did not intensify coffee staining; even distilled water caused a perceptible change. These results call for patient advice on sugared-tea intake and for broader, clinically oriented studies to confirm long-term aesthetic durability across composite brands.

Ethics Committee Approval

The study was approved by the relevant institution administration.

Author contribution statement

Concept: N.B., Y.H.Y.P., O.T.H.; Design: N.B., Y.H.Y.P., O.T.H.; Supervision: N.B., Y.H.Y.P., O.T.H.; Resources: N.B., Y.H.Y.P., O.T.H.; Materials: N.B., Y.H.Y.P., O.T.H.; Data Collection and/or Processing: N.B., Y.H.Y.P., O.T.H.; Analysis and/ or Interpretation: N.B., Y.H.Y.P., O.T.H.; Literature Search: N.B., Y.H.Y.P., O.T.H.; Writing Manuscript: N.B., Y.H.Y.P., O.T.H.; Critical Review: N.B., Y.H.Y.P., O.T.H.

Informed Consent

Written informed consent was obtained from participants who participated in this study.

Conflict of Interest

The author declare that they have no conflict of interest.

Financial Disclosure

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