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# Impact of different beverages on color and structural characteristics of aesthetic composite resins

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## Abstract

**Objective:** This study evaluated the color stability and surface roughness of two composite resins, Gradia Direct and Omnichroma, after immersion in various solutions.

**Methods:** In this in-vitro study, 80 composite resin samples were divided into two groups (n = 40) according to the composite resin brands: Group 1: Gradia Direct and Group 2: Omnichroma. Each group was further divided into four subgroups (n = 10) based on the immersion solution: A) distilled water (control), B) tea, C) cola, and D) coffee. Color stability was measured on day 1 (ΔE1) and 28 (ΔE1) compared to baseline, and surface roughness was measured at baseline and on day 28. Data were analyzed using two-way and three-way ANOVA and Tukey HSD test ($P < 0.05$).

**Results:** Two-way ANOVA indicated no significant difference in ΔE1 or ΔE28 between the two composite resins ($P>0.05$). However, beverage type had a statistically significant effect on both ΔE1 and ΔE28 ($P<0.05$). Pairwise comparisons revealed that coffee produced the greatest color changes on day 1 and day 28 ($P<0.05$). Cola and distilled water demonstrated comparable color changes ($P>0.05$), which were significantly lower than those of other groups ($P< 0.05$). Three-way ANOVA found no significant effects of beverage type, composite type, time of assessment, or their interactions on surface roughness ($P>0.05$).

**Conclusion:** Gradia Direct and Omnichroma showed comparable color stability and surface roughness after exposure to various beverages. Coffee and tea caused significantly greater discoloration effects than cola and distilled water on composite resins.

**Keywords:** Acidic drink, Beverages, Coffee, Composite resins, Surface properties, Tooth discoloration

## Introduction

Color stability and surface characteristics of cosmetic composites are critical factors in aesthetic dentistry (1). Restorative materials function in a complex oral environment where they are continuously exposed to saliva, fluctuating pH levels, and dietary substances. These factors can affect the aesthetic and mechanical performance of resin composites (2).

Discoloration of resin composites is a common reason for restoration replacement (3). Numerous studies have investigated the color alterations of restorative composites after exposure to simulated oral conditions (2, 4-6). These changes result from a combination of extrinsic factors, such as composition, acidity, and staining potential of beverages, as well as intrinsic factors, including the chemical composition of the resin matrix, type and amount of filler particles, and surface structure of the resin composite.

Beverages like soft drinks, tea, and coffee are known to alter the color of dental restorations due to their staining potential. The presence of chromogenic compounds in these beverages plays a critical role in causing stains. In addition, acidic beverages can contribute to surface degradation by roughening the resin or enamel surface, indirectly facilitating stain retention. The hydrophilicity and water absorption capacity of the resin matrix further increase the susceptibility of composite materials to staining, as more water absorption allows greater penetration of chromogens into the material (2).

Surface roughness is defined as the degree of surface irregularities such as ridges, grooves, and depressions, usually measured with a profilometer. Surface roughness affects the clinical performance of resin-based composites because roughened surfaces promote bacterial adhesion, plaque accumulation, and extrinsic discoloration (7).

In recent years, manufacturers have aimed to create restorative materials that better replicate the natural

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appearance of teeth. Omnichroma (Tokuyama Dental Corp., Tokyo, Japan) is a novel single-shade composite that achieves color matching via structural color, not through traditional pigments or dyes. Omnichroma uses uniformly sized spherical fillers (approximately 260 nm in diameter) composed of silicon dioxide ($SiO2$) and zirconium dioxide ($ZrO2$). These precisely sized filler particles create a photonic crystal structure that selectively reflects light in the red-to-yellow wavelength range, corresponding to the natural color spectrum of human teeth. In contrast, conventional composites like Gradia Direct rely on added pigments to mimic tooth shades (8).

There is limited evidence regarding the impact of different beverages on the color stability and surface roughness of recently introduced aesthetic composite resins. Therefore, this study aimed to evaluate and compare the color stability and surface roughness of two cosmetic composite resins (Gradia Direct and Omnichroma) after immersion in common beverages (cola, coffee, tea, and distilled water as a control).

## Materials and methods

The protocol of the present in vitro study was approved by the ethics committee of Tehran University of Medical Sciences (IR.TUMS. DENTISTRY.REC.1401.015)

Sample size was determined as n=10, using PASS software (PASS 11, NCSS, LLC., Kaysville, Utah, USA) based on the results of Choi et al. (9) with $\alpha = 0.05$, 80% power, and effect size of 0.5.

### *Sample Preparation*

The composite resins used in this study are summarized in Table 1.

For specimen preparation, a Mylar strip (Kerr Corp., Orange, CA, USA) was placed on a glass slab. Composite resin was then inserted into a cylindrical mold (10 mm diameter, 2 mm height) positioned on the glass slab. A second Mylar strip was placed over the composite, followed by a 1 mm-thick glass slab to apply uniform pressure, ensuring a flat and even surface. The excess material was removed, and the top surface of each specimen was light-cured for 40 seconds using a Demi Plus LED curing unit (Kerr Corp.) operating at a wavelength of 450–470 nm with an irradiance of 1330 mW/cm². After removal from the mold, the bottom surface of each specimen was additionally light-cured for 20 seconds to complete polymerization.

All specimens were polished sequentially using Sof-Lex™ discs (3M ESPE, St. Paul, MN, USA), progressing from coarse to superfine grit, with each disc applied for 30 seconds by the same operator. After polishing, the samples were rinsed under distilled water for one minute. To ensure complete polymerization and allow rehydration, all specimens were then stored in distilled water at 37°C for 24 hours.

### *Study groups and immersion protocol*

Eighty composite resin samples were prepared from two composite resin brands (n = 40). The study groups were as follows:

*Group 1:* Gradia Direct (GC Corp., Tokyo, Japan)

*Group 2:* Omnichroma (Tokuyama Dental Corp., Tokyo, Japan)

Each group was then randomly divided into four subgroups (n = 10) according to the immersion medium:

*Subgroup A (Distilled water):* Specimens were immersed in distilled water throughout the study, serving as the control.

*Subgroup B (Tea):* Specimens were immersed in a tea solution prepared by steeping one tea bag (Golestan Co., Tehran, Iran) in 200 mL of warm distilled water for 2 minutes, then allowing the solution to cool to 28°C

**Table 1.** Characteristics of the composite resins used in this study

| Material Brand | Manufacturer | Classification | Organic Content | Inorganic Content |
|---|---|---|---|---|
| Omnichroma | Tokuyama Dental Corp., Tokyo, Japan | Supra-nano spherical resin-based composite | UDMA, TEGDMA, mequinol, dibutyl hydroxytoluene, UV absorber | Spherical silica-zirconia fillers; average particle size: 0.3 µm; Weight: 79%; Volume: 68% |
| Gradia Direct | GC Corp., Tokyo, Japan | Microfilled composite | Urethane dimethacrylate (UDMA), dimethacrylate, camphorquinone | Fluoro-alumino-silicate glass and silica powder fillers; average particle size: 0.85 µm; Weight: 73%; Volume: 64% |

**Table 2**. Mean ± standard deviation (SD) of ΔE1 values for the two resin composites immersed in different beverages

| Composite | Distilled water<br>Mean ± SD | Tea<br>Mean ± SD | Cola<br>Mean ± SD | Coffee<br>Mean ± SD |
|---|---|---|---|---|
| Gradia Direct | 0.88 ± 0.25 | 2.46 ± 0.83 | 1.51 ± 0.65 | 5.41 ± 0.47 |
| Omnichroma | 1.70 ± 0.40 | 2.51 ± 1.13 | 0.99 ± 0.55 | 5.58 ± 1.55 |
| Total | 1.19 ± 0.51$^{A}$ | 2.48 ± 0.93$^{B}$ | 1.25 ± 0.62$^{A}$ | 5.50 ± 1.08$^{C}$ |
| The effect of composite type | | P=0.66 | | |
| The effect of beverage type | | P<0.001 | | |
| Interaction effect | | P=0.51 | | |

Different uppercase superscript letters indicate statistically significant differences (P < 0.05) between beverages, as determined by Tukey's post hoc test.

before use. Tea solutions were renewed every three days to prevent microbial growth.

*Subgroup C (Cola):* Specimens were immersed in cola (Coca-Cola; Khoshgovar Co., Tehran, Iran). Freshly opened bottles were used daily, and containers were tightly sealed to maintain carbonation.

*Subgroup D (Coffee):* Specimens were immersed in a coffee solution prepared by dissolving one teaspoon of Nescafé instant coffee granules (Nestlé, Vevey, Switzerland) in 180 mL of boiling distilled water, cooled to 28°C before use. The coffee was unsweetened and free of additives. Coffee solutions were renewed every three days to prevent microbial growth.

All immersion media were maintained at ambient temperature (~28°C). All specimens were rotated daily within the containers to ensure uniform exposure.

### *Color change measurements*

Color was assessed at baseline (before immersion), day 1, and day 28. Before each assessment, the specimens were thoroughly rinsed with distilled water and dried.

The color assessment was performed using a spectrophotometer (Vita Zahnfabrik, Bad Säckingen, Germany). The device was calibrated against a standard white reference before each measurement session. Four independent readings were taken per specimen at each time point, and the mean of L*, a*, and b* values was recorded. Color differences (ΔE) were calculated between baseline and day 1 (ΔE1), and between baseline and day 28 (ΔE28), using the CIE Lab* formula: ΔE = [ΔL2+Δa2+Δb2]½

### *Surface roughness assessments*

The surface roughness was measured as Ra (arithmetic average roughness), which represents the average deviation of surface peaks and valleys from the mean level in micrometers. Measurements were taken at baseline and on day 28, using a 3D optical profilometer (InfiniteFocus Real3D, Alicona, Belgium) at 100× magnification. For each specimen, five random points were selected, and five readings were taken.

### *Statistical Analysis*

Data analysis was performed using SPSS software (version 25; IBM Corp., Armonk, NY, USA). Two-way ANOVA was run to compare color stability between groups and beverages, followed by Tukey's post hoc test for pairwise comparisons. Surface roughness data were analyzed by three-way ANOVA. A significance level of P < 0.05 was set.

## Results

### *Color stability*

Tables 2 and 3 summarize the color change values (ΔE) of the tested composites at different immersion intervals compared to the baseline.

Two-way ANOVA revealed no significant difference in ΔE1 between the two composite resins (P=0.66). However, the effect of beverage type on ΔE1 was statistically significant (P<0.001). There was no significant interaction between composite resin type and beverage on ΔE1 (P = 0.51). Pairwise comparisons between beverages revealed that coffee (5.50 ± 1.08) and tea (2.48 ± 0.93) caused significantly greater color changes than cola (1.25 ± 0.62) and water (1.19 ± 0.51) (P < 0.05). Furthermore, the discoloration effect of coffee was significantly greater than that of tea (P < 0.05; Table 2).

On Day 28 (ΔE28), two-way ANOVA revealed no significant difference in ΔE28 between the two composite resins (P=0.28). However, the effect of beverage type on ΔE28 was statistically significant (P=0.02). There was no significant interaction between composite resin type and beverage on ΔE28 (P = 0.41). Pairwise comparisons between beverages revealed that coffee (9.10 ± 2.66) and tea (7.14 ± 3.26) caused significantly greater color changes than cola (4.13 ±0.74) and water (4.77 ± 5.55) (P < 0.05). Furthermore, the

**Table 3.** Mean ± standard deviation (SD) of ΔE28 values for the two resin composites immersed in different beverages

| Composite | Distilled water Mean ± SD | Tea Mean ± SD | Cola Mean ± SD | Coffee Mean ± SD |
|---|---|---|---|---|
| Gradia Direct | 3.91 ± 0.48 | 6.43 ± 0.86 | 3.71 ± 0.51 | 9.64 ± 1.12 |
| Omnichroma | 5.63 ± 7.78 | 7.84 ± 4.69 | 4.54 ± 0.74 | 7.91 ± 3.73 |
| Total | 4.77 ± 5.55$^{A}$ | 7.14 ± 3.26$^{B}$ | 4.13 ±0.74$^{A}$ | 9.10 ± 2.66$^{C}$ |
| The effect of composite type | P=0.28 | | | |
| The effect of beverage type | P=0.02 | | | |
| Interaction effect | P=0.41 | | | |

Different uppercase superscript letters indicate statistically significant differences (P < 0.05) between beverages, as determined by Tukey's post hoc test.

discoloration effect of coffee was significantly greater than that of tea (P < 0.05; Table 3).

### *Surface Roughness Testing*

Surface roughness results are presented in Table 4. Only minimal changes in surface roughness (Ra) were observed across all comparisons. Three-way ANOVA revealed no significant effects of beverage type, composite type, time of assessment, or their interactions on surface roughness.

## Discussion

This study evaluated the color stability and surface roughness of two aesthetic resin composites (Gradia Direct and Omnichroma) after immersion in common beverages. Both materials showed increases in discoloration (ΔE) over time, regardless of the staining solution. Considering that 24 hours of in vitro exposure roughly equals one month in vivo (10), the 28-day immersion corresponds to about 2.5 years of clinical use.

In clinical practice, beverages like coffee, cola, and tea often contact resin restorations. Previous studies have defined ΔE thresholds: changes below 1 are imperceptible, 1.0–3.3 are detectable only by trained observers and are clinically acceptable, while ΔE values above 3.3 are clinically unacceptable (11). In this study, both Gradia Direct and Omnichroma maintained color stability within clinically acceptable limits on day 1, except for subgroups immersed in coffee, which showed unacceptable discoloration. On day 28, color changes were unacceptable in all immersion media, with coffee showing the greatest changes, followed by tea.

In the present study, Gradia Direct and Omnichroma showed similar performance, with no significant differences in discoloration. Only slight variations were observed between the two composites, which may be attributed to differences in their resin matrices and filler compositions. On the other hand, the effect of beverages on the discoloration of resin composites was significant. On both day 1 and day 28, the most pronounced changes occurred after immersion in coffee, followed by tea, while cola caused discoloration comparable to distilled water. The pigments from the staining beverages diffuse and absorb into the composite matrix over time, progressively worsening discoloration. These findings emphasize that beverage

**Table 4.** Mean ± standard deviation (SD) of average surface roughness values (Ra, µm) for the composite samples immersed in different beverages

| | Distilled water | | Tea | | Cola | | Coffee | |
|---|---|---|---|---|---|---|---|---|
| | Baseline Mean ± SD | Day 28 Mean ± SD | Baseline Mean ± SD | Day 28 Mean ± SD | Baseline Mean ± SD | Day 28 Mean ± SD | Baseline Mean ± SD | Day 28 Mean ± SD |
| Gradia Direct | 0.29 ± 0.35 | 0.27 ± 0.25 | 0.28 ± 0.27 | 0.25± 0.08 | 028 ± 0.17 | 035 ± 0.22 | 0.23± 0.15 | 0.39 ± 0.15 |
| Omnichroma | 0.25 ± 0.08 | 0.24 ± 0.09 | 0.35 ± 0.13 | 0.31 ± 0.22 | 0.56 ± 0.40 | 0.44 ± 0.24 | 0.49 ± 0.22 | 034 ± 0.35 |
| The effect of composite type | | | P=0.06 | | | | | |
| The effect of beverage type | | | P=0.11 | | | | | |
| The effect of assessment time | | | P=0.79 | | | | | |
| Interaction between composite* beverage | | | P=0.27 | | | | | |
| Interaction between beverage* time | | | P=0.74 | | | | | |
| Interaction between composite* time | | | P=0.37 | | | | | |
| Interaction between composite* time* beverage | | | P=0.25 | | | | | |

type plays a more critical role in composite discoloration than the composite material itself.

The results of this study agree with those of some previous studies. For example, Ozkanoglu and Akin (12) found coffee and tea to cause more staining than water or Coca-Cola, with no significant differences between composites. Mundim et al. (13) also reported coffee as the strongest staining agent, while Coca-Cola had minimal effect despite its low pH. Bahbishi et al. (14) reported that tea caused the most staining among the tested beverages. Overall, these findings highlight that beverage type is a critical factor in the degree of composite discoloration.

The present results improve understanding of how composites respond to common staining challenges. These findings are crucial for patient education following aesthetic procedures. Patients should be made aware of the risks of beverage-related discoloration and the importance of special care to maintain and prolong the aesthetic appearance of composite restorations.

In the present study, no significant differences in surface roughness were found between Gradia Direct and Omnichroma. Furthermore, both composites showed non-significant changes across all beverages. No significant increase was observed in surface roughness from Day 1 to Day 28, indicating surface stability. These findings align with previous studies reporting minimal effects of beverages on composite roughness (14, 19, 20). However, da Silva et al. (21) demonstrated that alcoholic beverages like whisky and beer significantly increased roughness.

Surface roughness is influenced by filler type, particle size, matrix–filler bonding, and finishing and polishing procedures (18, 19, 22-29). Even small changes in surface roughness are clinically important, as they can increase plaque accumulation and affect the long-term performance of aesthetic restorations(19, 22). The relationship between surface roughness and color stability remains unclear. Some studies suggest that rougher surfaces are more susceptible to staining (15, 16), whereas others reported no consistent correlation (17, 18). The outcomes of this study also indicate that discoloration of resin composites in various beverages is not associated with changes in surface roughness.

This study has limitations. As an in vitro investigation, it does not fully replicate oral conditions such as saliva composition, thermal cycling, and dietary habits. Additionally, the study included only two composite materials and a limited range of beverages, which limits the generalizability of the findings. Future studies should test a wider range of beverages with different pH levels, use longer immersion times, and include newer composite formulations.

## Conclusions

Within the limitations of this study, Gradia Direct and Omnichroma exhibited comparable color stability and surface roughness after exposure to various beverages. Among the tested beverages, coffee produced the greatest color changes, followed by tea, while cola and water resulted in significantly less discoloration.

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Not applicable.

## Conflict of interest

The authors declare no conflict of interest.

## Author contributions

M.R. was involved in the study design, experimental procedures, data collection, data analysis, supervision, and manuscript editing. B.B. contributed to data collection, data analysis, supervision, and critical revision of the manuscript. Z.Q.A.A. participated in the study design, experimentation, and drafting of the original manuscript. All authors reviewed and approved the final version of the manuscript and contributed substantially to its preparation and content.

## Ethical approval

The protocol of the present in vitro study was approved by the Medical Ethics Committee of Tehran University of Medical Sciences (IR.TUMS. DENTISTRY.REC.1401.015).

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