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Effect of dietary agents on microhybrid composite discoloration and microleakage

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Abstract:
Dietary agents may impair both color stability and marginal integrity of resin-composite restorations. Eighty restored premolars were divided into tea, coffee, carbonated beverage, and tamarind groups (n = 20) and exposed for 15 days. Coffee caused the greatest discoloration ($\Delta E = 5.32 \pm 0.17$), while carbonated beverage and tamarind caused the greatest microleakage ($p < 0.001$). Discoloration and microleakage were not significantly correlated within any group (all $p > 0.05$). Thus, dietary agents therefore exert distinct chromogenic and interfacial effects that should be considered separately in restorative care.

Keywords: Microhybrid composite; color stability; coffee; carbonated beverage; tamarind; microleakage; spectrophotometry

Background:
Direct resin composites are integral to contemporary restorative dentistry because they permit conservative cavity preparation, adhesion, repair and close reproduction of natural tooth appearance **[1]**. Their long-term clinical acceptability, however, depends on maintaining optical stability and marginal integrity. Resin matrices may undergo oxidation, post-polymerization, water sorption and chemical degradation, while changes at the filler-matrix interface can alter light scattering and surface quality **[1]**. Composite color stability is influenced by resin chemistry, filler size and loading, silane coupling, degree of conversion, curing conditions, finishing and polishing and environmental exposure **[2, 3]**. Microhybrid composites combine relatively high filler loading and favorable mechanical performance with clinically acceptable polishability, but their organic matrix remains susceptible to water uptake and dietary colorants. Beverage composition is therefore important: coffee contains dark chromogens and polyphenols, tea contains tannins and water-soluble pigments, carbonated beverages are frequently acidic and tamarind preparations contain organic acids and plant-derived compounds **[4]**. Repeated exposure can alter surface roughness and microhardness, thereby increasing stain retention and degradation. Comparative immersion studies have shown that coffee often produces more discoloration than tea or cola **[5]**. Color change is commonly quantified in the CIE L*a*b* color space as the total color difference (ΔE) and spectrophotometric assessment is more reproducible than unaided visual evaluation **[6]**. Thermocycling combined with beverage exposure is widely used to simulate concurrent thermal and chromogenic challenges **[7]**. Marginal integrity is a distinct determinant of restoration longevity. Microleakage permits the movement of fluids, ions, molecules, or bacteria along the tooth-restoration interface and may contribute to marginal staining, post-operative sensitivity, recurrent caries and pulpal irritation **[8]**. Acidic media can soften resin matrices and degrade adhesive interfaces, whereas differences in the coefficients of thermal expansion of tooth structure and restorative materials may intensify interfacial stress. Finishing and polishing can reduce extrinsic discoloration but may not prevent staining or reverse chemical degradation **[9]**. Recent studies continue to show beverage-dependent changes in composite optical behavior **[10, 11]**. Therefore, it is of interest to compare the discoloration and microleakage of a microhybrid composite after repeated exposure to tea, coffee, a carbonated beverage and tamarind extracts and assessed the association between these outcomes.

Materials and Methods:

Study design and ethical aspects:
An *in vitro* controlled laboratory study was conducted using extracted human premolars. Ethical approval was obtained from before specimen collection. Teeth were extracted only for clinical indications and not for the purposes of this investigation. The study used four parallel exposure groups and two primary outcomes: total color change and linear dye penetration at restoration margins. The sample-size calculation assumed a 5% alpha error and 80% power to detect a between-group difference; 80 teeth were included (20 per group). A computer-generated random sequence allocated specimens to tea, coffee, tamarind extract, or carbonated beverage. Recently extracted, non-carious, unrestored human premolars removed for orthodontic indications were eligible. Teeth with developmental defects, restorations, cracks, fractures, caries, cervical abrasion, erosion, attrition, or other regressive changes were excluded. Residual soft tissue and calculus were removed; the teeth were disinfected in 2.6% sodium hypochlorite for 2 hours, rinsed under running water and stored in distilled water until use. Standardized Class V cavities (approximately 3 mm mesiodistally, 2 mm occlusogingivally and 1.5 mm deep) were prepared on the facial surface with a cylindrical diamond bur under water cooling, with the long axis parallel to the cementoenamel junction; no bevel was placed. Burs were replaced at regular intervals to minimize variation. Cavity walls were etched with 37% phosphoric acid for 15 seconds, rinsed and gently blot-dried. A fifth-generation etch-and-rinse adhesive was applied and light-cured according to the manufacturer's instructions. Cavities were restored with a universal dentin shade of microhybrid composite (Filtek Z250, 3M ESPE), light-cured and finished and polished with a multistep aluminum-oxide disc system. Each apical foramen was sealed with glass-ionomer restorative material to prevent solution penetration through the root canal.

Thermal aging and preparation of exposure solutions:
All restored teeth underwent 1,000 thermal cycles between water baths at 5 ± 2°C and 55 ± 2°C, with 30-second dwell times and a 5-second transfer interval. Baseline color measurements were obtained after thermocycling. The specimens were randomly

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assigned to four equal groups: tea, coffee, tamarind extract and carbonated beverage. For the tea, coffee and tamarind solutions, 2.8 g of the assigned product was added to 150 mL of boiling distilled water and allowed to cool to the test temperature. A commercially available cola was used for the carbonated-beverage group. Fresh solutions were prepared daily. Color was measured using a calibrated dental reflection spectrophotometer (VITA Easyshade) against a standard white background. The central restoration area was measured three times and the readings were averaged. Measurements were recorded as L*, a* and b* coordinates. Total color difference (ΔE) between baseline and post-exposure readings was calculated as follows:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Specimens were immersed in their assigned solution for 4 hours daily for 15 days. After each exposure, the teeth were rinsed with distilled water and stored in fresh distilled water until the next cycle. At the end of the immersion period, specimens were rinsed, gently dried and remeasured using the same spectrophotometric protocol.

Microleakage assessment:

After color assessment, each tooth was coated with two layers of nail varnish, leaving a 1-mm-wide margin around the restoration exposed. Specimens were immersed in 2% methylene blue for 24 hours at 37°C and then thoroughly rinsed. Roots were sectioned approximately 4-5 mm apical to the cementoenamel junction and crowns were sectioned buccolingually through the center of the restoration with a low-speed diamond disc under coolant. Sectioned surfaces were examined under a stereomicroscope at 16× magnification. Dye penetration at the occlusal and gingival tooth-restoration interfaces was measured in millimeters using image-analysis software. The examiner was blinded to group allocation and measurements were repeated when the margin was not clearly delineated.

Statistical analysis:

Data were summarized as mean ± standard deviation, median and range. Between-group differences in ΔE and microleakage were evaluated using one-way analysis of variance, followed by Scheffé post-hoc comparisons. Within each exposure group, the association between discoloration and microleakage was assessed using Pearson's correlation coefficient. Statistical significance was set at $p < 0.05$; exact p-values are reported where available and $p < 0.001$ denotes strong evidence against the null hypothesis.

Results:

All 80 specimens completed thermocycling, dietary exposure, spectrophotometric evaluation and microleakage assessment. Baseline restoration color coordinates were comparable across the four groups and no specimen was excluded because of restoration loss, visible fracture, or sectioning error. Dietary solution significantly affected color change (one-way ANOVA, $F(3, 76) = 1298.73$; $p < 0.001$). Coffee produced the highest mean ΔE (5.32 ± 0.17), followed by carbonated beverage (2.77 ± 0.13), tea (2.41 ± 0.25) and tamarind extract (2.15 ± 0.16). Descriptive values for both outcomes are presented in **Table 1**. All Scheffé-adjusted pairwise comparisons for ΔE were statistically significant **(Table 2)**. Microleakage also differed significantly among the dietary solutions (one-way ANOVA, $F(3, 76) = 735.35$; $p < 0.001$). Carbonated beverage produced the greatest mean dye penetration (1.37 ± 0.11 mm), closely followed by tamarind extract (1.33 ± 0.14 mm); tea and coffee produced lower values of 0.35 ± 0.04 mm and 0.37 ± 0.05 mm, respectively. Pairwise testing showed no significant difference between tea and coffee ($p = 0.955$) or between tamarind extract and carbonated beverage ($p = 0.587$); all comparisons between a low-leakage and high-leakage solution were significant at $p < 0.001$ **(Table 3)**. Discoloration and microleakage were not significantly correlated within any group: tea, $r = -0.087$ ($p = 0.716$); coffee, $r = -0.242$ ($p = 0.303$); tamarind extract, $r = 0.170$ ($p = 0.473$); and carbonated beverage, $r = -0.185$ ($p = 0.436$). Thus, the solution producing the greatest discoloration did not produce the greatest marginal leakage.

Table 1: Descriptive statistics for discoloration and microleakage by exposure group

Exposure group	n	ΔE, mean ± SD	ΔE median	ΔE range	Microleakage, mean ± SD (mm)	Microleakage median (range), mm
Tea	20	2.41 ± 0.25	2.44	1.80-2.90	0.35 ± 0.04	0.36 (0.27-0.42)
Coffee	20	5.32 ± 0.17	5.38	5.08-5.56	0.37 ± 0.05	0.37 (0.26-0.44)
Tamarind extract	20	2.15 ± 0.16	2.16	1.86-2.41	1.33 ± 0.14	1.30 (1.00-1.50)
Carbonated beverage	20	2.77 ± 0.13	2.80	2.51-3.01	1.37 ± 0.11	1.40 (1.10-1.50)

Table 2: Scheffé-adjusted pairwise comparisons for discoloration (ΔE)

Pairwise comparison	df	Scheffé F	p-value	Result
Tea vs coffee	3, 76	857.53	<0.001	Significant
Tea vs tamarind extract	3, 76	7.17	<0.001	Significant
Tea vs carbonated beverage	3, 76	13.13	<0.001	Significant
Coffee vs tamarind extract	3, 76	1021.48	<0.001	Significant
Coffee vs carbonated beverage	3, 76	658.47	<0.001	Significant
Tamarind extract vs carbonated beverage	3, 76	39.69	<0.001	Significant

Table 3: Scheffé-adjusted pairwise comparisons for microleakage

Pairwise comparison	df	Scheffé F	p-value	Result
Tea vs coffee	3, 76	0.11	0.955	Not significant
Tea vs tamarind extract	3, 76	358.25	<0.001	Significant

Pairwise comparison	df	Scheffé F	p-value	Result
Tea vs carbonated beverage	3, 76	389.36	<0.001	Significant
Coffee vs tamarind extract	3, 76	345.87	<0.001	Significant
Coffee vs carbonated beverage	3, 76	376.46	<0.001	Significant
Tamarind extract vs carbonated beverage	3, 76	0.65	0.587	Not significant

Discussion:

The present study showed that commonly consumed dietary products affected optical stability and marginal integrity through different mechanisms. Coffee produced the greatest discoloration ($\Delta E = 5.32 \pm 0.17$), whereas carbonated beverage and tamarind extract produced the greatest dye penetration. The absence of significant within-group correlations indicates that discoloration cannot serve as a surrogate for marginal leakage. Coffee-associated discoloration agrees with earlier work showing cumulative staining of methacrylate-based composites by coffee **[10]**. Beverage-related color change varies with material composition and exposure medium **[11]**. Similarly, Ferreira-Coelho *et al.* found that coffee and black tea produced marked color alterations and that the magnitude of staining depended on the surface sealant, supporting a material- and surface-dependent response to dietary chromogens **[12].** This variability is probably because coffee chromogens and polyphenols adsorb to the surface and diffuse into water-sorbing regions of the resin matrix. Carbonated beverage produced less discoloration than coffee but the greatest mean microleakage. Acidic food-simulating liquids can increase surface roughness and reduce microhardness and cola exposure can adversely affect the color stability and hardness of esthetic restorative materials **[13].** These processes may soften the resin-rich surface, weaken filler-matrix coupling and increase permeability at the bonded interface. Tamarind extract showed the lowest discoloration but microleakage comparable with that of the carbonated beverage. Its organic acids may challenge the restoration margin without producing the strongly visible staining associated with coffee. Clinically, an apparently acceptable color therefore does not establish that the margin remains intact. Tea and coffee produced similarly low microleakage despite different chromogenic effects, reinforcing that pigment concentration alone does not determine interfacial penetration. Thermocycling was standardized across groups; repeated temperature change can stress Class V bonded interfaces **[14],** but group differences observed after aging are more plausibly attributable to exposure-solution chemistry. The 2% methylene blue method permitted direct measurement of dye penetration after sectioning and has been used to assess marginal integrity of Class V restorations **[15].** Nevertheless, dye molecules are smaller than bacteria and a two-dimensional section samples only selected planes. Comparisons with three-dimensional leakage methods show that absolute leakage estimates are method dependent **[16].** The observed dissociation between discoloration and microleakage is biologically plausible. Color change depends on pigment adsorption and absorption, resin hydrophilicity, degree of conversion, surface topography and optical scattering; microleakage is more strongly influenced by cavity configuration, adhesive integrity, polymerization contraction, thermal stress and chemical degradation. Polymerization stress is further modified by bond strength, cavity compliance, restorative technique and time-dependent stress relaxation **[17].** These findings support separate clinical consideration of esthetic staining and marginal integrity. Patients with high coffee intake should be advised that visible color change may occur, whereas frequent exposure to acidic cola or tamarind preparations may warrant closer assessment of restoration margins even in the absence of marked staining. The study is limited by its short-term *in vitro* exposure model; absence of salivary clearance, acquired pellicle, biofilm, mastication and toothbrushing; use of one composite shade, adhesive and finishing protocol; lack of a distilled-water control; and two-dimensional dye-penetration assessment. Further studies should compare multiple composite formulations, include artificial-saliva and water controls, characterize solution pH and titratable acidity and combine spectrophotometry with surface profilometry, microhardness testing and three-dimensional leakage analysis **[18, 19].**

Conclusion:

Coffee produced high discoloration, whereas carbonated beverage and tamarind extract produced the high microleakage. Because discoloration and marginal leakage were not significantly correlated, restoration color should not be used to infer marginal integrity. Hence, dietary agents should therefore be considered separately for their chromogenic and interfacial effects on composite restorations.

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