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ORIGINAL ARTICLE

Effect of Staining Solutions on the Color Stability of Conventional and Bulk Fill Nanohybrid Resin Composites: A Spectrophotometric Analysis

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ABSTRACT

Aim: This study is aimed to evaluate the effect of staining solutions on the color stability of bulk fill and conventional nanohybrid resin composites (RCs) when subjected to various immersion periods.

Materials and methods: A total of 120 cylindrical Teflon molds (4 × 4 mm) were obtained and divided into four groups of 30 each. Molds of groups I and II were filled with Tetric N Ceram Bulk Fill (Ivoclar Vivadent, Schaan, Liechtenstein) and Filtek Bulk Fill (3M ESPE, St. Paul, MN, USA). Molds of groups III and IV were filled with Tetric N Ceram (Ivoclar Vivadent) and Filtek Z250 XTE (3M ESPE) incremental fill RC. Photo-activation was performed and specimens were incubated. Spectrophotometer analysis was done according to Commission Internationale d'Eclairage Lab color scale. After taking the baseline measurements, 10 samples from each group were immersed in distilled water (control, subgroup a), tea (subgroup b), and coffee (subgroup c) respectively, for 1, 7, and 30 days. The color values of each specimen were remeasured and color change value (E*ab) was calculated after 1, 7, and 30 days. Data were analyzed by Friedman's test and Mann–Whitney U-test; $p < 0.05$ is considered to be statistically significant.

Results: Group III specimens showed perceptible color changes at 30-day immersion period in coffee and tea. In group I specimens, color changes were perceptible at 7- and 30-day immersion periods in coffee and only 30-day immersion period in tea. Groups II and IV specimens showed perceptible color changes after all immersion periods in coffee and after 30 days in tea.

Conclusion: It can be concluded that Tetric N Ceram has less color change than the other nanohybrid RCs investigated when immersed in coffee and tea after various immersion periods.

Keywords: Bulk fill composite, Coffee, Color stability, Incremental fill composite, Tea.

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INTRODUCTION

Patients' great demand for esthetic appearance increases the significance of resin composite (RC) restorations in the dentist's routine practice.[1] Esthetic failure remains the most common reason for the replacement of these restorations.[2]

Several intrinsic and extrinsic factors cause the discoloration of resin-based composites.[3] Extrinsic factors include poor oral hygiene, smoking and drinking habits,[2] adsorption and absorption of water-soluble stains,[4] and ultraviolet radiation.[5] The susceptibility to extrinsic staining is also affected by composition and size of filler particles.[6]

Intrinsic factors affecting the color stability include the composition of resin matrix, depth of cure, shade and degree of conversion,[7] photoinitiator,[8,9] and water sorption.[10] Insufficient depth of cure is considered as the main disadvantage of resin-based composites.[11] Due to the insufficient depth of cure, incremental placement technique is employed with each increment not exceeding 2 mm while restoring deep cavities.[12] As this procedure is time consuming, bulk fill composites have been introduced with an increased increment thickness. Generally bulk fill composites are claimed to be curable to a thickness at 4 mm without adverse effect on polymerization shrinkage, cavity adaptation, and degree of conversion.[13-16]

In the dental literature, many studies compared the color stability of various conventional RC materials upon immersion in coffee, tea, and other beverages. Chan et al[17] investigated two composites by immersing the specimens in soy sauce, cola, coffee, tea, and distilled water and reported that soy sauce and coffee showed greater discoloration and stain resistance is affected by the type of material used.

Dietschi et al[10] tested 10 conventional composite materials and reported that erythrosine and coffee caused greatest color change among the solutions used (Table 1). The authors also concluded that the resistance to discoloration for an RC can be increased by polished surfaces, low water sorption, a high filler–resin ratio, reduced particle size and hardness, and an optimal filler–matrix coupling system, but only a few studies reported the color stability of bulk fill composites. Ertan Taskinsel et al[18] stated that nanocomposites exhibit better color stability than microhybrid composites due to the latter's low polishability.

However, there are no studies comparing the color stability of bulk fill and incremental fill nanohybrid RCs. So, the aim of this study is to compare the effect of the individual staining solutions on the color stability of different nanohybrid RCs used in the study.

MATERIALS AND METHODS

A total of 120 cylindrical split teflon molds (4 × 4 mm) were obtained and divided into four groups of 30 each. Molds of groups I and II were filled with Tetric N Ceram Bulk Fill (Ivoclar Vivadent, Schaan, Liechtenstein) and Filtek Bulk Fill (3M ESPE, St. Paul, MN, USA). For the bulk fill composites, a mylar strip was placed on a glass plate and the teflon mold was placed over it. The bulk fill composite was packed in bulk inside the mold until it was slightly overfilled and covered with a mylar strip. A glass slide of 1 mm thickness was placed on top of the mylar strip to remove excess material and to obtain a flat surface.

Molds of groups III and IV were filled with Tetric N Ceram (Ivoclar Vivadent) and Filtek Z250 XTE (3M ESPE) incremental fill RC respectively. For incremental fill RCs, the material was packed in 2 mm increments according to the manufacturer's instructions; each increment was cured from the top surface of the specimen.

Photoactivation was performed according to the manufacturer's instructions for 10 seconds at 1200 mW/cm^2 with a light-emitting diode light curing unit (3M ESPE, ELIPAR). The light guide tip was placed in contact with glass slide on the top surface of specimen. The output power was checked regularly with a radiometer (Ivoclar). Polishing techniques were not used to avoid modification of surfaces of the specimens, which may have influenced the results.

The specimens were incubated at 100% humidity at 37°C for 24 hours. The baseline measurements were performed using a spectrophotometer. The calibration was made with a standard white card, and the readings were recorded according to Commission Internationale d'Eclairage (CIE Lab). The measurements were taken at the center of the resin discs and were repeated twice in each sample, and the mean values were calculated.

After taking the baseline measurements, each group was divided into three subgroups of 10 samples each. Samples from each subgroup were immersed in distilled water (control, subgroup a), tea (subgroup b), and coffee (subgroup c) respectively, for 1, 7, and 30 days.

PREPARATION OF STAINING SOLUTIONS

Tea solution was prepared by dissolving 5 gm of instant tea (Taj Mahal, Brooke Bond, Mumbai, Maharashtra, India) into 250 mL of boiling water for 6 minutes. After stirring for 1 minute, the solution was filtered through filter paper. Coffee (Bru, Hindustan Unilever, Chennai, Tamil Nadu, India) solution was also prepared by the same method. The solutions were prepared daily.

Table 1: Composition of the resin composite materials used in the study

Groups	*Resin composite and shade*	*Filler weight (%)*	*Filler volume (%)*	*Filler type*	*Filler size*	*Monomer composition*
I	Tertic N ceram Bulk Fill (Ivoclar Vivadent, Schaan, Liechtenstein), A1	75–77	53–55	Barium glass filler, Ytterbium trifluoride, Silicon dioxide	0.6 μm	Bis-GMA, Bis-EMA, UDMA
II	Filtek Bulk Fill (3M ESPE, St. Paul, MN, USA), IVA	76.5	58.4	Non-aggregated zirconia and silica filler, aggregated zirconia/silica cluster filler, Ytterbium trifluoride	Non-aggregated silica filler: 20 nm, non-aggregated zirconia filler: 4 to 11 nm, aggregated zirconia/silica cluster filler: 20 nm silica and 4 to 11 nm zirconia	Bis-GMA, Bis-EMA, UDMA, AUDMA, DDDMA
III	Tertic N ceram (Ivoclar Vivadent, Schaan, Liechtenstein), A1	81	62–64	Barium glass filler, Ytterbium trifluoride, Mixed oxide, Polymer Filler	0.6-10 μm	Bis-GMA, Bis-EMA, UDMA
IV	Filtek Z250XTE (3M, ESPE, St Paul, MN, USA), A1	82	68	Non-aggregated zirconia and silica filler, aggregated zirconia/silica cluster filler, Ytterbium trifluoride	Aggregated zirconia/silica cluster filler: 0.01-3.5μm with an average particle size of 0.6μm, non-aggregated silica filler: 20 nm, non-aggregated zirconia filler: 4 to 11 nm	TEGDMA Bis-EMA, UDMA

Abbreviations: BisGMA: Bisphenol A glycidylmethacrylate; UDMA: Urethane dimethacrylate; BIS-EMA: Ethoxylated bisphenol A glycol dimethacrylate; AUDMA: Aromatic dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; DDDMA: 1,12-dodecanediol dimethacrylate

The color difference (ΔE*ab) was calculated from the equation[19] $\Delta E - {}^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½}$, where L* represents lightness, a* depicts chromaticity in green–red axis (−a = green; +a = red) and b* depicts chromaticity in blue–yellow axis (−b = blue; +b = yellow).

Each specimen should be rinsed thoroughly with water for 1 minute and dried with absorbent paper before each measurement. All the measurements were performed on the same surface of the specimens.

For statistical analysis, Statistical Package for the Social Sciences for windows version 11.5 was used. Friedman's test was used to compare the groups of each staining solution after different immersion periods. To compare the staining solutions after each immersion period, Mann–Whitney U-test was used; $p < 0.05$ is considered to be statistically significant for all tests.

RESULTS

The mean and standard deviations of color change values (ΔE*ab) of composite specimens after immersion in staining solutions are shown in Table 2. When the ΔE*ab value was > 3.3, staining was considered visually perceptible.[20]

Group I (Tetric N Ceram Bulk Fill): These specimens showed perceptible color changes after 30 days of immersion in tea and after 7 and 30 days of immersion in coffee (Table 2).

Group II (Filtek Bulk Fill): Color changes were perceptible in these specimens after 30-day immersion in tea. Perceptible staining was found in specimens immersed in coffee at all immersion periods (Table 2).

Group III (Tetric N Ceram): These specimens showed perceptible color changes after 30 days of immersion in tea and coffee (Table 2).

Group IV (Filtek Z250 XTE): Color changes were perceptible in specimens after 30 days of immersion in tea. Perceptible staining was found in specimens immersed in coffee at all immersion periods (Table 2).

Table 2: Mean and standard deviations of groups I, II, III and IV staining solutions

Resin composite		*Staining solutions*					
		Water (sub-group I)		*Tea (sub-group I)*		*Coffee*	
Groups	*Days*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
I	1	2.01	0.20	2.33	0.34	3.16	0.17
	7	2.06	0.18	2.27	0.30	3.49	0.38
	30	2.24	0.19	4.04	0.31	5.34	0.49
II	1	1.28	0.28	2.22	0.25	4.54	0.23
	7	1.85	0.17	2.45	0.20	5.48	0.21
	30	1.92	0.16	8.33	0.23	7.97	0.19
III	1	1.11	0.30	2.28	0.20	2.74	0.31
	7	1.53	0.23	2.10	0.23	2.53	0.21
	30	1.87	0.13	4.49	0.39	4.73	0.33
IV	1	1.83	0.19	2.33	0.25	3.54	0.18
	7	2.18	0.16	2.63	0.25	4.41	0.17
	30	1.94	0.19	8.14	0.21	8.25	0.23

Multiple Groups Comparison among Staining Solutions (Table 3)

Group I: After 1 day, no significant difference was observed between the staining solutions. After 7 and 30 days, significant difference was observed between water and tea and water and coffee.

Group II: Significant difference was observed among all the staining solutions after all immersion periods except between tea and coffee after 30 days of immersion.

Group III: After 1 day, no significant difference was seen among the staining solutions. After 7 days, significant difference was seen only between water and coffee. After 30 days, significant difference was observed between water and tea and water and coffee.

Group IV: Significant difference was observed among all the staining solutions after all immersion periods except between tea and coffee after 30 days of immersion (Table 3).

DISCUSSION

Esthetic failure remains the major cause for the replacement of RC restorations.[21] The color stability is determined by resin matrix, staining agents, depth of cure, and dimensions of filler particles.[22] To evaluate the color changes, CIE L*, a*, b* coordinates system was used in this study as it is appropriate for the determination of small color changes and shows sensitivity, repeatability, and objectivity.[10]

On evaluating the effect of staining solutions on the color stability of Tetric N Ceram, Tetric N Ceram Bulk Fill, Filtek Z250 XTE, and Filtek Bulk Fill, significantly higher discoloration was observed in Filtek Z250 XTE and Filtek Bulk Fill specimens after 30 days of storage in

Table 3: Mann–Whitney U-test results for ΔEab in terms of the staining solutions

Immersion period	*Staining solutions*	*Group I*	*Group II*	*Group III*	*Group IV*
1 Day	Water-tea	–	+	–	+
	Water-coffee	–	+	–	+
	Tea-coffee	–	+	–	+
7 Days	Water-tea	+	+	–	+
	Water-coffee	+	+	+	+
	Tea-coffee	–	+	–	+
30 Days	Water-tea	+	+	+	+
	Water-coffee	+	+	+	+
	Tea-coffee	–	–	–	–

+ indicates statistically significant difference (p<0.05); – indicates no statistically significant difference (p>0.05) coffee and tea. These color changes were related to the compositions of the RCs. Filtek Z250 XTE and Tetric N Ceram have similar resin matrix compositions with the addition of triethylene glycol dimethacrylate (TEGDMA) in the resin matrix of Filtek Z250 XTE. Previous studies reported the increase in the water uptake in the bisphenol A–diglycidylether methacrylate-based RCs from 3 to 6% as the proportions of TEGDMA increased from 0 to 1%.[23] This explains the greater discoloration of Filtek Z250 XTE compared with Tetric N Ceram. The greater color stability of Tetric N Ceram may also be attributed to the relatively higher percentage of urethane-dimethacrylate, which is more resistant to water, in its resin matrix.

Filtek Z250 XTE with smaller particle size is expected to have smoother surface and less discoloration. But the greater discoloration may be due to the presence of nanocluster and agglomerated filler particles. Previous studies concluded that these particles possess high water sorption character, thus making them less color resistant.[24] The increased discoloration of Filtek Bulk Fill is explained by the less filler loading (56–59% by volume) and also by the less water-resistant nanoclusters in the filler composition; due to the lower filler content, more water might get absorbed at the matrix–filler interface causing hydrolytic degradation of filler and eventually debonding of matrix–filler interface.[25] The less color stability of Tetric N Ceram Bulk Fill compared with Tetric N Ceram may be explained by the less filler loading in its composition (54–56% by volume) compared with Tetric N Ceram.

All the RCs investigated in this study exhibited acceptable color changes ($\Delta E < 3$) for all immersion periods after immersion in water; this finding is consistent with previous reports.[26] All the four composite resins demonstrated unacceptable color changes after 30 days of storage in coffee and tea. Chan et al[17] and Ertas et al[24] also reported that coffee causes more discoloration than tea. This greater color change following the immersion in coffee is attributed to the presence of yellow low-polarity chains. These low-polarity stains can penetrate deeper into polymer matrices of RCs both by adsorption and absorption. The high-polarity yellow stains from tea can precipitate on the surface only through adsorption.[27] Due to the stain's mobile and high-polarity phases,[28] they get eluted after rinsing with water.[10,29]

ΔEab values > 3.3 were considered clinically unacceptable by many authors.[2,20] In this study, color changes of Tetric N Ceram specimens exceeded the ΔEab value of 3.3 only after 30 days of immersion in coffee and tea solutions. Tetric N Ceram Bulk Fill showed $\Delta Eab > 3.3$ after 30 days of immersion in tea and after immersion in coffee for 7 and 30 days. Filtek Z250 XTE and Filtek Bulk Fill demonstrated perceptible color changes after 30 days of immersion in tea and for all immersion periods in coffee. These results were in agreement with a study conducted by Yannikakis et al.[29] The author reported that as the immersion time is increased, the color changes became more intensive.

This study demonstrates the effect of tea and coffee on the discoloration of two bulk fill and two conventional nanohybrid RCs. Further research is needed to investigate the effect of other frequently consumed drinks, such as soft drinks and alcoholic beverages on the RCs. Moreover, this study includes only one shade of each resin system. Further research should be done comparing the esthetic stability of different shades in each resin system as the discoloration is influenced by the shade of composite resin.[9]

CONCLUSION

Within the limitations of this study, the following conclusions can be made:

- Tetric N Ceram appeared to be more color stable than other RCs.
- All the four RCs compared are more vulnerable to coffee staining than tea.
- The discoloration effect of both the staining solutions depends on immersion time and resin matrix and filler loading.

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