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Original Article

Evaluation of the Color Stability of Newly Introduced Turkish Dental Composite Resin Products: An In Vitro Study

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CLINICAL SIGNIFICANCE

The study's results highlight that newly introduced Turkish composites offer similar color stability to established composites, suggesting their effectiveness for long-term dental restorations and providing reliable options for dental practitioners.

ABSTRACT

Objectives: This study aimed to evaluate the color stability of dental composites originating from Turkey by comparing Filtek Z550.

Materials and Methods: Four different solutions (Distilled water, tea, coffee, and cola) and four nanohybrid composites (Nova Compo C, RubyComp P, Astor Plus, and Filtek Z550 were used in the study. Composite specimens with a diameter of 8 mm and a thickness of 2 mm were produced using a cylindrical silicone mold. Both the top and bottom of the composites were cured with the B-Cure Plus curing light for 20 seconds. A total of 160 samples were obtained, 40 from each composite (n=10). The first shade measurement of the samples was carried out with a spectrophotometer device according to the CIE L* a* b* shade system. Color measurements were carried out on the 1st, 3rd, and 7th days.

Results: Nova Compo C, RubyComp P, and Filtek Z550 exhibited significantly higher color stability than Astor Plus ($p<0.001$). However, no significant difference was found between other dental composites ($p>0.05$). Distilled water and Cola caused significantly lower discoloration than tea and coffee; however, no significant difference was found between distilled water and cola ($p>0.05$). Discoloration increased significantly from day 1 to day 3 and from day 3 to day 7 ($p<0.001$).

Conclusion: Dental composite products newly introduced dental composite products in Turkey exhibited similar color stability when compared to Filtek Z550. Only Astor Plus exhibited lower color stability than others. The novel dental composite products originating from Turkey are promising regarding color stability.

1. Introduction

With the development of aesthetic perception and the increasing demand for esthetically pleasing dental restorations, the desire for a more beautiful smile has become a significant focus in dental clinics. Modern dentistry aims to restore lost dental tissues as naturally and effectively as possible, thereby enhancing both function and appearance.[1] In this context, resin-based dental composites (RBCs) have become widely used due to their excellent aesthetic properties, versatility, and ability to mimic the natural appearance of teeth. RBCs are composed of a resin matrix and filler particles, which together provide the necessary mechanical strength and aesthetic qualities required for dental restorations.[2] Their popularity is largely due to their ability to be color-matched to the patient's natural teeth, providing a seamless and visually appealing restoration.

However, despite their many advantages, RBCs are not without their limitations. Intrinsic factors such as changes in the filler, organic matrix, and silane in the composite resin content, as well as external factors like fluid absorption from the outside, can cause discoloration. The intrinsic factors primarily involve the chemical composition and structure of the resin matrix, including the type and amount of filler particles and the efficiency of the polymerization process.[3] For instance, a higher degree of conversion and a more stable resin matrix can enhance color stability. On the other hand, extrinsic factors, including dietary habits and the presence of staining agents like coffee, tea, and cola, contribute significantly to the discoloration of RBCs.[4] These beverages contain pigments and acids that can penetrate the resin matrix, leading to changes in color over time.[5]

Many methods such as visual assessment, colorimeters, spectrophotometers, digital cameras, and spectroradiometers can be used to measure color in dentistry. Each method offers unique advantages and limitations. Visual assessment, though widely used, is subjective and can be influenced by the observer's perception and lighting conditions. Colorimeters provide more objective measurements by quantifying color based on specific parameters, but they may lack the sensitivity required for detecting subtle differences in color shades. The spectrophotometer is the most preferred among these methods because of its advantageous properties such as higher sensitivity, repeatability, and ability to discriminate metamerism. It provides detailed spectral data across a wide range of wavelengths, allowing for precise and consistent color measurements.[6]

Color stability of dental composites originating from Turkey has not been evaluated yet. Filtek Z550 is a widely used dental nanocomposite that has proven its color stability in the previous studies.[7-9] Thus, while comparing the RBCs, Filtek Z550 was allotted as a control group. This study aimed to evaluate the color stability of RBCs originating from Turkey by comparing Filtek Z550. The aims of the present study were to test the following null-hypotheses:

1. There is no significant difference between dental composites regarding color stability.
2. There is no significant difference between solutions in terms of discoloration..
3. There is no significant difference between time periods regarding color stability.

2. Materials and Methods

2.1. Study design

Four different solutions and four nanohybrid composites were used in the study. The solutions included distilled water, tea

Table 1. The properties of the composite resins used in the study.

Composite resins	Composition	Manufacturer
Nova Compo C	The monomer matrix is composed of different dimethacrylates (18–22% weight) and ULS® (Ultra Low Syhrinkage)Monomer. The fillers contain barium glasses, ytterbium and prepolymer (83–78 % weight), additives, catalysts, stabilizers and pigments.	Imıcyrl, Turkey
RubyComp P	Methacrylate polymer (20%), inorganic fillers (80%), barium glass, mixed oxides, copolymers, photoinitiator, and stabilizer	Rubydent, Incidental, Turkey
Astor Plus	Bis-GMA, UDMA, TEGDMA based composite resins, inorganic fillers (77-78%), fillers silica, quartz, pigments, initiators	Dentac, Öncü Dental, Turkey
Filtek Z550	Silane treated ceramıc Bisphenol a polyethylene glycol dietherdimethacrylate Bisphenol a diglycidyl ether dimethacrylate (BisGMA) Silane treated silica Diurethanedimethacrylate (UDMA)	3M ESPE, USA

(Yellow Label Tea, Lipton, Turkey), coffee (Nescafe Classic, Nestle, Switzerland), and cola (Coca-Cola, USA). The nanohybrid composites were Nova Compo C (Imicryl, Turkey), RubyComp P (Rubydent, Turkey), Astor Plus (Dentac, Turkey), and Filtek Z550 (3M ESPE, USA). Composite specimens with a diameter of 8 mm and a thickness of 2 mm were produced using a cylindrical silicone mold. Resin composites were placed in the mold and compressed between two mylar strips and glass plates with slight hand pressure to extrude the excess material. The composites were placed and polymerized according to the manufacturer's instructions. A1 shade was used to standardize the color of each composite. Both the top and bottom of the composites were cured with the B-Cure Plus curing light (Woodpecker, China) for 20 seconds. A total of 160 samples were obtained, 40 from each composite (n=10). The samples were kept in distilled water at 37°C for 24 hours to complete their polymerization. The first shade measurement of the samples was carried out with a spectrophotometer device (VITA Easyshade Compact, VITA Zahnfabrik, Germany) according to the CIELAB (CIE Lab*) formula after drying with a paper towel.

Each composite resin was randomly divided into the following four solution groups: distilled water, cola (Coca-Cola Co, USA), tea (Yellow Label Tea, Lipton, Turkey), coffee (Nescafe Classic, Nestle, Switzerland). The tea was prepared by immersing a tea bag in 200 ml of distilled water boiled at 100 °C 5 to 10 times and resting for 3 minutes according to the manufacturer's instructions. According to manufacturer's instructions The coffee solution was made by adding 2 grams to 200 ml of distilled water that was boiled and left for 1 minute. Solutions were stored in sealed plastic containers.

The samples were kept in an oven at 37°C for 7 days in order to imitate the oral environment. Solutions were renewed every 24 hours for 7 days. Color measurements were carried out on the 1st, 3rd, and 7th days. Before each color measurement, the samples were washed with water for 10 seconds and dried with a paper towel. Spectrophotometer device was calibrated for each color measurement. The sample was measured 3 times and the average was taken and recorded. Measurements were performed under standard lighting on a white background. Color change values were calculated according to the formula $\Delta E = [(L1^* - L0^*)^2 + (a1^* - a0^*)^2 + (b1^* - b0^*)^2]^{1/2}$.

2.2. Statistical analysis

The Jamovi (Version 2.3.21) [ComputerSoftware], as accessed by https://www.jamovi.org, program was used for statistical analysis. Normality of data distribution was checked using the Shapiro–Wilk test. Due to normal distribution, Repeated Measure ANOVA was used for the color differences. Post-hoc comparisons were analysed with the Tukey's post hoc test (a = 0.05).

Table 2. Repeated Measure ANOVA test results regarding dental composites

Composite		Composite	Mean Difference	SE	p-value
Nova Compo C	-	Ruby Comp	0.11	0.25	0.969
Nova Compo C	-	AstorPlus	-1.42	0.25	**< 0.001**
Nova Compo C	-	Filtek Z550	-0.18	0.25	0.89
Ruby Comp	-	AstorPlus	-1.53	0.25	**< 0.001**
Ruby Comp	-	Filtek Z550	-0.29	0.25	0.648
AstorPlus	-	Filtek Z550	1.24	0.25	**< 0.001**

A post-hoc power analysis was conducted using the data from Table 2 to ensure the sample size was statistically sufficient. The analysis was performed using G*Power (Version 3.1.9.7, Heinrich-Heine-Universität Düsseldorf, Germany), calculating effect sizes from the mean differences and standard errors, with an alpha level of 0.05 and a sample size of 10 specimens per group. The average power across all comparisons was found to be 0.778, indicating high statistical power. This confirms that our sample size is adequate to detect significant differences in color stability among the composite materials tested, thus supporting the robustness of our findings.

3. Results

Nova Compo C, RubyComp P, and Filtek Z550 exhibited significantly higher color stability than Astor Plus ($p<0.001$). However, no significant difference was found between the other dental composites ($p>0.05$) (Table 2). Distilled water and cola caused significantly lower discoloration than tea and coffee ($p<0.05$); however, no significant difference was found between distilled water and cola ($p>0.05$) (Table 3). Color stability decreased significantly from day 1 to day 3 and from day 3 to day 7 ($p<0.001$) (Table 4). Marginal means plots were generated for dental composites (Fig. 1) and solutions (Fig. 2) depending on the periods.

4. Discussion

Mechanical properties of RBCs influence their clinical performance. In particular, the discoloration of the RBCs that developed over time is one of the most common reasons for replacing old restorations.[10] In this study, the color stability of three novel dental composites originating from Turkey was compared with Filtek Z550, which showed good color stability in previous studies, and their adequacy was evaluated.

The color stability of RBCs depends on the dimensions of the organic matrix filler particles, the depth of polymerization, and the colorants.[11] One of the exogenous causes of tooth discoloration is the dietary habits. These include tea, coffee, and nicotine. In this study, we used tea, coffee, and cola, which are commonly consumed daily, as staining solutions, which were evaluated in

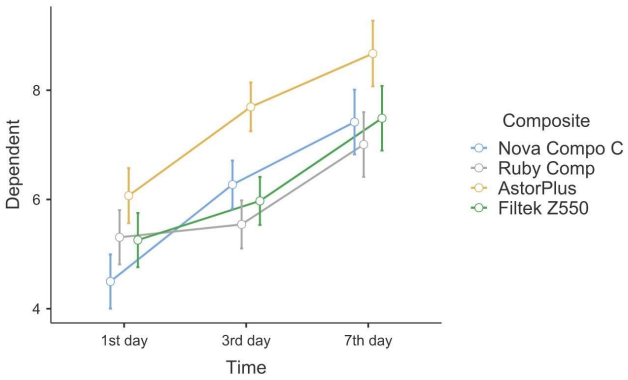

Fig. 1. Marginal means plots that were generated for dental composites

Table 3. Repeated Measure ANOVA test results regarding solutions

Solution		Solution	Mean Difference	SE	p-value
Distilled water	-	Cola	0.67	0.25	**0.036**
Distilled water	-	Tea	-4.85	0.25	**< 0.001**
Distilled water	-	Coffee	-10.54	0.25	**< 0.001**
Cola	-	Tea	-5.53	0.25	**< 0.001**
Cola	-	Coffee	-11.21	0.25	**< 0.001**
Tea	-	Coffee	-5.69	0.25	**< 0.001**

many studies. They indicated that the average daily coffee consumption is 3.2 cups and the average duration of consumption is 15 minutes.[12,13] The duration of 7 days was chosen to simulate the initial period of discoloration that occurs in clinical settings. According to previous studies[14,15], 24 hours of storage in a solution corresponds to one month of clinical exposure. Thus, a 7-day immersion period can simulate approximately seven months of daily beverage consumption. The 3-day duration was included to provide intermediate data points, offering insights into the progression of discoloration over time. This approach helps in understanding how discoloration evolves during the first week, which is often critical for clinical applications.

Previous studies on resin restorations reported that very smooth surfaces can be achieved when finishing with a matrix band. Although the surface roughness of the samples was not analyzed in this study, the samples were finished using transparent tape to standardize the finishing procedure. We preferred the Vita Easy Shade System as a color measuring device, since it offer the advantage of measuring the spectrum between 400-700 nm. While the human eye cannot detect values below 1.5, they can be measured with a spectrophotometer. ΔE values less than or equal to 3.3 are considered clinically detectable.[16] ΔE values above 3.3 have been reported to be clinically unacceptable and undesirable.[17]

The first null hypothesis of the study was rejected, and a difference was found between the RBCs in terms of color stability. Astor Plus showed lower performance in terms of color stability than other composites. The possible reason for this difference may be due to different mechanical properties, such as water absorption in composites.[18] Water absorption mainly occurs due to direct absorption in the resin matrix. The more the resin matrix is, the greater the water absorption.[19] Increased water absorption expands and plasticizes the organic matrix and hydrolyzes the silane. This may adversely affect the bonding of RBCs. The presence of microcracks in the resin matrix as a result of hygroscopic expansion and plasticizing effects, and the interfacial gaps formed between the filler and the resin matrix, cause staining and discoloration of the restoration.[20] Although the ratio of inorganic fillers in the resin matrix is close in all composites, the distribution of monomers in the resin matrix can affect color stability. UDMA monomer has been shown to be more resistant to color change than Bis-GMA.2 However, companies have not shared the percentages of monomers used. Consistent with previous studies[7-9], Filtek Z550 exhibited high color stability, probably due to mentioned intrinsic factors.

The second null hypothesis was rejected; coffee and tea caused more discoloration than other solutions. Many studies have shown that coffee causes more discoloration than other solutions.[21] The staining effect of coffee on composite resins may be related to RBCs being more susceptible to staining due to their water absorption properties. The absorption and adsorption of colorants by the organic phase has been described as the coloring mechanism of coffee. Tea and coffee contain yellow pigments of different polarities. Previous studies have also reported that coffee is more chromogenic than tea and cola, and coffee's yellow

Table 4. Repeated Measure ANOVA test results regarding time periods

Time		Time	Mean Difference	SE	p-value
1st day	-	3rd day	-1.09	0.14	**< 0.001**
1st day	-	7th day	-2.36	0.18	**< 0.001**
3rd day	-	7th day	-1.27	0.18	**< 0.001**

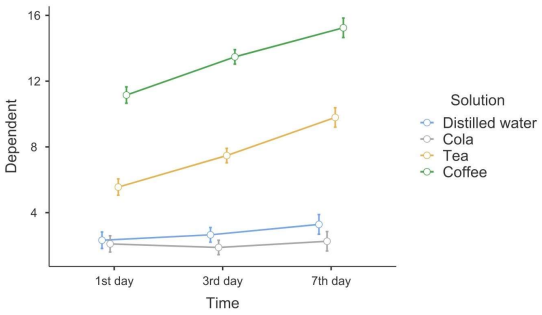

Fig. 2. Marginal means plots that were generated for solutions

pigments are less polar than tea. Although cola contains phosphoric acid, it does not show an intense coloration. Acids trigger the dissolution of materials and their erosive wear. There are also phosphate ions in Coca-Cola; these ions reduce the rate of dissolution of calcium phosphate, thereby suppressing the dissolution.

The third null hypothesis was rejected; The amount of discoloration increased as the waiting time of the samples in the solution increased. The analysis of immersion time alone revealed that the most noticeable discoloration occurred after 7 days. Irrespective of the type of solution used, findings revealed by previous studies, which showed that the longer staining periods increase discoloration, are consistent with the present study.

In this study, the color measurements of the dental composites were calculated based on the CIELAB (CIE Lab*) formula. The CIELAB formula is widely used and accepted in dental research for assessing color differences due to its ability to provide a comprehensive representation of color space. This choice allows for consistent comparison with previous studies that have also utilized the CIELAB system. However, it is important to acknowledge that the CIELAB formula has some limitations compared to the newer CIEDE2000 formula. The CIEDE2000 formula offers enhanced accuracy in measuring perceptual color differences, particularly in the areas of hue, chroma, and lightness.[22] It accounts for perceptual uniformity more effectively, which can be critical in certain dental applications where subtle color differences are significant.[23]

Additionally, color measurements in our study were performed under standardized lighting conditions on a white background. The selection of a white background was made to maintain consistency with the VITA Easyshade Compact device's calibration standards, which recommend a white background for optimal accuracy. Using a white background instead of a gray one provides higher contrast, enhancing the precision and reliability of the color measurements.[22] While gray backgrounds can minimize reflections and ambient light effects, the white background was deemed more appropriate for this study to ensure accurate calibration and measurement consistency.

Table 5. Color Change of Composite Materials in Different Solutions (1st, 3rd, and 7th Day)

Composite	Solution	1st day	3rd day	7th day
NC	Distilled water	2 ± 1.56	2.42 ± 0.72	3.4 ± 1.78
	Cola	2.3 ± 1.4	2.17 ± 1.03	2.58 ± 1.17
	Tea	4.62 ± 0.86	7.4 ± 1.54	9.98 ± 1.77
	Coffee	9.07 ± 2.02	13.1 ± 3.03	13.72 ± 4.03
RC	Distilled water	1.78 ± 1	1.43 ± 0.46	2.09 ± 1.17
	Cola	1.88 ± 1.12	1.27 ± 0.34	1.79 ± 0.58
	Tea	4.78 ± 1.04	7.12 ± 1.49	10.16 ± 2.07
	Coffee	12.79 ± 3.02	12.35 ± 1.63	13.98 ± 1.16
AP	Distilled water	2.43 ± 0.74	3.33 ± 0.55	3.26 ± 0.61
	Cola	1.19 ± 0.76	1.23 ± 0.91	1.26 ± 0.76
	Tea	7.2 ± 1.33	8.4 ± 1.18	10.48 ± 1.29
	Coffee	13.45 ± 1.95	17.82 ± 1.37	19.68 ± 1.7
FZ	Distilled water	3.07 ± 2.09	3.42 ± 1.92	4.39 ± 2.46
	Cola	3.03 ± 1.9	2.87 ± 1.56	3.41 ± 1.64
	Tea	5.63 ± 1.01	6.96 ± 1.14	8.55 ± 1.75
	Coffee	9.3 ± 1.66	10.64 ± 1.15	13.61 ± 2.91

NC: Nova Compo C, RC: RubyComp P, AP: Astor Plus, FZ: Filtek Z550

This study was conducted in vitro, which does not entirely replicate the oral environment. Future studies should consider in vivo conditions to better understand the real-world applicability of these findings. Additionally, the flat surface preparation of specimens in this study may not fully represent the complex surface morphology of actual dental restorations. The sample size, although sufficient for this study, could be expanded in future research to validate these findings more robustly. Polishing was not applied to the samples. Instead, to standardize the surface finish, all specimens were prepared using a transparent tape. This method ensured a consistent and smooth surface across all samples, which is essential for accurately assessing color stability without the variability that different polishing techniques might introduce. However, we acknowledge that this approach may limit the study's ability to fully replicate clinical conditions. In a clinical setting, polishing can enhance surface smoothness and potentially improve the color stability of composites. Therefore, the lack of polishing in this study is a limitation that should be considered when interpreting the results.

5. Conclusion

In conclusion, our study found that beverages such as coffee and tea cause significantly more discoloration in dental composites than distilled water and cola. The newly introduced Turkish composites demonstrated similar color stability to the well-established Filtek Z550, except for Astor Plus, which showed lower color stability. These findings have important clinical implications, suggesting that dental practitioners should consider patients' dietary habits when selecting composite materials to ensure long-term aesthetic outcomes. Composites like Nova Compo C and RubyComp P, which showed higher color stability, may be more suitable for patients who frequently consume staining beverages. Future research should focus on long-term clinical trials to confirm these in vitro results and explore new composite formulations with enhanced stain resistance to further improve patient care.

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Conflict of Interest
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