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The effect of different polishing systems on the discoloration of composite resins: examples of commonly consumed beverages

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ABSTRACT

Aims: The aim of this study is to evaluate the color stability of composite resin materials subjected to different polishing systems when exposed to commonly consumed beverages.

Methods: In this study, four different composite polishing systems (Zenit, 3M Sof-Lex, Sofu, Kerr) and three types of beverages (Nescafé 3-in-1, Lipton tea bags, and distilled water) were used. A micro-hybrid resin composite (Tokuyama) was selected for the study. A total of 84 disk-shaped composite resin samples (8 mm in diameter and 2 mm thick) were prepared. The samples were divided into four main groups according to the polishing systems used, and further divided into three subgroups based on the beverage types, with seven samples in each subgroup, resulting in a total of 12 study groups. Initial color measurements, as well as measurements taken on days 1, 7, and 28, were recorded using a vita easyshade spectrophotometer. The data were tabulated and statistically analyzed using SPSS 25.0 software, employing one-way ANOVA and Tukey HSD post-hoc tests (p=0.05).

Results: Examination of the 28-day staining results revealed a statistically significant difference between the results for distilled water and coffee, depending on the brand (p<0.05). Specifically, it was observed that the distilled water results for the Shofu and Zenit brands were higher compared to those of the Kerr brand, while the coffee results for the Kerr brand were higher than those of the Zenit brand. Additionally, there was a statistically significant difference among the 28-day staining results for the 3M, Kerr, Shofu, and Zenit brands (p<0.05). The results for tea from the 3M, Kerr, Shofu, and Zenit brands were observed to be higher compared to their results for distilled water and coffee.

Conclusion: Within the limits of this study, the color stability of composite resin materials varied depending on the type of composite resin and polishing system used. It was determined that the Kerr Opti-Disc polishing system had the highest success rate among all systems. Additionally, it was found that frequently consumed tea caused a higher degree of color change compared to coffee. Further supportive studies should be conducted with different composite materials and polishing systems.

Keywords: Composite resin, color stability, finishing and polishing, discoloration

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INTRODUCTION

Recent increases in aesthetic demands and rising societal awareness, which have also been felt in the field of dentistry, have led patients to request long-lasting aesthetic restorations.[1] Composite resins, frequently chosen by clinicians for their superior aesthetic properties, have enhanced their ability to natural tooth structures due to their color match and stability.[2]

By examining the reasons for the failure of commonly used composite resins, it is believed that their properties can be better understood, thereby improving treatment success and material performance. In addition to the application technique, long-term clinical success of aesthetic restorations depends on factors such as particle size, resin matrix structure, color match, and polishability. The color stability of the chosen composite resin is crucial for successful restorations that can be used over the long term. Color changes due to inadequate color stability of composites are among the primary reasons for the replacement of aesthetic restorations, particularly in the anterior region.[3]

One of the most common issues with composite resins is color change, which can result from various factors.[4] Changes in color due to the physicochemical properties of the resin are termed internal staining, while color changes due to application issues are referred to as external staining. While the composition of the composite resin and the percentage of inorganic fillers affect internal staining, external staining is influenced by factors such as contamination with saliva

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or blood during application, inadequate polymerization and polishing procedures, improper finishing techniques, smoking habits, poor oral hygiene, and dietary habits.[4,5]

External colorations resulting from factors such as smoking, dietary habits, and inadequate oral hygiene can be easily removed from the surface of restorations. However, internal colorations, caused by intrinsic factors, necessitate the complete removal and replacement of the restoration.[3]

Although the human eye has the sensitivity to distinguish even minimal color differences, color discrimination is a complex process involving various factors. Light reflected from an object is focused on the retina of the eye, where it stimulates cone cells, and this stimulation is then transmitted to the brain through a neural reaction chain. Consequently, an individual perceives the color of the object through this mechanism.[5,6] In clinical dentistry, color matching can be performed using a color scale or current digital measurement devices. Measurements taken using a color scale can be influenced by numerous factors such as the clinician's experience, light intensity, source, the color of the working environment's floor and walls, the patient's clothing, and any makeup present.[5,7] Modern digital measurement devices, such as colorimeters, spectroradiometers, and spectrophotometers, are advantageous due to their ability to provide more reliable and repeatable results.[8,9]

Increasingly digital clinical applications are also influencing color measurement systems. Current color measurement devices include colorimeters, spectroradiometers, spectrophotometers, and digital cameras.[10] These devices are based on various digital color analysis systems, which can be categorized as Munsell, CIE Lab (Commission Internationale de l'Eclairage), and RGB (red, green, blue).[9] The most commonly used system is CIE, a three-dimensional color model developed to define color. In this model, the L* value (Lightness) represents the lightness/darkness of the color and ranges from 0 to 100. A value of 100 indicates pure white, where light is fully dispersed, while a value of 0 represents ideal black. Positive a* values denote shades of red or purple, while negative a* values indicate green. Positive b* values represent yellowness, whereas negative b* values signify blueness. In this analysis system, the color difference between objects is calculated using the ΔEab* formula.[11]

The aim of this study is to compare the color stability of composite resins polished with four different composite polishing systems when exposed to three commonly consumed beverages. The null hypothesis of this study is that there will be no difference in color stability among composite resins polished with different polishing systems.

METHODS

Since the research did not involve any biological tissue, fluid or waste and was based solely on the use of manufactured artificial materials, ethics committee approval was not required.

In this study, G*Power (G*Power Ver. 3.1.9.2, Kiel, Germany) package program was used to determine the number of samples. The effect size was found to be 3.608 by taking a study with similar characteristics as a reference. For this effect size of 95% and 0.05 significance level, the minimum number of samples for each group was determined as 4. 7 samples were used in each group in the study. In this study, the supra-nano hybrid composite resin Tokuyama Estelite Sigma Quick (Tokuyama Dental Corporation, Tokyo, Japan) was used. The composite resin was polished with four different polishing systems to examine color changes in various beverages.

The color shade A2 composite resin was placed into cylindrical Teflon molds, measuring 6 mm in diameter and 2 mm in thickness, using an oral spatula. To prevent air bubbles within the sample, achieve a smooth surface, and remove excess material, light pressure was applied using glass ionomer cement and transparent tape. The polymerization of the composite samples was achieved using an LED light source (Hilux LEDMAX, Benlioğlu Dental AŞ, Ankara, Turkey) placed at the center of the samples for 20 seconds, as specified in the manufacturer's instructions. During the process, the light intensity of the device (approximately 1000 mW/cm^2) was also monitored with a radiometer (Hilux UltraPlus Curing Units, Benlioğlu Dental, İstanbul, Turkey). The samples were grouped according to the polishing systems used as follows:

1.Sof-Lex; 3M ESPE, St. Paul, MN, USA.

2.OptiDisc; Kerr, Bioggio, Switzerland.

3.SUPER Snap; Shofu, Japan.

4.Zenit Flex; President Dental, München, Germany.

A total of 84 samples were prepared, with 21 samples from each polishing system. After being removed from the molds, the samples were polished using four different polishing systems and then divided into subgroups for immersion in three different solutions:

1.Distilled water,

2.Tea (Lipton),

3.Coffee (Nescafe 3 in 1)

After the groups were randomly created, the polishing systems were applied for 60 seconds each, dry and at medium speed, using a clinical handpiece and micromotor to ensure standardization. Following the polishing procedures, all samples were stored in an incubator at 37°C in distilled water for 24 hours. The samples were then washed, dried, and prepared for initial measurements. Initial measurements were recorded using a spectrophotometer (Vita Easyshade Advance 4.0, VITA Zahnfabrik, Bad Säckingen, Germany).

The measurements of samples immersed in the three different solutions were repeated on days 1, 7, and 28, following each immersion period. For samples immersed in coffee and tea solutions, prior to measurement, they were washed with distilled water for 5 minutes and dried before recording the values.

Measurements were performed in a white room, on a white surface, and under D65 standard lighting conditions. Calibration of the device was conducted before each measurement. Each sample was measured three times to obtain an average value. The changes in the recorded values were calculated using the formula $\Delta E^*=[(L1^*-L0^*)^2+(a1^*-a0^*)^2+(b1^*-b0^*)^2]^{1/2}$.[11]

Statistical Analysis

The data obtained from the study were analyzed using the SPSS (Statistical Package for Social Sciences) for Windows 25.0 program. Descriptive statistical methods (mean, standard deviation) were employed for data evaluation. Normality was assessed using normal distribution tests and skewness-kurtosis values. For data showing normal distribution, one-way analysis of variance (ANOVA) was used to compare variables with more than two categories, and the Tukey test was applied to determine which groups exhibited significant differences. The significance level was set at 95%.

RESULTS

Upon examining the 24-hour discoloration results, no statistically significant differences were observed among the results for distilled water, coffee, and tea based on brand (p>0.05) (**Table 1**).

Regarding the solutions, no statistically significant differences were found in the 24-hour discoloration results among the 3M, Shofu, and Zenit brands (p>0.05). However, significant differences were noted for the Kerr brand (p<0.05), with tea discoloration results being higher than those for distilled water.

Table 1. 24-hours discoloration

	24-hours-discoloration			p
	Distilled water	Coffee	Tea	
3M	2.14±0.68	2.61±1.20	3.64±1.98	0.151
Kerr	2.36±0.73	2.78±1.17	4.19±1.35	0.017*
Shofu	2.51±0.75	3.46±1.55	3.06±0.70	0.276
Zenit	2.40±1.31	3.06±1.16	3.39±1.28	0.344
p	0.895	0.628	0.505	

The analysis of the 7-day discoloration results revealed that there were no statistically significant differences among the coffee results for different brands (p>0.05). However, significant differences were observed between the distilled water and tea results among the brands (p<0.05). Specifically, the Zenit brand showed higher discoloration results for distilled water compared to the Kerr brand, and the Zenit brand also had higher discoloration results for tea compared to the Shofu brand (**Table 2**).

Table 2. 7-days discoloration

	7-days discoloration			p
	Distilled water	Coffee	Tea	
3M	3.16±0.74	3.99±1.17	6.93±2.77	0.002*
Kerr	3.01±0.48	4.59±0.96	5.87±1.73	0.001*
Shofu	4.17±1.19	4.69±1.97	5.53±2.46	0.439
Zenit	4.44±1.10	4.15±1.63	9.35±2.18	0.000*
p	0.016*	0.776	0.021*	

Regarding solutions, no statistically significant differences were found in the 7-day discoloration results for the Shofu brand (p>0.05). In contrast, significant differences were noted among the 3M, Kerr, and Zenit brands (p<0.05). The 3M and Zenit brands exhibited higher discoloration results for tea compared to distilled water and coffee, while the Kerr brand showed higher discoloration results for tea compared to distilled water.

The analysis of the 28-day discoloration results revealed that there were no statistically significant differences among the tea results for different brands (p>0.05). However, significant differences were observed between the distilled water and coffee results among the brands (p<0.05). Specifically, the Shofu and Zenit brands showed higher discoloration results for distilled water compared to the Kerr brand, while the Kerr brand exhibited higher discoloration results for coffee compared to the Zenit brand (**Tablo 3**).

Regarding solutions, statistically significant differences were found among the 3M, Kerr, Shofu, and Zenit brands (p<0.05). The discoloration results for tea were higher for all brands (3M, Kerr, Shofu, and Zenit) compared to distilled water and coffee.

Table 3. 28-days discoloration

	28-days discoloration			p
	Distelled water	Coffee	Tea	
3M	5.30±1.08	7.86±3.17	15.79±7.88	0.002*
Kerr	3.62±0.78	11.05±4.8	22.02±7.36	0.000*
Shofu	5.75±1.06	6.87±1.99	15.58±8.30	0.003*
Zenit	5.82±1.99	6.25±2.02	15.99±2.63	0.000*
p	0.014*	0.046*	0.261	

DISCUSSION

In this study, the discoloration of composites polished with four commonly used polishing systems was evaluated against coffee, tea, and distilled water. After application of different polishing systems, composites immersed in coffee, tea, and distilled water exhibited clinically acceptable levels of discoloration without significant differences among them. Therefore, the null hypothesis of the study was rejected, as differences in color stability were observed among composites polished with different systems.

Recent advancements in adhesive technologies and the successes achieved in enamel and dentin adhesion have contributed to the widespread use of composite resins.[1] While the primary expectation from restorations made with composite resins is to provide long-lasting aesthetic appearance, color changes remain one of the significant disadvantages of these restorations. Studies have shown that dissatisfaction with dental treatments is attributed to color mismatch in 38% of cases.[12] Various factors such as inadequate polymerization, insufficient polishing, water absorption, oral hygiene, and dietary habits have been reported to affect the color stability of composite resin restorations.[13] Literature reviews reveal an increasing trend in coffee consumption due to the growing number of coffee shops and the extended duration of tea consumption, influenced by cultural habits in our country. This study focuses on the relationship between the color changes of supra-nano hybrid resin composites against frequently consumed tea and coffee and different polishing systems.[14,15]

The color detection phase is a multifactorial and highly complex process, influenced by factors such as ambient light source, material opacity, light transmission, light reflection, and varying subjective assessments.[11] To minimize potential visual discrepancies during this phase, digital color measurement devices have been developed. In this study, we utilized one such device, the spectrophotometer (Vita Easyshade Advance 4.0). The success and reliability of the Vita Easyshade device have been supported by various recent studies.[16-18]

The data obtained from the measurements using the spectrophotometer were analyzed using the L* a* b* color system to calculate ΔE values. Differences were interpreted using the ranges specified in the literature. In a recent study by Drubi-Filho et al.[19] ΔE values of 3.3 and above were reported as the clinically unacceptable threshold for color differences. Additionally, the literature indicates that a clinically acceptable ΔE value is 2.7 within a 50:50 confidence interval.[20] Therefore, in our study, values of ΔE 2.7 or lower were considered acceptable. The findings of our study indicated that, due to ΔE values exceeding 2.7 in all groups, the color changes were not clinically acceptable.

Studies have indicated that composite resins with a higher inorganic filler content exhibit less color change.[21] Contrary to these findings, Bagheri et al.[22] reported that composites with a high filler content experienced the greatest color change, suggesting that color change is not always directly related to the amount of filler. Another recent study on discoloration from 2022 also did not observe a direct relationship between filler content and color change.[23] Therefore, in our study, we aimed to evaluate the effects of polishing systems by using a single type of composite to isolate the impact of the polishing methods.

To ensure that composite restorations are long-lasting, successful, and aesthetic, a smooth composite surface must be achieved regardless of the carious lesion's location or classification.[24] Inadequate polishing results in a rough composite surface, leading to adverse clinical outcomes such as increased plaque accumulation, secondary caries risk, gingival inflammation, and discoloration.[25] Moreover, numerous studies have reported that the most successful smoothness in composites is achieved using transparent strips.[24] However, the outermost surface of the composite under the strip remains in contact with oxygen, resulting in an unstable condition and incomplete polymerization. This surface, exhibiting low microhardness, must be eliminated to prevent discoloration and wear in the restoration. Therefore, thorough finishing and polishing procedures are essential for composite resin restorations.[26] In this study, transparent strips were used prior to finishing and polishing procedures to obtain standardized surfaces. Although there is extensive research on finishing and polishing systems for composite resins, a universally accepted standard procedure for ideal finishing and polishing does not yet exist.[27]

Previous studies have indicated that the surface roughness obtained from polishing processes depends on the material's properties and type.[28] For an effective polishing procedure, the abrasive particles in the polishing system should be harder than the filler particles of the polished composite resin.[29] Consequently, polishing materials often use abrasives such as aluminum oxide or diamond particles, which are harder than the filler particles. In this study, all polishing materials used contained Al_2O_3 as the abrasive agent. According to our results, the highest color change was observed in the Zenit group, which may be explained by the softer abrasive particle composition used in this brand compared to the particles used in other polishing sets. The Optidisc Kerr and 3M Sof-Lex sets demonstrated better performance. This finding aligns with recent studies by Yılmaz et al.[30] which reported successful outcomes with aluminum oxide-impregnated rubber polishing systems (Sof-Lex, One-Gloss, Enhance). Additionally, Korkut et al.[31] in their 2021 study, noted that composite discoloration varied according to the polishing material rather than the composite resin type and that multi-step polishing systems have advantages.

Limitations

The findings of this research should be considered within certain limitations. First, it is important to note that this is an in-vitro study and that there are inherent limitations in simulating a natural in-vivo environment. In such studies, the evaluation of color changes is based solely on objective assessment without considering visual perception limitations and clinical impacts.

CONCLUSION

Within the limitations of this study, the color stability of composite resin materials varied depending on the type of composite resin and polishing system used. The findings indicate that the Opti-Disc from Kerr polishing system demonstrated the highest success rate among all systems evaluated. Additionally, it was determined that tea, which is frequently consumed, caused a higher degree of color change compared to coffee. Further research with different composite materials and polishing systems should be conducted to support these findings.

ETHICAL DECLARATIONS

Ethics Committee Approval

Since the research did not involve any biological tissue, fluid or waste and was based solely on the use of manufactured artificial materials, ethics committee approval was not required.

Informed Consent

Written informed consent was not required as the research was based on the use of manufactured artificial materials.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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