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Effect of additional polymerization process on color change in composite resins hold in different solutions

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ABSTRACT

Aims: In this study, it was aimed to compare the amount of coloration of composite resins with different filler content by keeping them in various coloring solutions after standard and additional polymerization processes.

Methods: Three types of composite resins with different contents were used in our study: Filtek™ Z250 (3M ESPE), G-aenial Anterior (GC) and Neo Spectra™ ST HV (Dentsply Sirona). A total of 240 composite resin samples were prepared, 10 (n:10) for each group, using molds with a depth of 2 mm and a diameter of 8 mm. The polymerization of the samples was carried out for 20 seconds using a LED curing device (Woodpecker Led-G, China). After finishing and polishing was done with Super-Snap (Shofu, JAPAN) finishing discs, additional polymerization was performed on half of the samples. Then, all samples were kept in distilled water for 24 hours at 37°C in an oven (Microtest MST 55, Ostim Ankara). The first color measurement of the samples extracted from distilled water was made with a spectrophotometer device [VITA Easyshade V (Vita Zahnfabrik, Bad Sackingen, Germany)]. After the first measurement, the samples placed in 100-mesh plastic containers were placed on bags of tea (Lipton, Rize, Turkey), filtered coffee (Nescafe Classic, Nestle, Turkey), mouthwash containing chlorhexidine (Kloroben mouthwash, Drogsan, Ankara, Turkey) and red wine (Buzbağ). Classic, Öküzgözü-Boğazkere, 2021 Elazığ, Turkey) was added. One week later, the samples were removed from the vacuum furnace, washed in distilled water, and the second measurements were made.

Results: A statistically significant difference was found between the coloration values caused by the solution groups ($p<0.05$). It was observed that the solution causing the most color change was wine, followed by coffee and tea, respectively. Although there was no statistically significant difference between the coloration values caused by the composite groups ($p>0.05$), it was determined that the composite resin material with the lowest color change was the microhybrid-based Filtek™ Z250. Although there was no statistically significant difference between the coloration values caused by standard and additional polymerization ($p>0.05$), it was determined that the additional polymerization process affected the color change amount of the materials positively.

Conclusion: According to the findings of this study; Among the coloring solutions used, it was observed that the solution causing the most coloration in composite resins was red wine, followed by coffee, tea and mouthwash containing chlorhexidine, respectively. However, it was concluded that the addition polymerization process reduces the coloration of the composite resins.

Keywords: Coloring solutions, additive polymerization, color stability

INTRODUCTION

With the increase in aesthetic awareness in today's society, patients have started to demand treatments that are longer lasting and meet the aesthetic needs of physicians. In order to meet these demands, composite resins have started to be used more in dentistry practice. It is thought that these materials can be better recognized and better treatments can be made by conducting studies on the properties and causes of failure of composite resins. Clinical success in aesthetic restorations; It depends on many factors, such as filler and resin matrix structure, polish ability and color compatibility of the material used. At the same time, color stability should be very good for composite resins made. Otherwise, after a certain period, discoloration occurs in the restorations and the need for renewal occurs. In this sense, the areas where patients complain the most are the aesthetic restorations made to the anterior teeth.[1]

Water absorption, surface hardness and roughness of the composite resins, polymerization method, finishing and polishing processes are the factors affecting the color stability. At the same time, the patient's hygiene and consumption habits also affect color stability.[2]

When the color stability studies on composite resins were examined, it was seen that coloring solutions such as tea, coffee, cola, fruit juice and red wine were used and they caused different levels of coloration. It is very important that dental materials used in the mouth maintain their color stability after exposure to liquids with coloring properties.[3]

The aim of our study; The aim of this study is to evaluate the coloration levels of composite resins with different contents kept in coloring solutions after standard and additional polymerization processes.

METHODS

This study does not contain any human or animal materials. It is an in vitro study under laboratory conditions. Therefore, it does not require an ethics committee approval. Institutional approval has been obtained. All procedures were carried out in accordance with the ethical rules and the principles.

This work; It was planned to evaluate the effect of the addition polymerization process on the color stability of three different composite resins with different filler content. In our study, one micro hybrid-based Filtek™ Z250 composite resin (3M ESPE), one nano hybrid-based G-aenial Anterior (GC) composite resin and one nano ceramic-based Neo Spectra™ ST HV (Dentsply Sirona) composite resin material were preferred to be used.

As a result of the power analysis of our study; The number of samples for each group was determined as 10 (n=10), with a 95% confidence interval and 5% sensitivity. A total of 240 test materials were prepared, 80 for each composite resin, by a single researcher at the Dicle University Faculty of Dentistry Restorative Dentistry Clinic. The materials were condensed by placing them in plastic molds with a depth of 2mm and a diameter of 8mm with the help of a mouth spatula. Then, it was compressed between the transparent tape and two glass plates and polymerized for 20 seconds with the help of an LED light device (Woodpecker Led-G, China) in accordance with the recommendations of the manufacturers.

Before the polymerization process, the power of the light device was checked by means of a radiometer (Hilux, Benlioğlu Dental AŞ, Ankara, Turkey). 80 samples prepared from each test material were divided into 4 groups of twenty (n=20). For the finishing and polishing of the materials used in the study; Super-Snap (Shofu, JAPAN) finishing disc sets were used. Polishing and finishing processes were performed on the upper surfaces of the materials close to the light device during the polymerization, in accordance with the instructions of the manufacturers. A new disk was used for each sample.

Twenty samples with standard polymerization in each group were separated as "standard light group". The polished surfaces of the remaining 20 test materials were subjected to additional polymerization for 20 seconds and separated as the "additional light group". All samples were washed under tap water and then dried. Before placing the samples in colorant solutions, they were kept in distilled water for 24 hours in an oven at 37°C (Microtest MST 55, Ostim Ankara) (**Picture 7**).

The first color measurements of the test samples, which were removed from distilled water and dried at the end of 24 hours, were performed using a spectrophotometer device [VITA Easyshade V (Vita Zahnfabrik, Bad Sackingen, Germany)].

For the reliability of the measurement process, the measuring tip of the device was placed at an angle of 90° to the surface. Each color measurement was repeated three times and the average of these measurement results was recorded as L0*, a0* and b0* values according to the CIELAB method. Color measurement samples were numbered. The spectrophotometer device was calibrated for each measurement. After the first measurement, all samples were placed in four different plastic molds with 100 pores in order of number. Tea bags (Lipton, Rize, Turkey), filtered coffee (Nescafe Classic, Nestle, Turkey), mouthwash containing chlorhexidine (Kloroben mouthwash, 0.12% chlorhexidine gluconate, Drogsan, Ankara, Turkey) and red wine (Buzbağ) to provide color change on them. Classic, 13% alcohol, Öküzgüzü-Boğazkere, 2021, Elâzığ, Turkey) prepared solutions were added, and the samples were kept in an oven at 37°C for 1 week.

The tea solution in which the samples will be placed was prepared by brewing a tea bag in 250 ml of boiled water. The coffee solution in which the samples will be placed was prepared by adding 2 grams of coffee to 200 ml of boiled distilled water, mixing and filtering it with filter paper after 10 minutes. All solutions were freshly prepared and refreshed daily.

After one week, the samples removed from the solutions were washed with distilled water and dried with blotting paper. The samples were subjected to color measurement for the second and last time, paying attention to their sequence numbers. The final measurements were repeated three times for each sample, as in the beginning and the averages were recorded. The difference (ΔE value) between the two measurements was calculated using the formula

$$\Delta E^*=[(L1^*-L0^*)2+(a1^*-a0^*)2+(b1^*-b0^*)2]½.$$

RESULTS

The data obtained in our study were analyzed with the licensed IBM SPSS 21 package program (License number: 5f551afac84a24ad7a95). While investigating the normal distribution of the variables; Shapiro Wilk's and Kolmogorov-Smirnov tests were used due to the number of units. While interpreting the results; In the case of $p<0.05$ as the significance level, it was accepted that the variables did not come from the normal distribution, and in the case of $p>0.05$, the variables came from the normal distribution.

To determine the effect of the factors on the dependent variable; Two Way ANOVA test was used. Significantly, different groups and interaction levels were determined. When examining the differences between groups; Independent T Test and One-Way ANOVA were used because the variables came from normal distribution. In case of significant differences in One-Way ANOVA, Tukey HSD was used when the variances of the groups were homogeneous, and Tamhane's analysis was used when the variances were not homogeneous.

As a result of the analysis of the effect of the factors on the dependent variable ΔE;

- The effect of the composite group on the dependent variable ΔE was not statistically significant ($p>0.05$).
- The effect of the solution group on the dependent variable ΔE was found to be statistically significant ($p<0.05$). The lowest value for ΔE is in Chlorhexidine solution.
- The effect of the light group on the dependent variable ΔE was not statistically significant ($p>0.05$).
- The interaction effect of Composite and Solution groups was statistically significant on the dependent variable ΔE ($p<0.05$).

- The interaction effect of composite and light groups was not statistically significant on the dependent variable ΔE (p>0.05).
- The interaction effect of solution and light groups was not statistically significant on the dependent variable ΔE (p>0.05).
- The triple interaction effect of Composite, Solution and light groups was not statistically significant on the dependent variable ΔE (p>0.05).

Although there was no statistically significant difference between the coloration values (ΔE) caused by the composite groups (p>0.05), it was determined that the composite resin material with the highest color change was GC, followed by the Spectra material.

Although there was a statistically significant difference between the coloration values (ΔE) caused by the solution groups (p<0.05), it was observed that the solution causing the most color change was wine, followed by coffee and tea, respectively (**Table 1**).

Table 1. Analysis results regarding the difference between solution groups in terms of ΔE values

Solution	ΔE						One Way ANOVA	
	n	Mean	Median	Min	Max	Sd	F	p
Tea	60	2.893	2.99	0.221	6.286	1.544	24.882	0.001
Wine	60	4.325	4.142	0.667	11.547	1.921		
Coffee	60	3.24	2.997	0.165	7.024	1.629		
Chlorhexidine	60	1.889	1.723	0.159	4.484	1.003		
Total	240	3.087	2.852	0.159	11.547	1.779		

According to the results of the multiple comparison test performed to determine which solution the difference originated from; wine solution was found to have a significantly higher coloring value than all other solutions (p<0.05).

It was determined that the chlorhexidine solution had a significantly lower coloring value than all other solutions (p<0.05). It was determined that the difference in coloring value only between the tea solution and the coffee solution was not statistically significant (p>0.05) (**Table 2**).

Table 2. Results of coloration values according to Tamhane's multiple comparison test

I. Solution	II. Solution	P
Tea	Wine	0.001
Tea	Coffee	0.796
Tea	Chlorhexidine	0.001
Wine	Coffee	0.007
Wine	Chlorhexidine	0.001
Coffee	Chlorhexidine	0.001

Although there was no statistically significant difference (p>0.05) between the coloration values caused by the standard and additional polymerization (ΔE), it was determined that the additional polymerization process affected the color change amount of the materials positively.

Although there was a statistically significant difference between the color change values (ΔE) observed in all three composite resin materials kept in different solutions (p<0.05), it was observed that the solution causing the most color change was wine, followed by coffee and tea, respectively. (**Table 3**).

According to the results of the multiple comparison test performed to determine which solution caused the difference between the color change values of the 3M composite resin material; It was determined that the wine solution had a significantly higher coloring value than all other solutions (p<0.05). However, the coloring value of the chlorhexidine solution was found to be significantly lower than the coffee solution (p<0.05). It was determined that the difference between the coloring values of all other solutions was not statistically significant (p>0.05).

According to the results of the multiple comparison test performed to determine which solution caused the difference between the color change values of the GC composite resin material; It was determined that the chlorhexidine solution had a significantly lower coloring value than all other solutions (p<0.05). It was determined that the difference between the coloring values of all other solutions was not statistically significant (p>0.05).

Table 3. Analysis results regarding the difference between solutions in terms of ΔE values in composite groups

Composite	Solution	ΔE						One Way ANOVA	
		n	Mean	Median	Min	Max	Sd	F	P
3M	Tea	20	2.336	2.048	0.672	4.988	1.228	22.503	0.001
	Wine	20	4.838	4.657	2.462	6.922	1.261		
	Coffee	20	2.981	2.715	0.165	6.513	1.703		
	C.hexidine	20	1.808	1.745	1.158	2.734	0.463		
	Total	80	2.991	2.536	0.165	6.922	1.68		
GC	Tea	20	3.538	3.264	0.508	6.286	1.584	7.806	0.001
	Wine	20	4.303	3.822	1.532	11.547	2.532		
	Coffee	20	3.64	3.394	1.109	7.024	1.86		
	C. hexidine	20	1.37	1.082	0.159	4.168	1.027		
	Total	80	3.213	2.983	0.159	11.547	2.113		
Spectra	Tea	20	2.805	2.907	0.221	5.543	1.616	9.903	0.001
	Wine	20	3.833	3.996	0.667	6.68	1.712		
	Coffee	20	3.1	3.047	0.219	5.116	1.275		
	C.hexidine	20	2.489	2.691	0.723	4.484	1.09		
	Total	80	3.057	2.949	0.219	6.68	1.504		

According to the results of the multiple comparison test performed to determine which solution caused the difference between the color change values of the Spectra composite resin material; only the coloring value of the wine solution was found to be significantly higher than the chlorhexidine solution ($p<0.05$). It was determined that the difference between the coloring values of all other solutions was not statistically significant ($p>0.05$) (**Table 4** and **Graphic 1**).

Table 4. Results of coloration values according to Tamhane's multiple comparison test

Composite	I. Solution	II. Solution	P
3M	Tea	Wine	0.001
	Tea	Coffee	0.691
	Tea	Chlorhexidine	0.412
	Wine	Coffee	0.002
	Wine	Chlorhexidine	0.001
	Coffee	Chlorhexidine	0.042
GC	Tea	Wine	0.836
	Tea	Coffee	1.0
	Tea	Chlorhexidine	0.001
	Wine	Coffee	0.925
	Wine	Chlorhexidine	0.001
	Coffee	Chlorhexidine	0.001
Spectra	Tea	Wine	0.302
	Tea	Coffee	0.988
	Tea	Chlorhexidine	0.979
	Wine	Coffee	0.577
	Wine	Chlorhexidine	0.034
	Coffee	Chlorhexidine	0.509

When the color change observed in the case of additional polymerization of composite resin materials kept in different solutions was compared with the color change that occurred with standard polymerization, there was no statistically significant difference between the ΔE values ($p>0.05$). However, it was observed that the color of the GC material, which was kept in a single wine, became darker with the application of additional polymerization.

DISCUSSION

Studies carried out to meet the aesthetic expectations of patients have enabled composite resins to find more use in dentistry practice. In line with the goal of increasing the success rate and clinical life of composite restorations, some changes have been made in the filler content and volume of the materials, and their physical and mechanical properties have been improved. However, the long-term discoloration problem in composite resins has not been completely prevented.[4]

Color changes in composite resins can result in restorations being renewed. Restoration renewal processes, on the other hand, can cause loss of workforce and time for both the physician and the patients, as well as the loss of substance in the teeth.[5]

One of the most important reasons for the color change seen in composite restorations is the nutritional habits of the patients. In particular, some beverages such as tea, coffee, cola and wine may cause discoloration in the teeth.[5,6] Some substances in the structure of these drinks are held responsible for the coloration. For example, in the researches; It is mentioned that tannic acid in black tea, melanoid (yellow-colored molecules) in the structure of coffee or alcohol and some pigments in red wine have dyeing ability because they show affinity for the polymer network of composite resins.[7] In addition, the color factors and fluoride in the antiseptic mouthwashes, which are frequently used during periodontal diseases and gingival problems, are also responsible for the color change in composite restorations.[8] Therefore, it is recommended to consider the consumption habits of the patients, especially when deciding on the type of composite resin to be used for anterior restorations.[7]

Coloring solutions such as tea, coffee, cola, and wine are generally used in most studies testing beverage consumption-induced discoloration in composite resins. In a study by Arocha et al., it was reported that the solution causing the most color change in composite resins was red wine, followed by coffee and black tea, respectively.[9]

The amount of tea consumption in our country is quite high compared to other societies.[10] The rapid increase in the number of places where coffee is consumed in recent years has led to an increase in the rate of coffee consumption in our society.[11]

Considering the consumption habits in our country, it was preferred to use tea and coffee as a solution in our current study. Again, mouthwashes containing red wine and chlorhexidine, which we think have a high coloring rate, were also included in our study in order to compare with similar research results.

The resistance of composite resins to coloration It depends on many factors such as the structure of the resin matrix and the amount of water absorption, the size and content of the filler particles, the continuity of the matrix-filler connection of the resin, as well as the surface properties of the material and the success of the finishing and polishing processes.[12] Based on this view, in our study; The color stability of three different composite resin materials containing one microhybrid (3M Filtek™ Z250), one nanohybrid (G-aenial Anterior, GC) and one nanoceramic (Neo Spectra™ ST HV, Dentsply Sirona) was evaluated.

In studies evaluating color stability and water absorption in composite resins, it has been determined that the amount of coloration is related to the rate of water absorption and the retention time in solution. It has been reported that water plays an intermediary role between color pigments and the resin matrix.[13] Studies have shown that in order for composite resins to change color, it is usually sufficient to keep them in solution for about a week.[14] In the researches, it was recommended to keep the composite resin samples in distilled water for one week and then in the coloring solution for 2-3 weeks before being placed in the coloring solution. In similar studies, it was stated that it would be appropriate to measure the color after the samples, which were kept in the coloring solution for about 3 hours, were left in distilled water for 21 hours.[15] It has been reported that the purpose of this process is to remove the unreacted substances in the structure of the composite resin and to ensure the hardening of the resin after polymerization.[16]

Nasim et al.[13] on the other hand, stated that the highest color change period in composite resins kept in coloring solutions for different periods is the first one-week period. In our study, it was deemed appropriate to keep the composite resin samples in distilled water for one day in order to detect the color change, and to keep them in the coloring solution for a similar time period of one week.

While some of the researchers recommended keeping the test samples at room temperature, the majority preferred keeping them at 37°C.[13] Yara Khalid et al.[16] recommended that the samples be kept in an oven at 37°C and stated that the oven device creates a balanced temperature distribution thanks to the fan circulation.

Since it is known that the average intraoral temperature value in humans is about 36.4°C, our samples were kept in an oven at 37°C in our study.

It has been reported that in order to ensure adequate polymerization in composite resins after light treatment, the resin should be at most 2 mm thick, otherwise the resin could not polymerize sufficiently.[17] Studies have found that insufficient polymerization in composite resins increases the coloration of the material, while additional polymerization reduces it.[1,13,18]

Based on this point of view, in order to apply additional light, it is recommended to remove the matrix band and apply light again after the polymerization process, or to apply additional light to the lower surface or both the lower and upper surfaces after the samples are polymerized. However, it has been reported that additional light can be applied after finishing and polishing processes in order to improve the physico-mechanical properties of the composite surface.[19,20] In our study, the composite samples that we placed in 2 mm thick plastic molds were polymerized for 20 seconds with a LED light device (Woodpecker Led-G, China) in accordance with the instructions of the manufacturers. After finishing and polishing the upper surfaces of the materials, additional light was applied to the polished surfaces of half of the samples for 20 seconds.

In many studies, it has been reported that the smoothest surface for composite resins is created by using transparent tape.[21] However, smooth surfaces created using transparent tape often become rough when occlusal adjustments are made to restorations. Therefore, it is recommended to finish and polish the surfaces of composite resins after polymerization. Otherwise, an oxygen inhibition layer containing incompletely polymerized monomers forms on the surfaces of the composite resins, and thus gingivitis, secondary caries, plaque increase and discoloration may occur. The oxygen inhibition layer, which is sensitive to coloration, is also cytotoxic.[22] Patel et al.[7] emphasized that polishing processes on composite resins will create smoother and smoother surfaces and will change color less. For this purpose, discs containing aluminum oxide have been used in many studies.[21,23] In our study; In order to prevent the formation of an oxygen inhibition layer on the composite resin surface and to create smoother surfaces, we performed the polymerization process by placing transparent tapes on both surfaces of the samples. At the same time, light was applied by placing a glass coverslip on the material in all samples in order to create a standard light distance during polymerization. Subsequently, the finishing and polishing processes of all samples were completed using discs containing aluminum oxide.

In dentistry, color measurement in restorations is made by visual methods or by using color measuring devices. Color selection by visual measurement The lighting conditions of the environment, the clothes that the patient wears during color measurement, the make-up, the eyestrain of the dentist or metamerism can prevent reliable measurement. However, the possibility of inconsistent results in color selection made by visual methods has increased the use of color measuring devices. Thanks to these devices, it is possible to make repeatable, consistent and more reliable color measurements.[24]

The biggest advantages of spectrophotometer devices are that they can make consistent measurements for a long time and give results in accordance with standards. Because of these features, they have been the most frequently used devices for color measurement in dentistry.[25]

Directoroğlu et al., as a result of a study in which they evaluated the success of the devices used in color measurement; They stated that the spectrophotometer device can make more reliable measurements compared to the colorimeter device. The reason for this is that colorimeter devices cannot record the spectral reflection and the filter in the device loses its effectiveness over time.[26]

In vivo[27] and in vitro[28,29] studies on the consistency and performance of measurement devices used for the detection of color change have reported that the 'Vita EasyShade' spectrophotometer device gives successful results. In our study, the detection of color change in the samples It is preferable to use the Vita Easyshade V (Vita Easyshade V, Vita Zahnfabrik, Bad Sackingen, Germany) spectrophotometer device as it can measure colors in the 400-700 nm range, allows repeat measurements, provides reliable results and gives the L* a* b* value together with its vita scale counterpart. was done.

It has been stated that standardization of ambient conditions is important in order to make standard measurements with a spectrophotometer device, for example, the lighting condition of the environment where the measurement is made and the color of the ground can have an effect on the results obtained.[30,31]

Based on this point of view, we performed the color measurements of the samples under darkroom conditions, under fluorescent daylight lamp illumination and on a white background. Thus, the effect of ground and lighting conditions on the results was tried to be eliminated. All measurements were made by the same person with the tip of the device placed at an angle of 90 degrees to the sample. At the same time, before measuring for each sample, the device was calibrated in accordance with the instructions for use.

CIE Lab and CIEDE 2000 systems are generally used to calculate the color change that occurs in restorative materials. In many studies on the subject; It has been reported that the CIE Lab system is used more frequently and is more successful in detecting color differences. However, in the literature, the success of the CIEDE 2000 system in detecting much smaller color differences is mentioned.[32,33] In our study, the analysis of color change in composite resin materials was performed using the CIEDE 2000 system.

The color change in the materials is determined by mathematically calculating the difference (ΔE) between the first measurement and the last measurement. The human eye has the capacity to detect color differences (ΔE) up to a certain threshold value. In studies, different ideas have been put forward about the limit value of clinically detectable color difference (ΔE). There are studies that think that the critical ΔE value for visible color change in the clinical setting should be 3.3[34] or 3.7.[35] As a result of a research conducted by Johnston and Kao on color change; It was stated that if the ΔE value is less than 1, the change cannot be detected, if it is between 1-2 values, the observers can partially notice the change, and if it is greater than 2, all observers can notice the color change.[36] According to a study by Ragain and Johnston, it was reported that dentists were able to detect a clinical ΔE color difference of 1.78, whereas this value was 2.69 for patients.[37]

In a study by Paravina et al.[38] emphasized that the ΔE value should be greater than 3.7 in the CIE Lab system and 3.1 in the CIEDE 2000 system in order for color stability to be considered clinically unsuccessful.

Similarly, in our study using the CIEDE 2000 system, values with ΔE greater than 3.1 were considered clinically unsuccessful in the color change analysis.

Reis et al.[35] in their study, stated that the structure of the material and the amount of organic matrix filler are important in the color change of composite resins. In composite restoration applications, it is emphasized that the reason for the discoloration of the interfaces where the finishing and polishing processes cannot be fully performed, which is difficult to access, is usually related to the organic matrix. However, it has been reported that composite resins containing urethane dimethacrylate (UDMA) have higher staining resistance than resins containing triethyleneglycol dimethacrylate(TEGDMA).[40]

In the surface roughness and color change studies of Lainovic et al.[41] using two microhybrid (Filtek Z250, Gradia Direct) and two nanohybrid (Filtek Z550, Tetric EvoCeram) composite resins; It has been reported that nanohybrid composites are more rough and discolored compared to microhybrid composites. It has been thought that the presence of large filler structures in nanohybrid composites, surface irregularities and defects during polishing may cause this situation.

Ertaş et al.[39] as a result of a study in which they examined the coloration level of composite resins with microhybrid and nanohybrid structures placed in water, cola, tea and red wine solutions, it was reported that Filtek Z250 and Filtek P60 microhybrid composite resin materials, which do not contain TEGDMA in the matrix content, undergo the least coloration (lowest ΔE).

In our study with similar solutions, it was determined that the microhybrid Filtek Z250 composite material exhibited less coloration compared to other composites. We believe that the better color stability in Filtek Z250 composite resins is due to the replacement of TEGDMA structure with hydrophobic UDMA.

In the study of Güler et al.[42] to compare the color stability of composite resin samples kept in different beverages; It was observed that the amount of coloration caused by red wine was above the clinically acceptable level (ΔE>3.1) in all groups and the coloration value caused by tea was below this level in all groups. The amount of coloration caused by the coffee solution has been reported to be above this level in some composite groups.

As a result of many researches; It has been reported that the amount of coloration caused by tea and coffee solutions on composite resins is at a clinically acceptable level (ΔE<3.1). However, there are also studies claiming the opposite (ΔE>3.1).[43] The reason why the results are different It has been attributed to the differences in the way the solutions are prepared and the application procedures.[44]

In our study, the clinical acceptability of the discolorations produced by tea and coffee solutions varied according to the materials used and application procedures.

In a study by Yapar et al., they kept dimethacrylate-based composite resins in tea, coffee, cola and red wine solutions for a week; explained that the solution causing the most coloration was red wine (ΔE>3.1), followed by coffee and tea, respectively.[32,45]

According to the results of another study by Barutcigil et al.[1] It was stated that red wine caused the most coloration in composite resins, followed by coffee, tea and distilled water, respectively.

Falkensammer et al.[46] In a similar study using red wine, black tea and chlorhexidine-containing mouthwash, they found that red wine caused the most coloration on composite resins, while mouthwashes containing chlorhexidine showed less coloration than red wine and tea in all study groups. It has been stated that the acidic structure of red wine and the presence of color pigments that change over time play a role in the emergence of this result. The amount of coloration caused by chlorhexidine-containing mouthwashes was found to be clinically acceptable (ΔE <3.1).

It is stated that the acidic nature of red wine, as well as its alcohol content, impairs the surface integrity of the composite resin and causes surface coloration. For all these reasons, it is stated that the composite restoration surfaces become rougher and the absorption of color pigments becomes easier.[47]

Consistent with these studies, in our study, it was determined that the solution that caused the most coloration was red wine, followed by coffee, tea and chlorhexidine-containing mouthwash, respectively. The amount of coloration caused by the red wine solution was found to be clinically unacceptable (ΔE>3.1). It was determined that the mouthwash containing chlorhexidine caused less coloration compared to all other solutions, and this amount of color change was at a clinically acceptable level (ΔE <3.1).

Although it has been reported that the additional polymerization process in composite resins positively affects the mechanical properties of the resin, there are also studies claiming the opposite.[45] It is thought that the reduction of the resin polymerization rate and the limitation of the degree of conversion after a certain time limit the positive effect of the addition polymerization.[48-50] As a result of this study, in which we investigated the effect of the addition polymerization process on the color stability of different types of composite resins; It was found that the addition polymerization process reduced the surface coloration.

CONCLUSION

1. In our study, it was determined that the samples applied an additional polymerization process showed less coloration. It has been observed that the addition polymerization process affects the mechanical properties of the composite resins positively and thus the color stability can be better.
2. In order to prevent the discoloration problem seen in composite restorations in the clinic, it is recommended that physicians perform additional polymerization after the finishing and polishing stages.
3. In our study, the solution causing the most coloration among all composite groups was red wine; The mouthwash containing chlorhexidine was the solution that caused the least coloration.

4. Considering the aesthetic concerns of the patients, polishing and polishing processes should be done very well, especially in the anterior region restorations. In addition, the consumption habits of the patients should also be considered. Suggestions such as rinsing the mouth with water and brushing the teeth can be given to the patients after the coloring foods are consumed.
5. In our study, the samples showing the least coloration were the microhybrid-based Filtek™ Z250 composite resin. It is thought that the structure of the material and the amount of organic matrix filler are important in the color stability of composites and resins. For this reason, the content of the material to be used in aesthetic restorations should be considered.

ETHICAL DECLARATIONS

Ethics Committee Approval: This study does not contain any human or animal materials. It is an in vitro study under laboratory conditions. Therefore, it does not require an ethics committee approval.

Informed Consent: This study is in vitro study under laboratory conditions. Therefore, it does not require informed consent.

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