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Original Article

Evaluation of the color stability and surface roughness of dual-cure, bulk-fill composites

Zehra Şivgan Güner[1], Behiye Bolgül[1], Tacettin İnandı[2]

[1] Hatay Mustafa Kemal University, Faculty of Dentistry, Department of Pediatric Dentistry, Hatay, Turkey
[2] Hatay Mustafa Kemal University, Faculty of Medicine, Department of Public Health, Hatay, Turkey

Abstract

Aim: In recent years, tooth-colored, dual-cure, bulk-fill composite resins, which have attracted attention for their ease of use, constitute one of the latest developments in pediatric dentistry applications. This study aimed to evaluate the color stability and surface roughness properties of three different dual-cure, bulk-fill materials and one light-cure, bulk-fill composite material used in pediatric dentistry.

Methodology: In this study, three different dual-cure, bulk-fill composites (Fill-Up, HyperFIL, Cention-N) and one light-polymerized bulk-fill composite (Reveal HD) were used. A total of 70 samples were obtained for surface roughness testing. The surface roughness testing was performed with a Hysitron TI 950 Triboindenter device. A total of 105 samples were obtained for the evaluation of color stability. Cherry juice, iced tea, and distilled water were used as solutions. Initial and final color measurements were made using a spectrophotometer. The color differences between measurements were recorded according to the CIEDE 2000 system.

Results: The least surface roughness among the composite groups was observed in the light polymerized Cention-N composite samples in the experimental group. In the Fill-Up and Cention-N composite groups in the experimental group, the surface roughness of the samples left to self-polymerization and the samples polymerized with light showed a statistically significant difference ($p < 0.05$). Among the composite groups, the highest amount of coloring was observed in the Fill-Up composite samples, which were left to self-polymerization and kept in cherry juice in the experimental group. The least coloration among the composite groups was observed in the Cention-N composite samples polymerized with light and kept in distilled water.

Conclusion: Based on this information, a decrease in surface roughness and an increase in color stability can be expected due to self-polymerization and the light polymerization of dual-cured, bulk-fill composites.

Keywords: pediatric dentistry, dual-cure, bulk-fill composites, surface roughness, color stability

Correspondence:

Dr. Zehra ŞİVGAN GÜNER
Hatay Mustafa Kemal University, Faculty of Dentistry, Department of Pediatric Dentistry, Hatay, Turkey.
E-mail:
zehra_sivgan@hotmail.com

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Introduction

Significant developments in resin materials used in dentistry have led to the widening of the indications for composite resins in large posterior restorations (1). Placing traditional composite resin restorative materials in a thick layer may cause residual monomers in the restoration due to the inability of the light to provide polymerization in these areas (2). Dual polymerization would prevent the limitation of polymerization in places where light cannot reach and thus create the need for incremental placement (3, 4).

In addition to the application method, the clinical and aesthetic success of a restoration depends on the particle structure and size of the material used, the resin matrix structure, the surface roughness, and the color matching (5). The color stability of the composite resin material used is crucial for a successful restoration, and the coloration of the composite resin over time is one of the most important reasons for the requisite repetition of restorations (6). A smooth restoration surface extends the life of resin materials and provides an aesthetic appearance (7, 8). The rough surfaces of the restoration can cause plaque build-up, discoloration, gum irritation, and recurrent tooth decay (9, 10). Composite resin materials should have ideal surface hardness and low surface roughness after polishing, and these properties should be maintained during long-term use in the oral environment (11). The manufacturers of the new dual-cure, bulk-fill composites claim that their products can be placed to an unlimited depth in a single layer. It is also suggested that dual-cure, bulk-fill composites can be applied without the need for light polymerization (12). Insufficient polymerization is known to have adverse effects on the color stability and surface roughness of the material (13).

Materials and Methods

Ethics committee approval was received for this study from Hatay Mustafa Kemal University (Decision no: 2019/19).

In this study, Fill-up (Coltene/Whaladent AG, Altstätten, Switzerland), HyperFIL (Parkell,Inc, NY, USA) and Cention-N (Ivoclar, Schaan, Liechtenstein) dual-cure, bulk-fill composites were used as the test group, and light-cured Reveal HD (Bisco, IL, USA) bulk-fill composites were used as the control group. The composites used and their compounds are shown in Table 1.

Polyethylene molds with a diameter of 6 mm and a depth of 5 mm were used in the preparation of the samples.

Table 1. Resin composites and compositions

Composite	*Type*	*Composition*	*Filler rates*	*Filler size*	*Manufacturer*
Fill-up	Dual cure bulk-fill composite	TMPTMA, UDMA, Bis-GMA, TEGDMA glass particles, amorphous silica and zinc oxide	By weight %65, by vol %49	average 2 µ	Coltene/ Whaladent AG
HyperFIL	Dual cure bulk-fill composite	Bis-GMA, UDMA and other dimectacrylate monomers	By weight %70	15 nm-3,5 µm	Parkell, Inc
Cention-N	Dual cure bulk-fill composite	UDMA and other dimectacrylate monomers, calcium fluorosilicate glass, barium glass, calcium barium aluminum fluorosilicate glass, ytterbium trifluoride	By weight %78,4, by vol %57,6	average 0,1-7µm	Ivoclar Liechtenstein
Reveal HD	Light-cure bulk-fill composite	UDMA and Bis-GMA ytterbium trifluoride			Bisco, USA

Preparation of Samples for Surface Roughness Measurement

The dual-cure, bulk-fill composites (Fill-Up, HyperFIL, Cention-N) used in the experimental group for surface roughness measurement were divided into two separate groups. Following the manufacturer's instructions, the first group samples were left for self-polymerization without using light. The second group samples in the experimental group and the samples in the control group were polymerized with a 1,200 mW/cm^2 LED polymerization device (Valo, Ultradent, City, USA) (n = 10). After the finishing and polishing procedures, the samples were kept in an incubator in distilled water at 37°C for 24 hours. The surface topography of the samples was evaluated by scanning five 40×40 µm areas obtained from the samples with a Berkovich-type tip on a Hysitron TI 950 Triboindenter (Hysitron, Minnesota, USA) device, and the surface roughness parameters were obtained numerically. The roughness values in Ra (nm) were recorded by taking the average of the measurements. Subsequently, an SEM (JEOL 5500/OXFORD Inca-X Scanning Electron Microscope) was used for a surface analysis of the samples. The surfaces of the composite samples were gold-plated on carbon tape under high vacuum. A qualitative analysis of the surface properties was achieved by obtaining images of the sample surfaces at 100x, 500x, and 5000x magnifications.

Preparation of Samples for Color Stability Measurement

The dual-cure, bulk-fill composites (Fill-Up, HyperFIL, Cention-N) used in the experimental group to evaluate color stability were divided into two separate groups. Following the manufacturer's instructions, the first group samples were left for self-polymerization without using light. The second group samples in the experimental group and the samples in the control group (Reveal HD) were polymerized with a 1,200 mW/cm² LED polymerization device (Valo, Ultradent, USA) (n=15). After the polishing processes, the samples were taken out of their molds and kept in an incubator for 24 hours in 37°C distilled water. The initial color measurements of the samples were carried out with the help of the spectrophotometer (VITA Easyshade® Advance 4.0) by measuring each sample three times with the three-point measurement mode of the device. As a result of the measurement, L *, a *, b *, c *, and h * values were obtained and recorded. Then, the samples were randomly divided into three groups and kept for one week in distilled water (MOS LAB), sour cherry juice (Cappy, Coca-Cola Company), and iced tea (Fusetea, DP beverages) (n=5). At the end of the week, the samples were dried with blotter paper, the final color measurement was performed, and the L *, a *, b *, c *, and h * values were obtained and recorded. The color differences (ΔE_{00}*) among the measurements were calculated with the CIEDE 2000 formula using the obtained values (14) (Fig. 1).

$$\Delta E_{00}^{*} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H}}$$

Figure 1. CIEDE 2000 formula (14)

Statistical analysis

Statistical analyses in this study were performed in the package program SPSS Statistics version 21.0 (IBM SPSS Inc., Armonk, NY, USA). The data were presented with arithmetic mean ± standard deviation. The assumption of normality in the data was assessed using the Kolmogorov-Smirnov test. It was found that the parameters obtained for evaluating the surface roughness and color stability were not suitable for normal distribution. The Ra values obtained from the composite samples to evaluate the surface roughness and the ΔE_{00} values obtained from the composite samples were compared using the Kruskal-Wallis test to appraise color stability. The results were rated at a significance level of $p < 0.05$.

Results

Evaluation of Surface Roughness of Composites

When the surface roughness values of the composite samples were examined, the lowest Ra value was seen in the HyperFIL composite samples. Among the samples that were polymerized with light, the lowest Ra value was seen in the Cention-N composite samples. Paired comparisons were made to assess the level of surface roughness (Ra) observed between groups. The comparison of the surface roughness of the composite samples left to self-polymerize and polymerized with light is shown in Table 2 and Fig. 2. In the Fill-Up and Cention-N composite groups, the surface roughness of the samples left to self-polymerization and the samples polymerized with light showed statistically significant differences ($p < 0.05$).

Table 2. Surface roughness mean values (Ra), standard deviations (SD), and p-value

Composite		Ra(nm)±SD	p
Fill-up	Self-cure	427,85±46,23	<0,001
	Light-cure	197,96±104,77	
HyperFIL	Self-cure	343,94±49,03	1
	Light-cure	299,01±64,57	
Cention-N	Self-cure	380,83±74,5	0,004
	Light-cure	162,12±75,9	
Reveal HD	Light-cure	272,7±164,08	

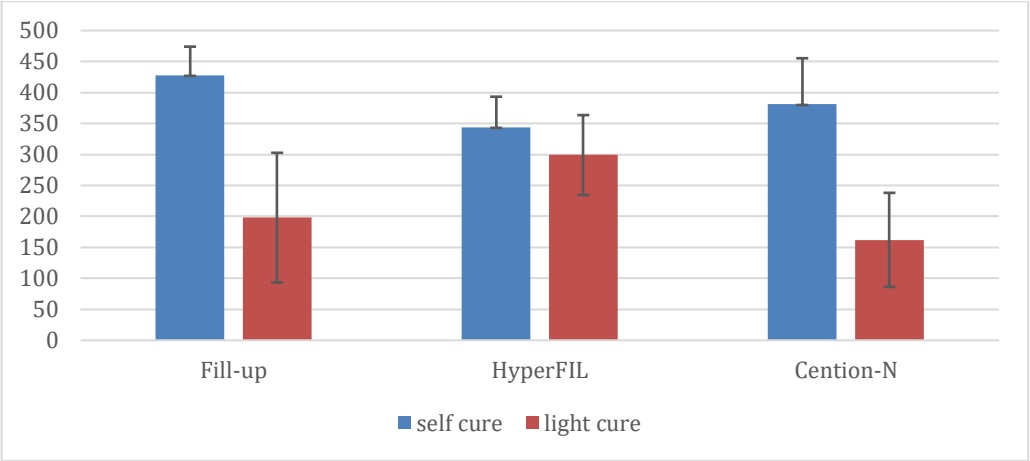

Figure 2. Comparison of the self-cure and light-cure surface roughness values of composites

When the surface roughness of composite resins was compared according to their brands, no statistical difference was found ($p > 0.05$) (Table 3, Fig. 3). SEM images of the samples were taken after SPM measurement (Fig. 4).

Table 3. Comparison of surface roughness of composite samples according to brands and p-values

	Self-cure		*Light-cure*	
	Ra(nm)±SD	p	Ra(nm)±SD	p
Fill-up	427,85±46,23	>0,05	197,96±104,77	>0,05
HyperFIL	343,94±49,03		299,01±64,57	
Cention-N	380,83±74,5		162,12±75,9	
Reveal			272,7±164,08	

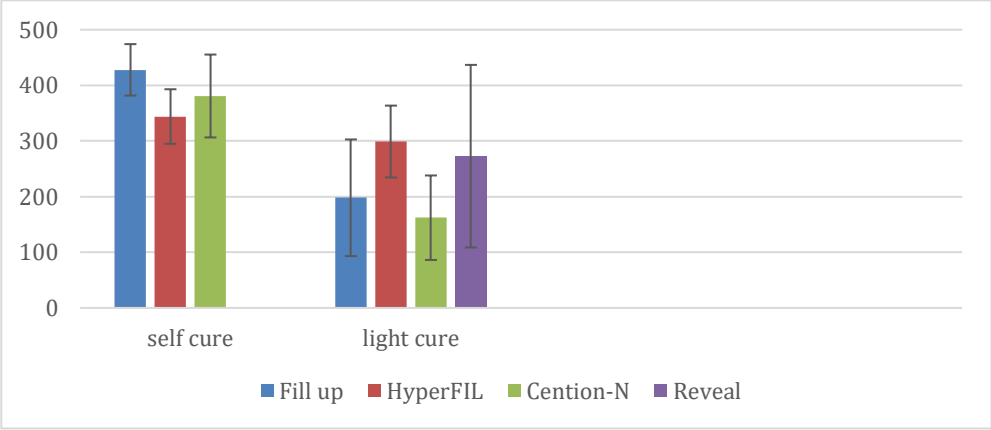

Figure 3. Comparison of surface roughness of composite samples according to brands

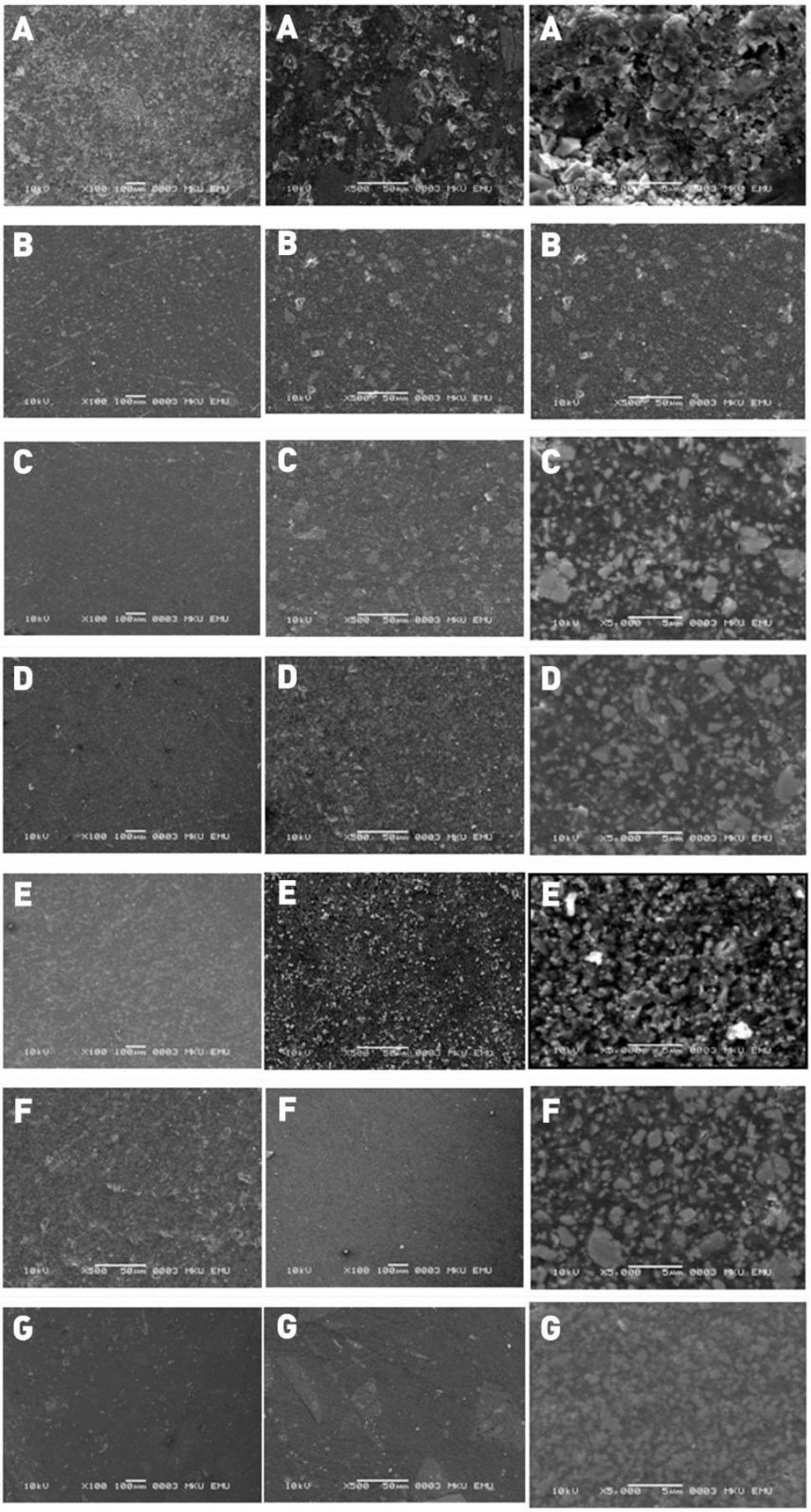

Figure 4. Premise. Each line's images represent the surface characterization of composite samples (100x, 500x, 5000x). In the lines, A: Self-cure Fill-up B: Light-cure Fill-up, C: Self-cure HyperFIL, D: Light-cure HyperFIL, E: Self-cure Cention-N, F: Light-cure Cention-N, G: Reveal HD

Evaluation of Color Stability of Composites

When the color changes to the composite samples were examined, the lowest ΔE_{00} of the samples left to self-polymerize was seen in the HyperFIL composite samples stored in distilled water. In the light-polymerized samples, the lowest ΔE_{00} was observed in the Cention-N composite samples stored in distilled water.

The coloration of the samples left to self-polymerization and light polymerization in the Fill-Up composite group kept in cherry juice and the Cention-N composite kept in cherry juice and iced tea showed statistically significant differences ($p < 0.05$) (Table 4).

The amount of coloration in all samples kept in cherry juice in the experimental group was statistically significantly higher than that of the samples kept in distilled water ($p < 0.05$).

Table 4. Average ΔE_{00} and p-values of dual-cure composites in the state of self-curing and light-curing

		Cherry juice		Iced tea		Distiled water	
		ΔE_{00}	p	ΔE_{00}	p	ΔE_{00}	p
Fill-up	self-cure	5,12±0,87	0,008*	3,64±0,82	>0,05	2,08±1,42	>0,05
	light-cure	2,91±0.01		2,83±0,23		1,28±0,55	
HyperFIL	self-cure	3,67±0,49	>0,05	3,25±0,59	>0,05	0,83±0,44	>0,05
	light-cure	3,34±0,21		3,17±0,17		0,54±0,04	
Cention-N	self-cure	3,88±0,28	0,008*	3,55±0,55	0,017*	1,08±0,16	>0,05
	light-cure	2,23±0,34		2,89±0,6		1,02±0,05	

The amount of coloration in all samples kept in cherry juice in the experimental group was statistically significantly higher than that of the samples kept in distilled water ($p < 0.05$).

The amount of coloration in all experimental group samples kept in iced tea except for the self-cure, Fill-Up group was statistically significantly higher than that of the samples retained in distilled water ($p < 0.05$).

The amount of coloration in light-cure Cention-N group samples kept in cherry juice is statistically significantly higher than the samples retained in iced tea ($p=0,003$) (Table 5).

Table 5. Average ΔE_{00} and p-values of composites in different solutions

		ΔE_{00}			ΔE_{00}			ΔE_{00}		
		Cherry juice	Distiled water	p	Iced tea	Distiled water	p	Cherry juice	Iced tea	p
Fill up	self-cure	5,12±0,87	2,08±1,42	0,016	3,64±0,82	2,08±1,42	>0,05	5,12±0,87	3,64±0,82	>0,05
	light-cure	2,91±0.01	1,28±0,55	0,008	2,83±0,23	1,28±0,55	0,008	2,91±0.01	2,83±0,23	>0,05
HyperFIL	self-cure	3,67±0,49	0,83±0,44	0,016	3,25±0,59	0,83±0,44	0,014	3,67±0,49	3,25±0,59	>0,05
	light-cure	3,34±0,21	0,54±0,04	0,004	3,17±0,17	0,54±0,04	0,006	3,34±0,21	3,17±0,17	>0,05
Cention-N	self-cure	3,88±0,28	1,08±0,16	0,009	3,55±0,55	1,08±0,16	0,036	3,88±0,28	3,55±0,55	>0,05
	light-cure	2,23±0,34	1,02±0,05	0,008	2,89±0,6	1,02±0,05	0,003	2,23±0,34	2,89±0,6	0,003
Reveal	light-cure	2,92±0,57	2±1,07	>0,05	2,98±0,32	2±1,07	>0,05	2,92±0,57	2,98±0,32	>0,05

The amount of coloration observed in the composite groups left to self-polymerization and kept in sour cherry juice differs statistically significantly (p=0.019). As a result of the pairwise comparisons made to determine which groups this difference originated from, it was observed that the samples in the Fill-up group showed significantly more coloration than the HyperFIL group (p=0.015).

The amount of coloration observed in the composite groups that were cured by light and kept in cherry juice showed statistically significant differences (p=0.006). As a result of the pairwise comparisons made to determine which groups this difference originated from, it was observed that the samples in the HyperFIL group showed significantly more coloration than the Cention-N group (p=0.003).

The amount of coloration observed in the composite groups that were polymerized with light and kept in distilled water showed a statistically significant difference (p=0.013). As a result of the pairwise comparisons made to determine which groups this difference originated from, it was observed that the samples in the Reveal HD group showed significantly higher coloration than the Fill-up group (p=0.014) (Table 6).

Table 6. Comparison of delta parameter in brands and p values

		Composite	ΔE_{00}	p
Cherry juice	self-cure	Fill-up	5,12±0,87[a]	0,019*
		HyperFIL	3,67±0,49[b]	
		Cention-N	3,88±0,28[a]	
	light-cure	Fill-up	2,91±0.01[a]	0,006*
		HyperFIL	3,34±0,21[a]	
		Cention-N	2,23±0,34[b]	
		Reveal HD	2,92±0,57[a]	
Iced tea	self-cure	Fill-up	3,64±0,82	0,484
		HyperFIL	3,25±0,59	
		Cention-N	3,55±0,55	
	light-cure	Fill-up	2,83±0,23	0,416
		HyperFIL	3,17±0,17	
		Cention-N	2,89±0,6	
		Reveal HD	2,98±0,32	
Distiled water	self-cure	Fill-up	2,08±1,42	0,085
		HyperFIL	0,83±0,44	
		Cention-N	1,08±0,16	
	light-cure	Fill-up	1,28±0,55[ab]	0,013*
		HyperFIL	0,54±0,04[b]	
		Cention-N	1,02±0,05[b]	
		Reveal HD	2±1,07[a]	

* there is a statistical difference between the groups indicated with different letters in the same column (p<0.05).

Discussion

It is claimed that the use of dual-cure bulk-fill composites eliminates the limitations of light polymerization and the need for incremental placement. Vandewalker et al. investigated the effect of self-polymerization and light polymerization of dual-cure bulk-filled HyperFIL and Injectafil DC composites on surface roughness (4). They found that no significant difference was observed in the surface porosity of the resin in the case of self-polymerization and light polymerization in both dual-cure composites. In addition, when the HyperFIL composite was left to self-polymerize and polymerized with light, it was found that the Ra values obtained when compared to Injectafil DC and Filtek Z250 composites were not significantly different. In our study, the surface roughness values of the self-cure and light-cure groups of the HyperFIL composite did not show a statistically significant difference. (p> 0.05). In our study, no significant difference was found in the surface roughness of HyperFIL composite samples when compared with other composite brands (p> 0.05). In the study of Naz et al., in which they examined the effect of chewing simulation on the surface roughness of

materials that Filtek Z250, Fuji IX, Z250 XT and Cention-N, they found that the surface roughness before the simulation was mostly seen in the Cention-N composite (15). In our study, no statistically significant difference was observed when the surface roughness values (Ra) of the Cention-N composite were compared with the other composite groups ($p>0.05$). In the study of Bhattacharya et al. investigating the effect of thermal cycle on color stability in various composites, it was stated that Cention-N composite showed better color stability compared to Fuji IX GP and Fuji IX GP Extra (16). Our study determined that Cention-N samples polymerized with light have the lowest ΔE_{00} values in all solution types.

It is claimed that dual-cure bulk-fill composite resins can be placed in the cavity as a single layer without limitation of depth (17). Based on this information, the amount of coloration seen in the self-polymerization and light polymerization of the composites in our experimental group in different solutions was examined. In the Cention-N composite groups kept both in iced tea and in cherry juice and in the Fill-up composite groups waiting in cherry juice, when they were left to self-polymerization and polymerized with light, the ΔE_{00} values showed statistically significantly different. Given this information, it can be said that providing light polymerization in addition to self-polymerization will have a positive effect on color stability in dual-cure composites.

Conclusions

In view of this information, a decrease in surface roughness and an increase in color stability as a result of the light polymerization of dual-cure, bulk-fill composites and self-polymerization can be expected. Accordingly, an increase in the life of restorations and increased clinical success can be observed. Since it is difficult to reflect the oral environment fully with in vitro studies, it may be recommended to conduct clinical studies in addition to laboratory studies to investigate the surface roughness of and color changes in composite material.

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Ethical Approval: Ethics committee approval was received for this study from Hatay Mustafa Kemal University accordance the World Medical Association Declaration of Helsinki, with the approval number: 2019/19.

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