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Original Article

Color stability comparisons of different type composite resins after curing and when aged in various staining solutions

Basak Yazkan[1], Duygu Recen[2]

[1]Department of Restorative Dentistry, Faculty of Dentistry, Pamukkale University, Denizli, Turkey
[2]Department of Restorative Dentistry, Faculty of Dentistry, Izmir Democracy University, Izmir, Turkey

Abstract

Aim: To compare the color stability of two bulkfill (ormocer based or not), two flowable (high and low viscosity) and a universal nanohybrid composite resin after curing and when aged in different staining solutions.

Material and Methods: Three hundred twenty discs were made from a low-flowable nanohybrid composite (GrandioSO Heavy Flow), a flowable nanohybrid composite (Grandio Flow), a bulkfill composite (GrandioSO x-tra), an ormocer-based bulkfill composite (Admira Fusion X-tra) and a universal nanohybrid composite (Grandio SO) (n=64). Specimens were subdivided into 4 subgroups, which were immersed in one of the following solutions for 3 hours a day for 30 days: distilled water, filter coffee, red wine and coke (n=16). Color evaluations were done using a dental spectrophotometer at three evaluation stages: immediately before curing, 24 hours after curing and 30 days of staining.

Results: After curing; the universal nanohybrid and bulkfill composite showed significantly greater ΔE values than other type composite resins ($p<0.05$). Bulkfill composite was the most stained resin type in all of the staining solution subgroups ($p<0.05$). The bulkfill composite followed by universal and flowable nanohybrid composite and the ormocer based bulkfill composite showed the lowest ΔE values after coffee staining ($p<0.05$). When effects of staining solutions are evaluated; coffee presented the highest staining effect, red wine was the second and, coke and water was the least stained solutions in application to all type of composite resins ($p<0.05$).

Conclusions: According to this study, it can be concluded that bulkfill composites showed the least resistance to staining and the ormocers were successful in color stability. In all tested materials, color changes after curing and after coffee staining were clinically perceptible. Therefore, when choosing a particular shade, such possible color changes should be taken into consideration.

Keywords: Composite resins; staining; color; flowable hybrid composites; ormocers

INTRODUCTION

Since their introduction over half a century ago, composite resins have achieved popularity for anterior and posterior direct restorations (1). Some of the reasons behind these are the compatibility of successful adhesive systems and their pleasing harmony with the color of the adjacent tooth which responds esthetic expectations of the patients (2).

Despite these superior properties above mentioned, discoloration of composite resins is still an unsolved problem (3-5). Staining may occur due to intrinsic and/or extrinsic factors (6). Intrinsic staining is known to be associated with matrix, type, amount of fillers, initiator and accelerator system and polymerization degree of the composite resins (7,9).

Extrinsic discoloration is also occurs as a result of adsorption or absorption of coloring agents onto the surface and can be removed by polishing or chemically cleaning (4). Color change in composite resins has been investigated with many studies using different coloring agents. Coffee, tea, red wine, carbonated drinks and fruit juices are the common staining agents used (4,10,11).

It has been reported that physicochemical conditions such as daylight, ultraviolet irradiation, thermal changes and humidity can cause color alterations in composite resins (10). Therefore, artificial aging methods are commonly used to predict these possible color alterations in composite resins over time. (12,13).

Composite resins are being developed day by day. A

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Corresponding Author: Duygu Recen, Department of Restorative Dentistry, Faculty of Dentistry, Izmir Democracy University, Izmir, Turkey, **Email:** recenduygu@hotmail.com

fundemantal change observed in these is the ormocers. Conventional composite resins consist of a matrix containing Bis-GMA, methacrylate or other organic resins. However, as an improvement in composite resins, ormocers contain multifınctional urethane and thioether (meth) acrylate akoxysilanes. It is reported that this monomer lowers polymerization shrinkage and highers abrasion resistance and improves its esthetic properties (14).

Another development to simplify the placement of large restorations and to save treatment time is bulkfill composites (15). Bulkfill composites are frequently preferred due to some advantages such as controlled polymerization contraction stresses and reduced cuspal deflection (16).

There are very few studies that evaluated and compared the color stability of ormocer based composite resins and bulkfill composites. Much more studies should be done to have better knowledge about these composites. Therefore this in vitro study was designed to determine and compare the color stability of an ormocer based, a bulkfill, a low-flowable, a flowable and a universal nanohybrid composite resin after curing and when aged in various staining solutions (red wine, coffee, coke, and distilled water).

The null hypotheses tested were that: (1) Composite resin's type had no effect on color change after curing and when aged in various staining solutions; (2) The staining solution had no effect on color change.

MATERIAL and METHODS

Specimens' preparation

Three hundred twenty disc shaped specimens were prepared from five different type composite resins (n=64). The specimens were subdivided into 4 subgroups, which were immersed in one of the following solutions 1 hours a day for 30 days: distilled water, coffee, coke and red wine (n=16).

The tested materials were: a low-flowable (GrandioSO Heavy Flow, Voco GmbH, Cuxhaven, Germany), a flowable (Grandio Flow, Voco GmbH, Cuxhaven, Germany), a bulkfill (GrandioSO x-tra, Voco GmbH, Cuxhaven, Germany), an ormocer-based bulkfill (Admira Fusion, Voco GmbH, Cuxhaven, Germany) and a universal nanohybrid composite (Grandio SO, Voco GmbH, Cuxhaven, Germany). Content, manufacturer, shade and type informations of composite resins used for each group were presented in Table 1.

Specimens were prepared according to manufacturers' application instructions using a silicon ring mould (internal diameter 6 mm, external diameter 8 mm and height 2 mm). Moulds were overfilled with tested materials and covered with a strip band (Henry Schein, Melville, NY) and pressed between glass slides. Composite resins were cured using using a LED lamp at a distance of 1 mm (1000 mW/cm2, using standart power curing mode of VALO™ Cordless, Ultradent, South Jordan, UT 84095, USA).

The upper surfaces of the specimens were polished with medium (10 s), fine (10 s) and super-fine (10 s) aluminium oxide-impregnated discs (Sof-Lex, 3M ESPE, St. Paul, MN, USA), respectively, under dry conditions. Then, specimens were stored in distilled water for 24 hours at room temperature.

Staining

The followings were used as staining solutions: Coffee (10 mg powder and 200 ml of boiling water; Nescafe Classic, Nestle, Vevey, Switzerland), coke (The Coca-Cola Company, Atlanta, Georgia, USA), red wine (Kayra Vintage Öküzgözü, Elazığ, Turkey) and distilled water. All specimens were immersed in staining solutions and were kept at room temperature 1 hours a day for 30 days. Staining solutions were refreshed daily.

Color measurements

Color evaluations were done using a dental spectrophotometer (Vita Easyshade V, Vita Zahnfabrik, Bad Säckingen, Germany) against a standart black background (Leneta, Mahwah, USA). The L* a* b* values were recorded at three evaluation periods: before curing (baseline), 24 hours after curing and 30 days of staining.

Before each specimens' experimental measurements, spectrophotometer device was calibrated according to the manufacturer. Vita Easyshade V was placed in the charging station and it recognized the calibration block. After 2 short signal tones calibration was completed. All measurements were performed at the center of each specimen by the same investigator. Three readings for each specimen were made at each evaluation period and arithmetic means of these readings were taken into consideration. The ΔE* values between each evaluation periods were calculated using the following equation (17):

$\Delta E^* = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2]1/2$

$\Delta L^* = L(final) - L(initial)$ and $\Delta a^* = a(final) - a(initial)$ and $\Delta b^* = b(final) - b(initial)$.

Statistical analysis

Shapiro-Wilk tests were used for testing normality. The Kruskal–Wallis Variance Analysis was used for the comparisons among groups. The post-hoc Mann Whitney U-Test with Bonferroni Correction was used when the Kruskal Wallis Variance Analysis determined a significant difference. Also, Friedman test was used for dependent group comparisons. Wilcoxon Signed Rank test with Bonferroni Correction for post hoc analysis was used when Friedman test determined a significant difference. All statistical analyses were analysed by SPSS, 25.0 IBM SPSS Statistics 24 software (Armonk, NY: IBM Corp.) and p value less than 0.05 was considered statistically significant.

RESULTS

The mean values and standard deviations of the color change (ΔE) values after 30 days of immersion in the different staining solutions are shown in Table 2.

Twenty-four hours after curing; the universal nanohybrid and bulkfill composites showed similar and significantly greater ΔE values than other materials (p<0.05, Table 2). The rest of the materials showed statistically similar ΔE values (p>0.05, Table 2).

At 30 days of water, red wine and coke immersion; the bulkfill composite presented significantly greater staining than others (p<0.05, Table 2). The rest of the materials showed statistically similar ΔE values (p>0.05, Table 2).

At 30 days of coffee immersion; the bulkfill composite presented significantly greater staining than other materials (p<0.05, Table 2). The bulkfill composite followed by universal and flowable nanohybrid composite (p<0.05, Table 2). The ormocer based bulkfill composite showed the lowest ΔE values (p<0.05, Table 2).

When effects of staining solutions are evaluated; coffee presented the highest staining effect, red wine was the second and, coke and water were the least stained solutions in application to all the resin materials (p<0.05, Table 2).

Table 1. Content, manufacturer, shade and type informations of composite resins used for each group

Resin Composite's Type	Manufacturer	Shade	Organic matrix	Fillers	Multivariate analysis	Batch Number
Flowable Nanohybrid	Voco GmbH, Cuxhaven, Germany	A2	Bis-GMA, TEGDMA, HEDMA	Glass ceramic, silicon dioxide	81%/65	1820527
Low-Flowable Nanohybrid	Voco GmbH, Cuxhaven, Germany	A2	Bis-GMA, BisEMA, TEGDMA, HEDMA, camphorquinone, Amina, BHT	Glass ceramic, silicon dioxide	83%/68	1822588
Bulkfill	Voco GmbH, Cuxhaven, Germany	A2	Bis-GMA, UDMA, TEGDMA	Barium, boron, aluminum, silicate glass	86%/70.1	1810691
Universal Nanohybrid	Voco GmbH, Cuxhaven, Germany	A2	Bis-GMA, BisEMA, TEGDMA, camphorquinone, Amina, BHT	Glass ceramic, silicon dioxide	89%/73	1822397
Ormocer Based Bulkfill	Voco GmbH, Cuxhaven, Germany	A2	Aromatic and aliphatic dimethacrylates, methacrylate-functionalized polysiloxane	Barium , aluminum, glass, silicon dioxide, camphorquinone	84%/69	1822603

UDMA: urethane dimethacrylate; TEGDMA: ttriethyleneglycol dimethacrylate; Bis-EMA: Bisphenol A polyethylene glycol diether dimethacrylate; Bis-GMA: Bisphenol A dimethacrylate; HEDMA: hydroxyethyl dimethacrylate

Table 2. Mean ± standard deviation of ΔE values calculated from mean ΔL*, Δa*, Δb* values for each composite resin material

	Ormocer Based Composite	Universal Nanohybrid Composite	Bulkfill Composite	Low-Flowable Nanohybrid Composite	Flowable Nanohybrid Composite
ΔE Before Curing- After Curing	5.86 ± 0.32^{aA}	6.79 ± 0.19^{bA}	6.4 ± 0.37^{bA}	5.73 ± 0.32^{aA}	6.12 ± 0.33^{aA}
ΔE After Curing - Water Staining	1.61 ± 0.37^{aB}	1.25 ± 0.35^{aB}	2.48 ± 0.2^{bB}	1.46 ± 0.26^{aB}	1.47 ± 0.2^{aB}
ΔE After Curing - Coffee Staining	4.46 ± 0.47^{aA}	5.95 ± 0.24^{bA}	6.41 ± 0.19^{cA}	5.27 ± 0$^{.3dA}$	5.89 ± 0.25^{bA}
ΔE After Curing - Red Wine Staining	3.28 ± 0.2^{9aC}	2.97 ± 0.18^{aC}	4.03 ± 0.26^{bC}	3.21 ± 0.23^{aC}	3.30 ± 0.24^{aC}
ΔE After Curing - Coke Staining	1.28 ± 0.38^{aB}	1.32 ± 0,23^{aB}	2.48 ± 0.19^{bB}	1.59 ± 0.33^{aB}	1.53 ± 0.23^{aB}

* Different lowercase letters in rows and uppercase letters in columns indicate statistically significant difference (p<0.05)

DISCUSSION

Color stability of composite resins has been evaluated in many clinical and in vitro studies. In these studies, it was stated that factors affecting the color stability are the type of matrix, the size of the fillers and the depth of polymerization of the composite resins (4,18,19-21). The present study evaluated and compared the color stability of a low-flowable nanohybrid, a flowable nanohybrid, a bulkfill, an ormocer-based bulkfill and a universal nanohybrid composite resin after curing and after 30 days kept in different staining beverages widely consumed (coffee, red wine and coke) and distilled water used as control.

Dental spectrophotometer and CIE L * a * b * coordinate system which were also used in previous studies, were used for color analysis in this study. This system was preferred because it is very suitable for detecting small amount of color differences and it has features such as repeatability and objectivity (22). Many authors reported that ΔE values ranging from 1-3 are clinically acceptable, but ΔE values greater than 3.7 are clinically unacceptable (23,24).

Effects of type of the composite resin on the color stability

According to the obtained results, our first null hyphothesis was rejected, because not all composite resin types showed the same performance in terms of color stability. After curing; the universal nanohybrid and bulkfill composite presented greatest color change. Bulkfill composite was the least resistant composite type. According to the coffee staining results, ormocer based bulkfill was the composite with the highest color stability. In this study, all type of composite resins revealed clinically acceptable ΔE* values when evaluated immediately after polymerization and after one month of coffee staining.

It is known that there may be a significant color change immediately after curing. The color change during polymerization can be explained by the increasing refractive index of the resin phase when the monomers turn into polymers (25). It is also reported that chromatic changes in camphorquinone (CQ) may cause discoloration after curing (26). It is noteworthy that the color of all composite resins tested in this study changed significantly after curing. Therefore, clinicians may be suggested to evaluate color harmony by polymerizing a small piece of composite resin on tooth surface before starting restoration.

In this study bulkfill composite presented greatest color difference after polimerization and after staining in all staining solution subgroups. The results of this study are similar to some other studies that detect more color change in bulkfil composites than conventional composites (26, 27). This color change in bulkfills can be attributed to the large amount of CQ as reported before (26). Bulkfill composites contain different fillers, prepolymer shrinkage stress relievers and special photo initiators. These composition differences in bulkfill composites may lead more color changes. Bulkfill application technique can also create a large number of filler / matrix interfaces due to differences in their refractive indices. Therefore, a lower degree of curing may be achieved due to the fact that less photons reach the deeper parts of the composite resin (27).

The color alterations that occurs after aging in distilled water can be defined as internal coloration of resin (6). In this study water aging did not significantly alter the color (ΔE<3.7) for all type of composite resins. Nonetheless, bulkfill composite had the greatest ΔE value (2.48). Composite resins' matrix and size of the filler particles may affect the color change susceptibility of bulkfills. In fact matrix is a determinant factor. It was reported that hydrophilic resin monomers can effect color stability due to their water sorption. If the resin matrix shows a high degree of water absorption, it can absorb other colorant fluids that cause staining along with water. On the contrary, fillers can not absorb water, but can adsorb water (27). This can cause hydrolysis of silane (28). Micro cracks that may occur as a result of hydrolysis can cause stain penetration, thus resulting as discoloration (28).

It has been reported that UDMA is more resistant to staining than Bis-GMA. This is because UDMA has lower water absorption than other dimethacrylates (29). In addition, it has been shown that resins with high degree of monomer conversion have higher color stability due to their low amount of unreacted monomers and low solubility (30). The degree of monomer conversion of light-cured composite resins vary with the concentration of some monomers. The conversion degree of some monomers in composite resins are as follows: Bis-GMA <Bis-EMA <UDMA <TEGDMA (31). In this study, the results could not be associated with the color change that may occur due to the monomer of resins. It is difficult to fully relate the results to the structure of composite resins, unless the manufacturers report the contents of the resins in detail.

According to the results of this study, it can be said that ormocer based composite is more resistant to discoloration than bulkfill composites. All composite resins presented clinically significant color change when immersed in coffee solution.

Effects of staining solution on the color stability of resin materials

In different in vitro studies it has been reported that coffee, coke or red wine can cause a significant change in the color of composite resins (32). In this study, control group (distilled water) kept the same color without changing. In contrast, all resins showed clinically perceptible color differences after staining with coffee. Coke and red wine did not have clinically significant influence on the color stability of materials except only for bulkfill composite exposed to red wine (ΔE>3.7). Our results are in accordance with other studies which demonstrated coffee has more staining effect than other staining solutions (6,33,34).

It is known that coffee has high staining capacity.

According to Güler et al. (35) the average time required to consume 1 cup of coffee is 15 minutes, and those who consume coffee often drinks 3.2 cups a day. In this study, it has been reported that storage in a 15 day coffee solution may correspond to approximately 1 year. According to this study, it can be said that the time applied in this present study corresponds approximately to 2 years.

Smilar to this study, another research revealed that despite the presence of phosphoric acid, coke did not have a strong effect on color change (36). The etching ability of acids is different. In general, there are two methods to determine the acid content: pH and the titratable acidity. It is reported that measuring the titratable acidity is more accurate method than evaluating initial acidity to predict the erosive potential of a beverage (37). Despite the high pH of coke, its low staining effect of cola can be associated with its low titratable acidity.

There are limitations associated with this present study. This study was conducted in vitro conditions. Intraoral conditions may result in discoloration of restorative materials. Therefore, both in vitro and in vivo future studies that should include more optical parameters like gloss and surface roughness analyses were also recommended.

CONCLUSION

According to the results of this study, it can be said that bulkfill composites showed the least resistance to staining and ormocers was successful in this regard. When the clinical significance of color change is evaluated, all type of composite resins tested here revealed ΔE* values greater than 3.7 at two measuring points: after polymerization and after coffee staining. Therefore, it should be noted that color change and discoloration of composite resins are still a problem. When choosing the color of a restoration, it should be predicted that the color may differ immediately after curing. It can be suggested that a piece of resin intended to be applied can be cured to confirm the selected shade before restorative procedures.

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