Effect of fiber reinforcement on color stability of composite resins

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Abstract

Aim: The aim of this in vitro study was to determine the effect of fiber reinforcement on the color changes of two different composite resins.

Materials and Methods: A silorane-based composite (Filtek Silorane, A2 shade) and a methacrylate-based composite (Valux Plus, A2 shade) were used in this study. Three groups of samples (control group with no reinforcements, polyethylene fiber [Ribbond THM]-reinforced composite, and glass fiber [everStick® Net]-reinforced composite groups) were prepared from each composite (n = 8). The color change was calculated between baseline and 1 day (ΔE1) and between baseline, 7 days (ΔE2), and 21 days (ΔE3) with a spectrophotometer. The data were analyzed by ANOVA, Duncan’s multiple-range tests and independent sample t-test.

Results: Statistical analysis of variance presented the statistically significance difference between composite, fiber, and time for ΔE (P < 0.05). The Ribbond reinforced composite showed a similar color change to the control group (ΔE = 3.69), while the everStick reinforced composite showed the largest total color change (ΔE = 4.13). It was determined that the time is an effective factor on the color stability of reinforced composites (P < 0.05).

Conclusion: The addition of fiber may lead to color change in composite resins. The amount of change may differ depending on the structural properties of the composite resin or the fiber and time.

Keywords: Color stability; composite resin; fiber

INTRODUCTION

Research in esthetic dentistry, often conducted by dental material manufacturers, focuses on new techniques and materials to increase the clinician’s ability to provide cosmetic dental treatment. In recent years, a significant increase has been observed in the development and use of dental esthetic restorative materials.[1] Expectations from the ideal restorative material include sufficient bonding strength to enamel and dentine, color stability, resistance to abrasion and water dissolution, similar elasticity and thermal conductivity to tooth structure, marginal integrity and resistance to microleakage, biocompatibility, and ease of application.[2,3]

Fiber-reinforced composites have recently been successfully used in dental restorations with appropriate mechanical properties. Compared to metals, fibers offer many advantages such as superior strength-to-weight ratios, ease of repair, low corrosion, similar translucency to the tooth structure, and good bonding properties.[4] With these advantages, fibers are used in dentistry in different areas such as periodontal splinting, orthodontic applications, single crowns, post-core systems, adhesive fixed partial prosthesis, and stabilization of traumatic teeth.[5,6]
For more than 40 years, resin composites have provided dentists with a tooth-colored, direct restorative material that now serves as an acceptable alternative to metallic restoratives. To achieve the best esthetics, resin composite restorations must match natural teeth in appearance and must maintain that appearance over time. The shade match is important, but so are properties such as translucency, surface roughness, gloss, fluorescence, and opalescence. Intrinsic color stability and resistance to staining affect the long-term esthetics of composite restorations.[7,8]

Composite resins are hydrophobic and harden via polymerization reaction. They show successful results in the long term with appropriate color stability as a direct restorative material.[9] However, the color of the composite’s paste may change during the polymerization. Color change of composites studied in vitro before and after light curing ranged from 3 to 12 ΔE units, with values L* a* b*, in general, decreasing (became darker and less chromatic).[10] Composites can undergo color changes in the mouth as a result of several factors, including chemical changes caused by free radical degradation, sorption foods, and retention of plaque caused by surface roughness.[11]

Photometric and colorimetric instruments measure the object’s color and express it in three coordinate values (L*, a*, b*) in CIELAB color space. The L* coordinate denotes the brightness of the object, while the a* value represents the red or green chroma and the b* value represents the yellow or blue chroma. The color difference of two objects can be determined by comparing the differences between the respective coordinate values for each object. The formula used for calculating color differences in this system is as follows:

$$\Delta E = \sqrt{(L_f - L_i)^2 + (a_f - a_i)^2 + (b_f - b_i)^2}$$

where the initial (i) and final (f) are color descriptors and L*, a*, and b* are differences in color parameters for the two specimens measured for comparison. Numeric expression of color allows clear identification of the color difference between objects.[12-14] The ΔE* value refers to relative color changes that an observer can report for material between different times. Thus, ΔE* is clinically more meaningful than the L*, a*, and b* values.

Fibers are used for splinting, bridge support, or strengthening composite resin restoration in anterior areas where esthetics are important.[15] However, there are not enough studies in the literature investigating the effect of fiber addition on the color of the composite restoration. The aim of this study was to determine the effect of fiber reinforcement on the color changes of two different composite resins and to evaluate the color change of composite resins immediately after polymerization, at 1 day, at 7 days, and at 21 days. The null hypothesis of the study is that the addition of fiber does not affect the color of the composite resin depending on time.

### MATERIALS AND METHODS

The chemical composition and manufacturer details of the materials are listed in Table 1. A silorane-based resin composite (Filtek Silorane [FS]; 3M™ ESPE™ Dental Products, St. Paul, MN, USA) and a methacrylate-based resin composite (Valux Plus [VP]; 3M ESPE Dental Products, St. Paul, MN, USA) of A2 shade were used in this study. The specimen size was determined based on the results of Tuncdemir and Güven,[16] aiming to obtain a power of 80%. Twenty-four samples were prepared in three groups of each composite (n = 8). The first group was used as control group with no reinforcements, the second group was reinforced with a polyethylene fiber (Ribbond Inc. Seattle, Washington, USA), and the third group was reinforced with a glass fiber (everStick®; Stick Tech, Turku, Finland) [Figure 1]. Fibers were cut using special scissors to a length of 6 mm and a width of 2 mm, then were placed at the center of the composite disc specimens with sufficient pressure, and light cured for 20 s. Composite resin discs with a diameter of 8 mm and a thickness of 2 mm were prepared and covered with celluloid strips on glass plates. After curing with a light-curing unit (Elipar S10, 3M ESPE, St. Paul, Minn, 1200 mW/cm²) for 40 s each from the bottom and topsides, the strips were removed. The power of the curing light was checked with a radiometer (Kerr Corp, California, USA). The specimens were placed in hermetically sealed plastic bags containing distilled water, and the bags were incubated at 37°C for 24 h at 100% relative humidity. The color change was calculated between baseline and 1 day (ΔE 1), baseline and 7 days (ΔE 2), and baseline and 21 days (ΔE 3). Similar to the methods used in the literature,[17,18] our specimens were kept in distilled water for 21 days and the aging effect was achieved. ΔE = 3.3 was determined as the clinically acceptable color change limit.

The color values of the specimens were measured on white backgrounds with a spectrophotometer (Shadepilot; DeguDent GmbH, Rodenbacher Chaussee 4 MHT, Optic Research AG, 63457 Hanau, Germany) [Figure 1]. The color measurements were recorded under the D 65 machine, which reflects daylight. L, a, and b values of each specimen were recorded. Color stability analyses: a spectrophotometer was used to determine CIE Lab tristimulus parameters (Illuminant D65, specular component included): L* (lightness, from 0 = black to 100 = white), a* (from − a = green to + a = red), and b* (from − b = blue to + b = yellow).

Statistical analysis was conducted with SPSS software 20 (SPSS Inc., Chicago, IL, USA). Means and standard deviations were calculated. Two-way analysis of
Table 1: Materials used in the study

| Materials       | Type/composition                                      | Manufacturer                     | Lot number   |
|-----------------|------------------------------------------------------|----------------------------------|--------------|
| Ribbond THM     | Ultra-high-molecular-weight polyethylene fiber        | Ribbond, Inc. Seattle, Washington, USA | 9649         |
| everStick C and B | Glass fiber                                             | Stick Tech Ltd, Turku, Finland    | 2080407-ES-217 |
| Filtek Silorane | Silorane-based composite                               | 3M ESPE, Seefeld, Germany        | N2799431     |
| Valux Plus      | Dimethacrylate-based composite bisphenol A-glycidyl dimethacrylate, triethylene glycol dimethacrylate, silica (85 wt.%) | 3M, St. Paul, MN, USA            | N 267883     |

Figure 1: The fibers and color-measuring instrument used in this study

variance (ANOVA) analyzed the obtained data and then Duncan test was performed for comparisons among groups at the 0.05 level of significance.

RESULTS

Statistical ANOVA presented statistical significance for composite, fiber, and time for ΔE (P < 0.05). The interaction of composite, fiber, and time was not found statistically significantly important (P > 0.05) [Table 2]. Statistically significant differences were detected between the time-depending color changes of the samples using different composite resins and different fiber systems (P < 0.05). Ribbond reinforced specimens showed the largest total color change (ΔE = 4.13), whereas everStick reinforced specimens (ΔE = 3.69) showed a similar total color change to the control group (ΔE = 3.62) [Table 3]. The mean color change in VP specimens (ΔE = 4.24) was statistically significantly higher than that of Silorane specimens (ΔE = 3.37) (P < 0.05) [Table 4]. It was determined that the time factor had an influence on the color stability of reinforced composites (P < 0.05) [Table 5].

DISCUSSION

Color plays an important role in the success of esthetic restorations. In order to provide esthetic for a long time, the color of the restorative material must be compatible with the tooth color and resist coloring so that the esthetic expectation of the patient can be met for a long time.\textsuperscript{[19]} Discoloration can be assessed using different techniques, such as visual or instrumental techniques. For the color change measurement of composite resins, a digital spectrophotometer can be used. These devices permit good reliability of the result better than visual assessment or other instruments.\textsuperscript{[20]} Due to these advantages, we used spectrophotometer in this study for color measurement.

It has been reported by Seghi et al.\textsuperscript{[21]} that at a ΔE value equal or lower than 1, the color change can be perceived with difficulty, whereas a ΔE value >2 can usually be detected clinically. Um and Ruyter\textsuperscript{[22]} argued that the ΔE = 1 value is visually perceptible in their studies. On the other hand, in the literature, another threshold value was regarding determine the color stability of a material by visual inspection.\textsuperscript{[23]} It is believed that this threshold is at a higher level of ΔE and this value determines the clinical acceptability of the colored materials correctly. Johnston and Kao\textsuperscript{[23]} investigated color differences by visual evaluation and colorimetry and they found that the threshold value at which the color difference can be distinguished in the oral environment is ΔE = 3.3. A clinically acceptable ΔE value was stated to be 3.3 because a lower ΔE value visually is not perceived.\textsuperscript{[23,24]} In our study, mean color change values in the fiber-reinforced composite groups and control group were found above the clinically acceptable limit. According to this result, our hypothesis that fiber addition does not affect the color of the composite resin has been rejected.

Water absorption may lead to color change in restoration.\textsuperscript{[25]} As a result of water absorption, micro fractures or voids in the interface between the filler and the matrix cause stain penetration and color change. For this reason, the chemical properties, filler type, and amount directly affect the color change in resin composites.\textsuperscript{[26]} The new restorative material of the FS composite resin is based on the ring-opening reaction-based silorane chemistry. Siloranes which were used in the past for industrial purposes with their hydrophobic properties have recently begun to be used in dentistry. The silorane monomer consists mainly of siloxanes and oxiranes.\textsuperscript{[27]} Like some other silicone-containing monomers, siloranes can be highly hydrophobic and possibly become inaccessible to attack by water or water-soluble species to the oxirane groups.\textsuperscript{[28]}

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In our study, the mean ΔE value was found statistically significantly lower in FS composite samples (P < 0.05). FS composite content and chemical structure may lead to less color stability than that of conventional methacrylate-based composite used in our study. Similar to our study, Kang et al.[29] kept silorane and methacrylate-base composite specimens in different solutions in their study, and they were observed less color change in silorane composite samples.

In the present study, both composites were found to have a mean ΔE value higher than 3.3 in the control and fiber groups. The mean ΔE value in the glass fiber group was found lower than that of the polyethylene fiber group. These results may be related to the chemical structure of the fibers we use in our study. Glass is an amorphous material consisting of silica tetrahedral combined in a random mesh. This inorganic structure is different from fibers containing organic structures such as polyethylene. Fibers with inorganic content exhibit more hydrophobicity and more resistance to discoloring than organic fibers.[30,31] The differences in chemical structure may be explained that Ribbond (polyethylene)-reinforced composite materials showed more color change than everStick (glass)-reinforced composite materials in the present study. Similar to our results, Tuncdemir and Aykent[32] found that glass fiber-reinforced composite samples exhibited less color change than polyethylene fiber-supported specimens in their studies. In addition to the chemical structure, the color of composite paste may change during the polymerization. The structural differences of the composite resins and their different degree of polymerization may also affect the ΔE values after polymerization.[33] The different light transmission properties of glass fiber and polyethylene fiber can cause the fiber-reinforced composite to have different degrees of polymerization.[34,35] The fact that our composite resin specimens have different degrees of polymerization due to fiber addition and optical properties may also explain the differences in color changes.

When we investigate all the specimens in our study, the color change was observed over time. It has been reported in the literature that discoloration was observed in composite samples in distilled water due to water absorption.[36] The discoloration in the specimens on days 7 and 21 would have caused the increased water absorption in our specimens. In our study, specimens were kept in distilled water in a laboratory environment. Fiber-reinforced composite resin restorations may be exposed to the effect of coloring foods and beverages in the mouth over time. This limitation of our study should be taken into consideration, and our results should be examined with clinical studies.

**CONCLUSION**

Within the limitations of this study, the addition of fiber may lead to color change in composite resins depending on time. The amount of change may differ depending on the structural properties of the composite resin and fiber. Clinicians should take this into consideration when choosing the color of the restoration.

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**Conflicts of interest**

There are no conflicts of interest.

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