Original Article

In Vitro Evaluation of Veneering Composites and Fibers on the Color of Fiber-Reinforced Composite Restorations

Masoomeh Hasani Tabatabaei[1], Zahra Hasani[2], Elham Ahmadi[3]

[1]Associate Professor, Dental Research Center Dentistry Research Institute and Department of Operative Dentistry, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[2]Dentist
[3]Assistant Professor, Department of Operative Dentistry, Shahrekord University of Medical Sciences, Shahrekord, Iran & Dental Research Center Dentistry Research Instituteof Tehran University, Tehran, Iran

Abstract

Objective: Color match between fiber-reinforced composite (FRC) restorations and teeth is an imperative factor in esthetic dentistry. The purpose of this study is to evaluate the influence of veneering composites and fibers on the color change of FRC restorations.

Materials and Methods: Glass and polyethylene fibers were used to reinforce a direct microhybrid composite (Z250, 3M ESPE) and a microfilled composite (Gradia Indirect, GC). There were eight experimental groups (n=5 disks per group). Four groups were used as the controls (non-FRC control) and the others were used as experimental groups. CIELAB parameters (L*, a* and b*) of specimens were evaluated against a white background using a spectrophotometer to assess the color change. The color difference (ΔE*) and color coordinates were (L*, a* and b*) analyzed by two-way ANOVA and Tukey's test.

Results: Both types of composite and fiber influenced the color parameters (ΔL*, Δa*). The incorporation of fibers into the composite in the experimental groups made them darker than the control groups, except in the Gradia Indirect+ glass fibers group. Δb* is affected by types of fibers only in direct fiber reinforced composite. No statistically significant differences were recognized in ΔE* among the groups ($p>0.05$).

Conclusion: The findings of the present study suggest that the tested FRC restorations exhibited no difference in color in comparison with non-FRC restoration. Hence, the types of veneering composites and fibers did not influence the color change (ΔE*) of FRC restorations.

Key Words: Color; Fiber-reinforced Composite Resins; CIELAB

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Corresponding author:
E. Ahmadi, Department of Operative Dentistry, Shahrekord University of Medical Sciences, Shahrekord, Iran & Dental Research Center Dentistry Research Instituteof Tehran University, Tehran, Iran

dr.elham.ahmadi@gmail.com

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INTRODUCTION

Resin-bonded fixed partial dentures (FPDs) are inexpensive and there are more conservative treatment options for replacing missing teeth [1, 2]. Metal resin-bonded FPDs continue to decrease demand because of the existing several disadvantages. While metal substrate is durable and stiff, it has considerable esthetic problems such as discoloration of the gingiva and abutment tooth 'graying'. The other drawbacks may occur with these prostheses; namely, the potential for alloy hypersensitivity, re-

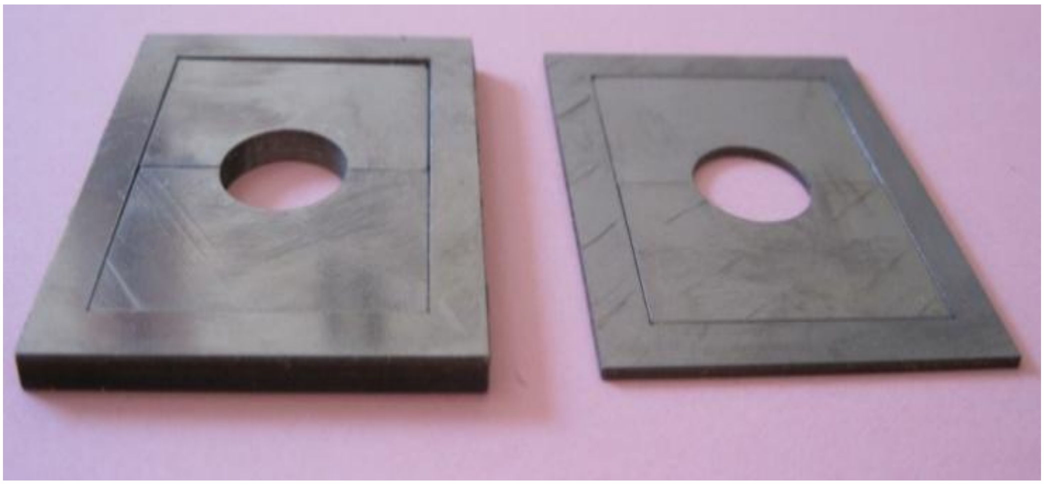

Fig 1. Two stainless steel molds, 13 mm in diameter and 1mm or 3mm height

tainer fracture, and loss of attachment from bridge abutments, corrosion and health risks to laboratory staff [3-5]. Given thes problems, two somewhat alternative treatments have been introduced for a broad range of clinical applications. These are ceramic and composite materials. Nowadays, composite materials have been a subject to attention for metal-free FPDs after the advent of using fibers as frameworks to reinforce them. Fiber-reinforced composite (FRC) FPDs have good rigidity against masticatory forces. In addition, these economically feasible restorations have proper esthetics, low weight and favorable elastic modulus [2, 4, 6]. Conversely, color stability and wear resistance are remarkable potentials of ceramics, but these materials have some liabilities such as brittleness, disability of adhesion to tooth structure and having the potential to damage the unrestored opposing teeth [3, 7]. Based on these backgrounds, currently FRC are not only used for crowns and inlays, but also for a variety of esthetic restorations in clinics, for example the suprastructure of implants and FPDs [8]. Different kinds of fiber materials exist in the market, but at present polyethylene and glass fibers are the most popular [9].

To date, several studies have evaluated the mechanical properties (flexural strength and fracture strength) of FRC [4, 6, 8, 10], but a few studies have been conducted to find out and understand the color properties of FRC [11-14]. Sampath et al. [11] stated significant color change between non-FRC and FRC restorations with a decrease in lightness. Tuncdemir and Aykent [14] measured the effect of fiber reinforcement on the color stability of composite resin. They concluded that an everStick net fiber-reinforced anterior composite combination exhibits trace color change, but the other FRC groups reveal slight color change without accelerated aging. After accelerated aging, they found no significant color difference between FRC and non-FRC restorations. These studies analyze different types of composites with varying types of fibers and the results are different [11-14]. So, this study investigated the influence of glass and polyethylene fibers and veneering composites (direct and indirect) in the FRC system on color differences. The null hypothesis assumed in this study was that the fibers and veneering composites did not influence the color differences of fiber-reinforced composites and non-fiber-reinforced composites.

MATERIALS AND METHODS

Two types of fiber-reinforced system and veneering composite were investigated in the present study (Table 1).

Specimen preparation: Using two stainless steel molds, 13 mm in diameter and 1mm or 3mm height, 40 cylindrical specimens were prepared (fig 1).

Specimen group categorizations are demonstrated in Table 2. Each group contained 5 specimens. The thinner mold was used for veneering composite. Forty cylinders of each composite veneer were prepared. Composite resin veneers were packed into a mold on a glass plate.

After packing, a second glass plate was placed over the mold, followed by compression to run off the excess composite resin into the escape area.

The Z250 cylinders were light-cured using the light curing unit (Bluephase Ivoclar Vivadent, Austria) for 20s with an output of 1,000 mW/cm2 light intensity. The output of the curing light was checked with a radiometer (1,000 mW/cm2). But the initial curing of GRADIA specimens was done according to the recommendations by GC STEPLIGHT SL-I for 10s [15]. After light-curing, the top glass plate was removed and the specimens were then removed from the mold.

Table 1. Brand and Manufacturer of Fibers/Base Composite and Veneering Composites

	Product Name	Manufacturer
Veneering Composite (A2 Shade)	Filtek Z250	3M,St Paul,MN, USA
	GRADIA indirect	GC, Tokyo, Japan
Fibers/Base Composite	Polyethylene fibers/ Nulite F(medium)	BioDental Technologies Pty Ltd
	Fiber glass (FITA/RIBBON-FIBREX-LAB)/ Adhesive C	ANGELUS

Table 2. Groups of Study

	Group
Nulite F/ Polyethylene fibers/ FiltekZ250	G1
Nulite F/FiltekZ250 (Control)	G2
Nulite F/Polyethylene fibers/ GRADIA indirect	G3
Nulite F/GRADIA indirect (Control)	G4
Adhesive C/Fiber glass/ FiltekZ250	G5
Adhesive C/FiltekZ250 (Control)	G6
Adhesive C/Fiber glass/ GRADIA indirect	G7
Adhesive C/GRADIA indirect (Control)	G8

Twenty (1 mm height) cylinders of each base composite were prepared according to the manufacturer`s recommendations (16-18). A 20-second duration cure and handling of glass slab was similar to the veneering composite. These cylinders were entered in the thicker mold.

In the cylinders of Nulite F base composites, polyethylene fibers were cut in 10 mm size, impregnated in resist resin and embedded on thin layers of Nulite F composites and post-cured 20 seconds after, then a small layer of Nulite F composite covered the fiber. Subsequently, the cylinders of each veneering composite material were carried to a thicker mold and pressed with a glass slab to remove the excess composite.

In Z250 veneering composite, the specimens were light cured using the blue phase (Ivoclar Vivadent, Austria) visible-light-curing unit for 20s with 1000mw/cm2 light intensity (G1) and GRADIA Indirect completion of curing was done in GC LABOLIGHT LV-Ш, П cure unit (G3) [15]. In Adhesive C cylinders, the proper pieces (10 mm) of glass fibers were cut, placed on a thin layer of Adhesive C composite and cured for 20 seconds.

Veneering composites in (G5) and (G7) were used in a similar manner as explained above for (G1) and (G3), respectively.

In G2 and G6, Z250 cylinders were placed in thicker molds and the remaining spaces in the molds were packed with Nulite F and Adhesive C, respectively. For G4 and G8, GRADIA Indirect cylinders were placed in thicker molds and the remaining spaces in the molds were packed with Nulite F and Adhesive C, respectively.

The cure approaches performed in these groups were akin to the modes explained before.

Color measurements: The color parameters of the disks were measured over a white background using a reflection spectrophotometer (Color-eye 7000A, GretagMacbeth, New Windsor, NY, USA), according to CIE L* a* b* color system relative to the standard illumination Tungsten D65 lamp. Prior to each of the color measurement series, a calibration was done based on the manufacturer's instruction. Here, a*, b* represented the colors on the green-red and blue-yellow axes, respectively and L* represented lightness scale. The color differences (ΔE) between the groups were calculated by equation: $\Delta E^* = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2]1/2$ [12].

Statistical analysis: The extent of significant color difference was evaluated by two-way analysis of variance (ANOVA) combined with Tukey's HSD at the 0.05 level of significance. SPSS Statistics Windows Version 18.0 (SPSS Inc., Chicago, Illinois, USA) was applied for data collection and analysis.

RESULTS

The values of ΔL*, Δa*, Δb*, and the differences in color (ΔE) are indicated in Table 3. No statistically significant differences were recognized in ΔE* among groups ($p>0.05$). The least value of ΔE* was 1.91. The order of color differences of the experimental groups is shown as G1>G7>G3>G5. Application of two-way ANOVA revealed that ΔL*, Δa* and Δb* were significantly affected by the veneering composites ($p<0.05$), and by the fibers ($p<0.05$).

Table 3. ΔL*, Δa*, Δb* and ΔE* for All Studied Groups

Groups	ΔL*(Mean+ SD)	Δa*(Mean+ SD)	Δb*(Mean+ SD)	ΔE*(Mean+ SD)
G1	$-1.77\pm 0.52^{a,b}$	$0.98\pm0.29^{a,b}$	-0.93 ± 0.61^{d}	2.32±0.46
G3	$-1.20\pm0.37^{a,c}$	$-0.37\pm0.10^{a,c}$	-1.54±0.72	1.98±0.77
G5	-0.21 ± 0.32^{b}	-0.42 ± 0.20^{b}	-1.82 ± 0.45^{d}	1.91±0.43
G7	0.035 ± 1.66^{c}	-0.61 ± 0.32^{c}	-0.77±1.27	2.08±0.54

The similar superscript lower case letter in similar column shows significant difference ($p<0.05$)

The negative sign of ΔL^* shows that incorporation of fibers into composite in experimental groups made them darker than the controls, except in G7. G1 exhibited a red-blue shift ($\Delta a^*= 0.98$, $\Delta b^*= -0.93$ and the other groups (G3: $\Delta b^*= -1.54$, $\Delta a^*= -0.37$, G5: $\Delta b^*= -1.82$, $\Delta a^*= -0.42$, G7: $\Delta b^*= -0.77$, $\Delta a^*= -0.61$) a green-blue shift. Pairwise comparison by Tukey's HSD test confirmed the significant statistical differences in Δa^* and ΔL^* between G1 and G3, between G1 and G5 and between G3 and G7 ($p<0.05$). Furthermore, pairwise comparison by Tukey's HSD test indicated no significant statistical differences in Δb^* between G1 and G3 and between G3 and G7 ($p<0.05$. Tukey's HSD indicated statistical differences in Δb^* between G1 and G5 ($p=0.004$).

DISCUSSION

The null hypothesis was verified because no significant differences between the groups studied in ΔE were observed. ΔE values of all groups vary from 1.91 to 2.32, which were lower than the threshold of clinical acceptable color difference [19]. Clinical color-matching tolerance between the tooth and restorations may be categorized according to ΔE, based on clinical studies below: (ΔE:0=perfect, ΔE:0.5-1=excellent, ΔE:1-2= good, ΔE:2-3.5=clinically acceptable, ΔE :> 3.5=mismatch) [20]. According to these classifications, clinical color match in G3 and G5 was good, while in G1 and G7 it was clinically acceptable.

These results were in disagreement with the findings of a previous study [12], whereby incorporation of fibers in the composite caused color mismatches that were not clinically acceptable ($5.29 < \Delta E < 8.19$). They only investigated the incorporation of glass-fiber in single-layer and double-layer in direct DPI Curex microhybrid composite (shade A1) and the overall thickness of all specimens were 2mm. One possible explanation about the different results is that the greater amount of veneering composite for covering specimens may reduce the effect of fibers. Since the type of fibers and veneering composites were clearly different from the current study, direct comparison was impossible. Tuncdemir and Aykent [14] demonstrated that the types of composite and fiber materials used explained the color difference between FRC and non-FRC restorations without aging. They have reported less color differences ($0.32<\Delta E<1.03$) between groups than those observed ($1.91<\Delta E<2.32$) in the present study. We used base composites that were recommended by manufacturers [16-18]. Differences in the range of ΔE in our study and the previous study [14] may be due to the use of these base composites. Investigation by Nakamura et al. [11] showed that reproduction of the similar color to the veneering composite was possible in all experimental groups (except in the case of FibreKor).

As indicated in earlier studies, the key factors affecting the optical properties (color change) in composites are as follows: (i) size, shape and filler content [21,22], (ii) type of polymerization, (iii) organic matrix [23], and (iv) thickness of composite [24]. Z250 is a microhybrid composite that contains BIS-GMA, UDMA and BISEMA monomers and Zirconium/Silicon fillers (60% volume, 0.01 to 3.5 micrometers) [25]. GRADIA is a micro-filled UDMA-based composite that is mixed with a fine particle glass filler, silica nanofiller and prepolymerized filler (75 wt %) [26]. Although compositions and the method of polymerization of the studied composites varied, these differences had no significant effect on color changes. These results could be linked to the interaction between fibers and composites.

On the other hand, this in vitro finding may be different from the clinical circumstances. Meanwhile, all specimens employed as the model of color assessment in this study were flat and this led to the omission of surface morphology-associated color characteristics.

In this study, color evaluation was performed using a spectrophotometer.

The comparison between the observations of the human eyes or conventional methods showed that spectrophotometer offered a 33% enhancement in precision. In the present study, the visual inspection of skillful people and other viewers did not verify the results of the spectrophotometer. Conversely, one review highlighted that visual and instrumental methods completed each other and could serve as a guide towards predictable cosmetic results [27]. Thus, evaluation of other color coordinates is essential.

With respect to the values of ΔL, the incorporation of fibers caused a decrease of the L* values (samples became darker) for all the experimental groups except in G7. More negative ΔL values between the polyethylene experimental groups and the glass experimental groups possibly originated from the greater thickness of the polyethylene fibers, and also from the difference in the nature of fibers between these two types of fibers, which could result in a slighter amount of beam reflected back; back-scattered out of the specimen or absorbed [12]. In the present state of our knowledge, we did not find any justification for the result in G7.

There is a color shift of experimental groups towards the shorter wavelength regions, which is in the direction of green and blue, except in G1. These findings are inconsistent with the previous study because they saw a shift toward the longer wavelength (red-yellow) [12]. Perhaps the interactions between fibers and veneering composite in all experimental groups (except in G1) were followed by shifts toward the lower wavelength area. On the basis of the limited information on the interaction modality of the optical properties of the fiber and the veneering composite in literature, we did not suggest any explanation responsible for the shift to the red axis in G1.

It should be kept in mind that the result of the present article is based on an in vitro condition. Meanwhile, this study only investigated the combination application of the two types of fibers and veneering composites. Therefore, it is intricate to generalize the outcome of this study to all FRC systems and clinical conditions. The clinical conditions may worsen the status of the continuing test and may affect the results. Several variations exist between clinic and test conditions that may influence the color change of FRCs including: (i) the investigated specimens had flat surfaces; whereas, in clinical status the anatomical surfaces were reproduced on prosthesis, (ii) the preparation of the abutment teeth, (iii) oral conditions (loading, temperature changes, saliva, diet and oral hygiene). Consequently, a more complete strategy should be developed to assess the oral environment effects on color changes of FRCs.

CONCLUSION

With the limitations of the current study, veneering composites and the fibers showed no statistical effect on the color change (ΔE) of FRCs. All experimental groups were darker compared with the control groups except for the glass fibers-Gradia Indirect group.

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