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In Vitro Efficacy of Listerine Whitening Mouthwash for Color Recovery of Two Discolored Composite Resins

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ABSTRACT

Objectives: Color stability of composite resins has a significant role in their durability and clinical service. Considering the increasing use of composite resins and their gradual discoloration, this study aimed to assess the efficacy of Listerine whitening mouthwash for color recovery of two discolored composite resins.

Materials and Methods: This in-vitro experimental study was performed on 20 samples fabricated of Filtek Z350XT (3M ESPE, St. Paul, MN, USA) and IPS Empress Direct (Ivoclar Vivadent, Schaan, Liechtenstein) composite resins. Primary colorimetry was performed using a spectrophotometer. The samples were immersed in a coffee drink for 7 days. They were then immersed in Listerine mouthwash for 4 minutes daily for 56 days. After this period, the color change of composite resins was reevaluated. Data were analyzed using repeated-measures analysis of variance (ANOVA) and t-test.

Results: The primary color change of Z350XT after immersion in coffee was 1.6 times greater than that of IPS composite ($P<0.0001$). The color recovery of IPS and Z350XT after immersion in the mouthwash was 1.06±0.58 ($P<0.01$) and 2.58±1.65 ($P<0.001$) units, respectively. The color change of Z350XT after exposure to the mouthwash was 25% (1.4 times) greater than that of IPS ($P<0.01$).

Conclusion: Both composite resins experienced a clinically unacceptable discoloration after exposure to coffee ($\Delta E>3.3$). Filtek Z350XT showed greater color change than IPS. Use of Listerine whitening mouthwash caused significant color recovery in both composite resins.

Keywords: Listerine; Mouthwashes; Colorimetry; Tooth Discoloration; Composite Resins; Coffee; Spectrophotometry

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INTRODUCTION

Because of the increasing demand for having whiter teeth, researchers and manufacturers have aimed to produce novel whitening agents with improved efficacy and with a higher level of safety [1]. The public knowledge about dental aesthetics has greatly enhanced during recent years, and as a result, the demand for durable and aesthetic tooth-colored restorations has increased [2].

Composite resins are commonly used as tooth-colored restorative materials due to advantages such as ideal aesthetics and their ability to bond to enamel and dentin. Aesthetic dental materials must be able to simulate the natural appearance of teeth and match the color of the remaining tooth structure [3]. Composite resins have an appropriate appearance at first; however, their color stability in the oral environment is suboptimal as they undergo color change over time in the oral environment. Discoloration of composite restorations results in color mismatch and compromises aesthetics; this often necessitates periodic polishing and may lead to the replacement of restorations, which is time-consuming and costly [3].

Discoloration of composite resins may occur due to extrinsic and intrinsic factors. Plaque accumulation, superficial stains that penetrate into the superficial layers of composite resins, colored foods and drinks, smoking, and poor oral hygiene are among the extrinsic factors that cause discoloration of composite restorations [4,5]. Intrinsic factors include resin matrix, size of filler particles, and the photoinitiator of composite resins. Incomplete polymerization of resin matrix negatively affects the color stability of composites. Also, the filler particle size affects the smoothness of the surface and its stainability [6].

Coffee has yellow stains with low polarity and delayed release that can penetrate into the organic phase of composite resins and cause discoloration. This is particularly due to the compatibility of polymers with yellow coffee stains [4,7].

Several processes are employed to whiten the color of discolored teeth and tooth-colored restorations, including the use of whitening toothpastes, professional stain removers, polishing techniques, porcelain veneer restorations, crowns, and composite resins [4,8]. Mouthwashes are among the most popular oral hygiene and tooth whitening measures due to their easy use, low cost, and availability [3,8]. At present, several whitening mouthwashes are available in the market, and the manufacturers claim that they all whiten the tooth shade within a short period of time [1].

Listerine Healthy White Vibrant contains 0.02% sodium fluoride (NaF), which effectively prevents caries. Aroma, alcohol, disodium sulfate, hydrogen peroxide (H_2O_2), menthol, phosphoric acid, poloxamer 407, sodium saccharine, sucralose, and water are among its other constituents. These agents work either by bleaching or by removal and controlling of stains. H_2O_2, as a strong oxidizing agent, breaks long-chain organic pigment molecules into short-chain compounds. However, the application of peroxide in mouthwashes is challenging because of shortened exposure times and safety restrictions [1].

Despite the increasing use of whitening mouthwashes, information about their actual efficacy is limited [1,8]. Considering the gap of information in this respect and the limited number of studies on the efficacy of Listerine whitening mouthwash for color recovery of discolored composites, this study aimed to assess the efficacy of Listerine whitening mouthwash for color recovery of two discolored composite resins.

MATERIALS AND METHODS

This in-vitro experimental study was conducted on 20 composite disk-shaped samples fabricated of Z350XT (3M ESPE, St. Paul, MN, USA) and IPS Empress Direct (Ivoclar Vivadent, Schaan, Liechtenstein) composite resins in plastic molds measuring 8 mm in diameter and 2 mm in thickness. Table 1 shows the characteristics of the composite resins used in this study. An adequate amount of composite was placed in the molds. Using glass slabs with 1-mm thickness, the composite was compressed in the mold to prevent voids or any irregularity on the surface. Each sample was then light-cured with an overlapping technique using a quartz-tungsten-halogen light-curing unit (Coltolux 50; Coltene/Whaledent GmbH, Langenau, Germany) with a light intensity of 500 mW/cm^2 for 40 seconds. The curing light intensity was assessed by a radiometer

Table 1: Characteristics of the materials used in this study

Material	Shade	Manufacturer	Monomer composition	Fillers	Photoinitiator	Batch No
IPS Empress Direct	Shade B1 enamel	Ivoclar, Vivadent, Schaan, Liechtenstein	Dimethacrylat es20-21.5 wt%	Ytterbium tri-fluoride, barium-aluminum-fluorosilicate glass, mixed oxide, silicon dioxide, and prepolymer with a particle size of 0.4-100 nm.	Lucirin TPO	N798000
Filtek Z350XT	Universal B1 enamel	3 M ESPE, St. Paul, MN, USA	Bis-GMA, UDMA, Bis-EMA, TEGDMA, PEGDMA	Non-aggregated 20-nm silica filler, non-aggregated 4-11-nm zirconia filler Aggregated zirconia/silica cluster filler comprised of 20-nm silica and 4-11-nm zirconia particles	Camphorquinone/ amine	V06633

bis-GMA: bisphenol A-glycidyl methacrylate, UDMA: urethane dimethacrylate, TEGDMA: triethylene glycol dimethacrylate, bis-EMA: bisphenol A ethoxylated dimethacrylate, PEGDMA: polyethylene glycol dimethacrylate

(Dentamerica, San Jose, CA, USA) before each use. Ten samples were fabricated of each composite resin. The samples were then immersed in distilled water at 37°C for 24 hours to allow completion of polymerization. The samples were then polished using medium and soft Sof-Lex discs (3M ESPE, St. Paul, MN, USA). Primary colorimetry was performed using a spectrophotometer (CS-2000; Konica Minolta, Japan) against a standard white background. Next, a coffee drink was prepared by adding 2 g of coffee (Nestle Gold Blend, Switzerland) to 236.6 ml of boiling water, and after 10 minutes of mixing, the samples were immersed in coffee for 7 days because the mean time of drinking of a cup of coffee is 15 minutes, and the mean consumption rate of coffee is 2 to 3 cups per day. Thus, the 7-day immersion period in our study corresponded to 5.6 months of coffee consumption and its effect on composite restorations in the clinical setting [4].

The samples were immersed in the coffee drink in screw-top containers to prevent evaporation of the solution at room temper-ature. The coffee solution was refreshed daily. After 7 days, the samples were removed from the solution [4], were rinsed under running water for one minute, and were again subjected to colorimetry. The a, b, and L parameters were measured, and Δa, Δb, and ΔL were calculated by subtracting the secondary values from the baseline values. Color change (ΔE) was calculated using the formula below [4]:

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

Colored samples were then immersed in Listerine (Johnson & Johnson Consumer Inc., Skillman, NJ, USA) for 4 minutes daily for a total of 56 days at room temperature [3]. The samples were stored in distilled water at 37°C in a dark environment for the rest of the day. An experienced technician evaluated the color recovery of the samples after 56 days by spectrophotometry.

Repeated-measures analysis of variance (ANOVA) was used to analyze the color change of composite samples after immersion in coffee and their color recovery after immersion in Listerine. T-test was used for the comparison of the groups. Data were analyzed using SPSS 20 (SPSS Inc., Chicago, IL, USA). The level of significance was set at 0.05.

RESUTS

Table 2 shows the color change of the composite resins after immersion in coffee

Table 2: Color change of composite resins after immersion in coffee and after exposure to Listerine mouthwash (n=10)

Color change / Composite resin	After immersion in coffee	After exposure to Listerine mouthwash	Color recovery
IPS Empress Direct	9.32±1.59	10.05±2.15	1.06±0.85
Filtek Z350XT	15.5±2.04	12.56±1.44	2.58±1.65
P-value	P<0.0001	P=0.01	P=0.02

and after exposure to the mouthwash. The primary color change after immersion in the coffee drink was 9.32±1.59 for IPS and 15.5±2.04 for Z350XT; this difference between the two composite resins was statistically significant (P<0.0001). Color change after immersion in the mouthwash was 10.05±2.15 for IPS and 12.56±1.44 for Z350XT; this difference between the two composite resins was statistically significant (P<0.01). The color recovery was 1.06±0.85 for IPS and 2.58±1.65 for Z350XT. The two groups were significantly different in this regard, and color recovery was significantly greater in Z350XT (P<0.02). The color recovery was also statistically significant in each group (P<0.01 for IPS and P<0.001 for Z350XT).

DISCUSSION

This study aimed to assess the efficacy of Listerine whitening mouthwash for color recovery of discolored IPS Empress Direct and Filtek Z350XT composite resins. The results showed a clinically unacceptable color change of both composite resins following immersion in the coffee solution (Δ>3.3). The initial color change was greater in the Z350XT group by 1.6 times, and this difference was statistically significant (P<0.0001). Color change for Z350XT after immersion in the mouthwash was 25% higher than that of IPS, and this difference was statistically significant (P<0.01). The color recovery in Z350XT was 1.52 units or 2.4 times greater than that of IPS (P<0.02). The color recovery in both groups was statistically significant (P<0.01 for IPS and P<0.001 for Z350XT).

Color stability of dental restorations is an important factor determining their clinical endurance [2]. Color change of composite resins depends on their surface topography, size and amount of filler particles, water sorption, and hydrophilic nature of their resin matrix. A scanning electron microscopic (SEM) analysis showed that coffee and tea can degrade the organic phase of the matrix and remove filler particles from the surface of composite restorations [4,7]. IPS Empress Direct and Filtek Z350XT composite resins evaluated in this study are both methacrylate-based composites; however, they are different in chemical formulation, properties, and degree of cross-linking [6].

IPS Empress Direct is a nanohybrid composite that includes dimethyl methacrylate monomer. Inorganic fillers comprise 75 to 79 wt% or 52-59 v% of its composition. The size of the inorganic fillers ranges from 40 to 3000 nm (mainly 550 nm) [6].

Filtek Z350XT includes bis-GMA (bisphenol A-glycidyl methacrylate), UDMA (urethane dimethacrylate), TEGDMA (triethylene glycol dimethacrylate), and bis-EMA (bisphenol A-ethoxylated dimethacrylate). It contains nano-fillers, including non-aggregated 20-nm silica fillers, non-aggregated 4-11-nm zirconia fillers, and zirconia/silica aggregated cluster fillers (20-nm silica and 4-11-nm zirconia fillers). Translucent shades have medium-size clusters (0.6 to 20 μm). Inorganic fillers have 72.5 wt% and 55.6 v% of translucent shades and 78.5 wt% and 63.3 v% of other shades [6]. Our results showed that both primary color change and color recovery after immersion in the mouthwash were greater in Filtek Z350XT. Higher stainability of Z350XT can be due to its matrix composition, the orientation of filler particles, and porosity of glass fillers [9-12].

Some studies have reported that composite resins with less inorganic fillers experience greater color change because a higher volume of resin matrix results in greater water sorption [3,7,13]. On the other hand, TEGDMA contained in Z350XT results in the release of high amounts of monomer and greater color change in the composite [12]. The presence of BisGMA, UDMA, PEGDMA (polyethylene glycol dimethacrylate), and TEGDMA in Z350XT creates a more compact and denser polymer network. Several studies have shown that denser networks have a more heterogeneous structure, which makes them susceptible to water sorption in-between polymer clusters [6]. New photoinitiators, such as Lucirin TPO in IPS, absorb the light energy in lower ranges of the visible light spectrum [6]. Z350XT has camphorquinone photoinitiator, which is a visible light-sensitive di-ketone initiator responsible for the initiation of polymerization of free radicals. Comphorquinons are yellow in color, and in case of inadequate irradiation activation, some of the camphorquinones remain inactive. As a result, some yellow color remains in the final color of the composite, conferring a darker shade [6]. In our study, immersion in the mouthwash caused significant color recovery in both composite resins. The H_2O_2 present in the composition of mouthwashes breaks down into water and oxygen and creates free radicals, which are highly reactive and cause bleaching [4].

Mouthwashes are now highly popular due to their low cost and availability. Thus, it is imperative to assess their effects on dental composite restorations [3]. Mouthwashes contain bleaching agents such as peroxides, pyrophosphates, sodium hexametaphosphate, sodium citrate, and enzymes. These agents act as a bleaching agent and eliminate the stains. Peroxide is a commonly used dental bleaching agent that whitens teeth and composite resins via an oxidation reaction during which a long chain of organic pigmented molecules breaks into short chains [1]. Listerine mouthwash used in our study also contains H_2O_2. Villalta et al [5] showed that color change of composite resins after using whitening agents is due to extrinsic cleansing of samples instead of an internal color change. Color recovery of composite samples by Listerine in our study can also be due to extrinsic cleansing; further studies are required in this respect.

Karadas et al [3] evaluated the effect of mouthwashes containing H_2O_2 on discolored direct composite resins. Color recovery of samples was significant after immersion in mouthwash. The group subjected to Listerine showed color recovery similar to that caused by Opalescence whitening gel [3]. ElEmbaby [2] evaluated the effect of mouthwashes on color stability of resin-based restorative materials and concluded that the composition and formulation of composites, their filler size, and type of photoinitiator directly affect their color change. This finding was in agreement with our result. They also mentioned that, depending on the chemical formulation, mouthwashes can also cause significant color change [2]. Kazemi and Johar [9] reported that H_2O_2 and carbamide peroxide, present in the composition of whitening agents, effectively bleached the discolored composites in their study.

Celik et al [6] showed that although the color change was not clinically perceivable, all resin restorations experienced a color change after immersion in mouthwashes, which was different from our findings

Color perception is a complex concept affected by several factors including translucency, opacity, vision, and type and direction of the light. To decrease subjective errors in color assessment, a spectrophotometer was used in this study, which is currently the most reliable tool for colorimetry [1]. In this study, the baseline color of each sample served as a control, and there was no need for a separate control group [1]. Also, all the samples were light-cured for 40 seconds with an overlapping technique using a quartz-tungsten-halogen light-curing unit with a light intensity of 500 mW/cm^2. The light intensity was checked by a radiometer before each curing as inadequate curing results in a yellowish color change of composites as a result of the

presence of unpolymerized camphorquinone.
A coffee drink was used as the coloring agent in this study because of its increasing use by the Iranian population. The samples were immersed in coffee for 7 days because the mean time of drinking of a cup of coffee is 15 minutes, and the mean consumption rate of coffee is 2 to 3 cups per day. Thus, the 7-day immersion period in our study corresponded to 5.6 months of coffee consumption and its effect on composite restorations in the clinical setting [4]. Also, the surface of all the samples was polished with medium and soft Sof-Lex discs since a resin-rich unpolished surface is more susceptible to discoloration.
Further research is required to assess the efficacy of Listerine mouthwash and other mouthwashes for color recovery of composite resins discolored due to exposure to other coloring agents. Also, oral clinical conditions with regard to the presence of saliva and thermal alterations should be better simulated in future studies. Also, the effect of tooth-brushing must be taken into account in future studies.

CONCLUSION

Both IPS Empress Direct and Filtek Z350XT showed a clinically unacceptable discoloration following exposure to the coffee solution. Immersion in Listerine caused significant color recovery in both composite resins. Filtek Z350XT experienced significantly greater color change and color recovery compared to IPS.

CONFLICT OF INTEREST STATEMENT

None declared.

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