Original Research

Effects of 0.2% Chlorhexidine and Re-polishing on the Color Stability of Nanofilled Composite Resins

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Abstract

Introduction: The growing demand for esthetic dental procedures has resulted in the increased development of new restorative composite resins. The success of composite resin restorations depends on their color stability over time. The present study aimed to evaluate the effects of 0.2% chlorhexidine (CHX) and re-polishing on the color stability of nanofilled composite resins. **Methods:** This interventional, *in-vitro* study was conducted on 48 disk-shaped samples (diameters: 8×2 mm), which were prepared using Z350 (3M ESPE, USA) and Grandio (VOCO, Germany) A_2 shade composite resins. The samples were divided into four groups of 12 and immersed in CHX and distilled water for 14 days. Colorimetry of the samples was performed before and after immersion in the solutions and after re-polishing using a spectrophotometer. Data analysis was performed using the analysis of variance (ANOVA) and Tukey's test at the significance level of $\alpha=0.05$. **Results:** All the composite resin samples exhibited discoloration ($\Delta E_1<3.3$), and a significant difference was observed in discoloration with CHX between the two composite resins ($P<0.05$), with greater discoloration in the Grandio composite resin ($\Delta E_1=2.041$). In addition, the color changes of the samples were considered significant between water and CHX ($P<0.05$), and a distinct color change was denoted in the samples after re-polishing. **Conclusion:** According to the results, the color changes in the composite resins were a function of the type of the composite resin and solution used for immersion.

Keywords: Chlorhexidine, Dental Polishing, Composite Resin, Spectrophotometry.

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Introduction

The growing demand for esthetic dental procedures has resulted in the increased development of new restorative composite resins (1). The success of composite resin restorative materials largely depends on their color stability over time (2). Currently, despite the advancement in dental composite resin technology, the long-term color stability of these materials in the oral cavity is considered to be a major issue (3).

Discoloration of composite resin restorations in the long run leads to patient dissatisfaction and is one of the reasons for the replacement or repair of these restorations. Such procedures waste the time of the patients and impose excess costs (4). In general, the main influential factors in the discoloration of composite resins are divided into intrinsic and extrinsic factors. The intrinsic factors involve changes in the resin material, which depend on parameters such as the type of the composite resin (filler content and filler size). The extrinsic factors are staining through the superficial or deep absorption of dyes due to contamination with the external sources used by the individuals, such as medications and foodstuff (e.g., tea, nicotine, and chlorhexidine mouthwash).

Chlorhexidine (CHX) is an antiseptic mouthwash, which prevents plaque formation, gingival inflammation, and dental caries, and is often administered for a minimum of two weeks (5). On the other hand, the most significant side-effect of CHX is the discoloration of teeth and restorative materials. Among the other disadvantages of CHX are changes in taste, sensitivity of the oral mucosa, and taste of the material (5). In order to avoid extrinsic staining, it is essential to decrease the surface roughness of the restoration since the structure of composite resin and features of its particles directly affect the surface smoothness of composite resin resonations. The main techniques used for the polishing of the material also affect its surface quality and staining (6, 7).

Currently, use of nanofilled composite resins has been on the rise owing to their advantages and advancement in this technology (8). The developments in filler technology have resulted in the significant improvement of filler size, low wear, and high resistance against the degradation of resin materials. Moreover, smaller filler size might contribute to the reduction of staining and enhancing of the esthetic appearance (8, 9).

Some of the tools used to determine color include calorimeters, spectrophotometers, spectroradiometers, and digital cameras. Spectrophotometry is an optimal, accurate technique for qualitative color analysis (10).

Since limited studies have been focused on the discoloration of nanofilled composite resins due to CHX, the present study aimed to evaluate the effects of CHX mouthwash and re-polishing on the color stability of two types of composite resins (Z350 and Grandio), which are commonly used in the anterior regions of the oral cavity, using a spectrophotometer.

Materials and Methods

This interventional, *in-vitro* study was conducted on two types of nanofilled composite resins, the features of which are presented in Table I. The A_2 shade was selected since it is most commonly used in esthetic restorative procedures. In addition, a plastic washer was employed to prepare 24 samples from each material (diameter: 8 mm, thickness: 2 mm). Samples with voids or thickness of more or less than two millimeters were excluded from further assessment.

The mold containing the composite resins was placed on a glass slab. Afterwards, a celluloid tape strip was placed on the upper surface of each sample, and another glass slab was placed on each sample. Following that, a five-kilogram weight was placed on the samples in order to exert pressure, so that the samples would have a uniform thickness, as well as to eliminate air bubbles. The samples were light-cured from the upper surface using a light-curing unit (Woodpecker, China) for 40 seconds at the light intensity of 850-l000 W/cm^2. At the next stage, the samples were immersed in distilled water for 24 hours to ensure the completion of the polymerization process. The upper and lateral surfaces of the samples were polished with Sof-Lex disks within the range of course, medium, fine, and superfine. In each polishing step, the samples were polished with each disk for 30 seconds under dry conditions.

After each polishing process, the samples were rinsed with water and dried with a piece of dry cloth to be prepared for the next stage of polishing. The initial polishing of the samples was carried out in the oxygen-inhibited layer in order to achieve a homogenous surface and eliminate possible contaminations. Furthermore, this technique was employed to minimize discoloration due to the surface roughness of the samples, so that the color changes calculated at the end of the study could be attributed to the inherent features of the composite resins. To ensure uniform, smooth surfaces, all the procedures were performed by one operator, and the samples were evaluated using a spectrophotometer.

In total, 24 samples were randomly divided into two groups of 12 based on the used solution. Each sample was completely immersed in the relevant solution in a vertical position using a piece of thread. The vertical position minimized the deposition of staining agents on the surface of the samples. The samples were immersed in the solutions, so that they would have no contact with each other or with the container walls. Therefore, the specimens only had contact with the solutions. CHX mouthwash (Behsa, Iran) and distilled water were selected as the required solutions.

The samples were immersed in the selected solutions twice daily for one minute for 14 days and incubated in artificial saliva at the temperature of 37°C. It is notable that the solutions were refreshed every day. After 14 days, the samples were evaluated using a spectrophotometer. Afterwards, all the samples were re-polished using polishing disks (coarse, medium, fine, and superfine; Sof-Lex) in a low-speed hand piece with moderate pressure using the initial technique. At the next stage, the samples were evaluated using a spectrophotometer for the third time.

A SP64 portable spectrophotometer (Xrite Co.) was used to determine color changes at the wavelength of 400-700 nanometers at the angle of 10°, and the measurements were performed using the Color iControl software (standard version). Three color parameters were determined at baseline, after immersion in the solutions, and after re-polishing and reported in the CIEL*a*b*color coordinate system. The color difference (ΔE) between the color coordinates was also verified using the following equation:

$$\Delta E^* = ([L1^* - L0^*]^2 + [a1^* - a0^*]^2 + [b1^* - b0^*]^2)^{1/2}$$

Where *L* represents the degree of gray corresponding to a lightness, *a* is the red (+a value)-green (-a value) axis, and *b* shows the blue (-b value)-yellow (+b value).

In the present study, ΔE was calculated twice; at the first stage, ΔE_1 was calculated in order to determine the color values before and after immersion in the solutions. At the second stage, ΔE_2 was calculated in order to determine the color values after re- polishing and at baseline.

Data analysis was performed in SPSS version 20 using descriptive statistics for quantitative variables, which were expressed as mean and standard deviation.

In addition, Shapiro-Wilk test was used to evaluate the normal distribution of the data. Since the data were distributed normally, the analysis of variance (ANOVA) was applied for the analysis of the four sample groups, and Tukey's test was used for the paired comparison of the groups. In all the statistical analyses, the significance level was considered at $\alpha=0.05$.

Table I. Detailed Features of Evaluated Composite Resins and Polishing Disks

Brand Name	Composition	Shade	Batch	Manufacturer
Z350	BisGMA, UDMA, TEGDMA, and BisEMA	A_2	5929260	3M ESPE, USA
Grandio	BisGMA and TEGDMA	A_2	1529375	VOCO, Germany
Sof-Lex	Aluminum Oxide, Grit (coarse, medium, fine, and superfine)	——	49580	3M ESPE, Brazil Ltd

Results

According to the results of two-way ANOVA, type of the composites (P=0.002), type of the solutions (P<0.001), and their interactions had significant effects on the color changes in resin composites (P=0.006).

Table II shows the mean ΔE_1 and Δl_1 values in the four sample groups (Fig. 1). Accordingly, a significant difference was observed between the groups in this regard (P<0.001). The highest ΔE_1 was observed in the Grandio composite resin in CHX (2.041), while the lowest ΔE_1 belonged to the Z350 composite resin in distilled water (0.592). Moreover, the results of Tukey's test revealed a significant difference in terms of ΔE_1 between groups one and two (P<0.001), groups one and four (P<0.001), groups four and two (P<0.001), groups three, two, and four (P<0.001), and groups three and four (P<0.001). However, the difference between groups one and three was not considered significant in this regard (P=0.999) (Table II).

Table II shows the mean ΔE_2 values in group two (Z350 immersed in CHX) and group four (Grandio immersed in CHX) after re-polishing (Fig. 2). Accordingly, significant color changes were observed after re-polishing, and there was a significant difference between the mentioned groups in this regard (P=0.049).

Table II. Significant Differences between Sample Groups in Terms of ΔE1 (small letters) and ΔE2 (capital letters)

Variable Groups	ΔE1		ΔE2	
	Mean	**SD**	**Mean**	**SD**
Group 1	0.592^{a}	0.192	-	-
Group 2	1.292^{b}	0.269	1.11^{A}	0.544
Group 3	0.595^{a}	0.081	-	-
Group 4	2.041^{c}	0.478	1.71^{B}	0.662

Figure 1. A: Z350, B: Grandio (after immersion in distilled water) C: Z350, D: Grandio (after immersion in hlorhexidin)

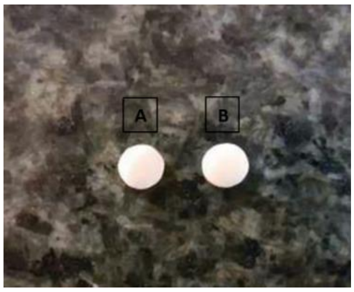

Figure 2. A: Z350, B: Grandio (after re-polishing)

Discussion

The success of composite resin restorative materials largely depends on their color stability and absence of color changes over time (2). Color changes in composite resin restorations in the long run are one of the main reasons for their replacement (4). The present study aimed to determine the effects of 0.2% CHX and re-polishing on the color stability of Z350 and Grandio composite resins.

According to the obtained results, CHX caused color changes in the nanofilled Z350 and Grandio composite resins ($\Delta E_1<3.3$), while these changes were considered clinically acceptable. In addition, the results of re-polishing were indicative of the improved color changes in the composite resin samples, while the improvement did not reach the baseline status.

Colorimetry is a process affected by several factors. In the present study, a spectrophotometer was used for the evaluation of color changes in order to avoid subjective errors. Furthermore, we applied the CIELAB color system, which is currently considered to be the most accurate tool for the evaluation of color changes (2, 11). The CIELAB color system chiefly relies on human perception for color measurement and is widely used presently (2, 12). In this system, colors are introduced based on three parameters, including $\Delta E<1$, which is not perceived by humans, ΔE of 1-3.3, which is perceptible by experts, and $\Delta E>3.3$, which could be detected by laypersons (13, 14).

Based on the findings of the current research, it could be concluded that distilled water caused minor color changes in the composite resin samples (ΔE_1=0.592-0.595). However, the samples that were immersed in CHX exhibited more significant color changes compared to those immersed in distilled water (ΔE_1=1.292-2.041). This is consistent with the results obtained.Baig et al (15), Click et al (16), and Khaledi et al (17). However, in the present study, CHX resulted in the ΔE range of 1-3.3, which might lead to the conclusion that $\Delta E<3.3$ is not significant in this system and could be considered acceptable.

Color changes in teeth, especially those resulting from mouthwashes, are distressing to patients. In this regard, Eriksen et al (18). suggested that a minimum of three mechanisms are responsible for the formation of external pigments, including the production of coloring agents in the plaque by chromogenic bacteria, residual staining ingredients in the diet, and formation of coloring products due to the changes in the pellicle components. Due to limitations of mechanical control of dental plaques, researchers have currently been focused on chemical mouth rinses and evaluation of their effects (18).

CHX is one of the most commonly used mouth rinses in dentistry, which causes brown stains on teeth and tooth-colored restorations, mucosa, and the tongue. The external factors that are responsible for discoloration are the absorption and adsorption of coloring agents due to contamination with external sources. This could be attributed to the binding of CHX cationic groups to dietary factors (e.g., garlic acid and tanis) and deposition of these coloring agents on teeth and mucosa, with predominantly external staining (12).

In contrast with the results of the present study, Turgut et al. (19) reported that 0.12% CHX (Klorhex) led to the discoloration of composite resin, which was not acceptable clinically ($\Delta E>3.3$). On the same note, Rashid Baig et al (20). evaluated Tetric N-ceram, Ivoclar Vivadent AG, and FL-9494 Schaan nanofilled composite reins. In the mentioned research, the samples were immersed in various solutions, such as Rexidin, for 24 minutes. According to the findings, Rexidine caused maximum discoloration compared to other mouthwashes (ΔE=3.22), which was close to the clinical standard. In another study, Ahrary et al (21). stated that all the examined mouth rinses, including CHX, resulted in the perceptible discoloration of composite resins ($\Delta E>3.3$). The more significant staining of the samples reported in the mentioned study compared to the current research might be attributed to the duration of immersion in CHX, CHX concentration, and differences in the restorative materials.

Some of the inherent factors of composite resins that are involved in their color stability are the structure, matrix composition, filler size and its distribution, and filler-matrix interface (2, 15). Grandio has a filler content of 71.4% and is a light-cured composite resin with the resin matrix of BisGMA, BisEMA, and TEGDMA. The mean filler size of Grandio is 20-60 nanometers. Similarly, Z350 resin composite has a filler content of 78.5% and is a nanofilled composite resin with the resin matrix containing BisGMA, UDMA, TEGDMA, BisEMA, and PEGDMA and mean filler size of 2-20 nanometers (15, 22). Several studies have indicated that the UDMA in Z350 composite resin is more resistant to staining compared to the BisGMA in Grandio composite resin (23). In addition, it has been reported that under similar circumstances, Z350 absorbs less water (24). Furthermore, the presence of hydrophilic and hydrophobic monomers in its structure and its matrix composition affect its color stability (2, 15). UDMA-based monomers exhibit less propensity for color changes due to their lower viscosity, low water sorption, and better polymerization compared to other methacrylate-based monomers (11, 25).

Size and distribution of fillers have been reported to be correlated with color changes. The composite resins with large filler particles are more susceptible to color changes due to water aging compared to the composite resins with smaller filler particles, which is associated with the filler-matrix interface (26), and might be another possible cause of the poor color stability of Grandio composite resin compared to Z350 composite resin as it has larger filler sizes. In this regard, Jeong-Kil Park et al (27). Claimed that Z350 composite resin exhibited less color changes compared to Grandio composite resin, which is in congruence with the results of the present study. It is notable that in the mentioned study, coffee, green tea, and ethanol were used instead of CHX.

Mehdiseyar et al (25). conducted a research aiming to evaluate the effect of coffee on the color changes in Z350, Grandio, and Herculite HRV nanofilled composite resins, in which the samples were immersed in coffee for 72 hours. According to the findings, the three composite resins underwent color changes, which were not considered clinically acceptable ($\Delta E>3.3$). Contrary to the expectations, the researchers observed that Grandio exhibited less color changes compared to Z350, which was attributed to the cluster structure of the fillers and porosities in Z350, leading to the higher susceptibility of this composite resin to color changes (25). The discrepancy between the results of the mentioned study and our findings could be attributed to the longer duration of sample immersion, as well as the differences in the applied solutions, since the previous studies in this regard have denoted that the bulk of the discoloration caused by coffee is intrinsic, and CHX predominantly causes extrinsic staining.

In the present study, color improvement was observed after re-polishing in both composite resins; however, the color differed from the baseline. Selection of an effective technique for the removal of stains *in-vivo* depends on whether staining is extrinsic or intrinsic. In surface staining, re-polishing is suggested as a simple, practical technique (28). Since the ethanol found in the chemical composition of CHX may compromise the bond between the resin matrix and inorganic fillers, it could cause the discoloration of the resin matrix (29). The stains caused by CHX are intrinsic and extrinsic at the same time. It is notable that the surface staining occurring due to the penetration of staining agents into the organic phase cannot be restored to the baseline color of the composite resin by re-polishing (28).

In another study in this regard, Zajkani et al. (30). reported that despite a noticeable color change in the samples after re-polishing, the color change did not reach the baseline level, which is in line with the results of the present study. On the other hand, Ahrari et al. (21) used a powered toothbrush to remove the stains caused by CHX in composite resin restorations, which had a minor effect on the removal of the stains from the samples, and the bulk of the stains caused by mouth rinses could not be removed by a toothbrush.

Considering the limitations of this experimental research and the parameters used in this study (i.e., resin composite and solution), it is recommended that further investigation be conducted in order to evaluate the color changes in the other types of resin composites (e.g., micro-hybrid) in various conditions, such as different polishing methods, staining solutions, and immersion times.

Conclusion

According to the results, the color changes in nanocomposite resins are influenced by the type of the composite and staining agents. CHX mouth rinse was observed to causes color changes in the nanofilled composite resins, while the changes were considered clinically acceptable. In addition, re-polishing resulted in the improved color changes in composite resin.

Conflicts of interest

None declared.

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