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ORIGINAL ARTICLE

Evaluation of the Color Matching of Composite Resin Restoration used for Repair with Initial Composite Resin Restoration

Saeedeh Asdagh[1], Mehdi Daneshpooy[2], Mahdi Rahbar[2,3], Shima Ghasemi[4], Shahrzad Ghasemzadeh[5]

[1]Department of Operative and Esthetic Dentistry, Faculty of Dentistry, Zanjan University of Medical Sciences, Zanjan, Iran.
[2]Department of Operative and Esthetic Dentistry, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran.
[3]Research Center for Prevention of Oral and Dental Diseases, Baqiyatallah University of Medical Sciences, Tehran, Iran.
[4]Department of Prosthodontics, Dental and Periodontal Research Center, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran.
[5]Dentist, Private Practitioner, Tabriz, Iran.

Author to whom correspondence should be addressed: Mahdi Rahbar, Department of Operative and Esthetic Dentistry, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, East Azarbaijan Province, Iran. Phone: +98 914 1543176. E-mail: mahdirhbr@gmail.com.

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Abstract

Objective: To investigate the color matching of the composite resin used for repaired with initial composite resin restoration after the aging process. **Material and Methods:** After preparation of 30 composite resin samples, their color were determined using the spectrophotometer four times and the average was recorded. After the initial aging, the color of the samples was measured again. Then, the repair process was performed with an appropriate composite resin color for each sample and the aging process was performed again. After the second aging, the color of the initial and the repaired composite resins were measured. Then, the data were analyzed by paired T-test. The level of significance was set at 5%. **Results:** The color difference of the initial composite resin between before and after initial aging, as well as the color difference of repaired composite resins between before and after second aging, were significant ($p<0.001$). Also, after the second aging, the color difference between initial and repaired composite resin restoration were significant ($p<0.001$). **Conclusion:** The color matching of the repaired composite resin with the initial one is not acceptable. In this way, replacement of initial composite suggested instead of repaired.

Keywords: Color Matching; Composite Resin; Tooth Color; Aging.

Introduction

Today, color change is one of the most common causes of repeated replacement of composite resin restorations. In fact, esthetics is one of the main considerations of the patients seeking dentistry [1]. Among the dental restorative materials, resin composite resins have been found to be highly accepted among dentists and patients due to their adequate strength, excellent primary esthetic, lower cost than ceramics, and dentin bonding [2]. Of course, the success of restorative materials such as composite resins mostly depends on their color stability over time. So, color change is one of the most common causes of frequent replacement of composite resin restorations, dissatisfaction among patients, and the associated economic problems for the patients [1,3].

Composite resin restorations color change in the oral environment; but the important issue is the extent of this change of color, which should not be detectable to the eyes [3]. Composite resin color change can be caused by internal or external factors. Internal factors induce changes in the resin matrix and the interspersed matrix and filler. The external factors include the absorption of foreign pigments, smoking and the consumption of food and drink [4,5].

Previous study evaluated the color change of three microhybrid composite resins and five nanohybrid composite resins and found that all micro and nanohybrid composite resins undergo a change in color due to the aging process. The color change was found to be not significant in microhybrids [6].

Evaluation of the color stability of three composite resin types after accelerated artificial aging showed that the color change of the studied composite resins is higher than the acceptable clinical limit. In this study, Z250 microhybrid composite resin had higher color stability than nanocomposite resins [7].

Comparison of the color stability of two nanocomposite resins and two microhybrid composite resins in solutions of tea, coca-cola, coffee, and artificial saliva showed that tea and coffee create unacceptable color changes in all of these composite resins, while artificial saliva and coca-cola did not cause significant color change [8]. The color stability of four types of different resin composite resins was investigated in eight different solutions; artificial saliva created the lowest and red wine produced the highest amount of discoloration in these composite resins. Also, Filtek Supreme and Filtek Z250 composite resins exhibited the highest and the lowest color stability, respectively [4]. The results of the color stability comparison in nanocomposite resins and microhybrid composite resins in three solutions of tea, coffee, and cola showed that the color stability of the nanocomposite resins was significantly higher than the microhybrid composite resins [9]. According to some studies, the color change of nanocomposite resins is more than the acceptable clinical level ($\Delta E > 3/3$) and also in some studies, the color change of these composite resins has been clinically acceptable [3,10,11].

In the recent years, with improving the mechanical and physical properties of composite resins and with proper usage of these materials, the longevity of composite resin restorations has increased. In spite of all this, an old composite resin restoration may lose its esthetic and quality despite maintaining its original bond strength due to various factors such as color change and partial and superficial fractures. New restorations may also not be satisfactory due to over-finishing, color discrepancy, air bubbles, and inappropriate contours [12].

Factors such as the extent, location, and cause of restoration failures, the quality of the present restoration, the life expectancy, and cost affect the design of the final treatment, including replacement or repair [13]. Although a complete replacement of an unsuccessful composite resin restoration results in better clinical results and greater esthetic, it causes the removal of previously etched enamel and subsequently, more enamel etching to increase the enamel bond. In addition, the complete removal of the previous restoration leads to a wider cavity, the removal of intact tooth structure, increased probability of damage to the pulp, and wasting time and cost [14,15]. Therefore, in some cases, such as color changes, small recurrent caries along a margin of an appropriate restoration, over-polishing, wearing or lapping of previous composite resin restorations, the addition of new composite resin to existing composite resin restorations is a commonly used treatment [16].

On the basis of a research in different databases, we concluded that there is a contradiction on the color stability of the nanocomposite resins among the various studies [4,6,8-11]. On the other hand, in spite of various studies regarding the repair composite resin bond strengths to initial composite resin restorations [12,15], a study that investigates the color matching of the repaired composite resins with the initial composite resins was not found. Hence, in this study, we will consider this issue for the first time and answer the following questions: Does a repaired composite resin color matching adequately with the initial composite resin during the aging process?

Material and Methods

Study Design and Data Collection

To determine the sample size, we used the results obtained in a previous study [6]. Considering the mean difference of 0.9 between the measurement of seven days and 14 days, respectively, with a standard deviation of 0.97 and 0.34, and also considering $\alpha = 0.05$ and power of 90%, 27 samples were estimated. To increase the validity of the study, 10% were added to this number and 30 samples were considered.

This study used nano-hybrid composite resins (3M ESPE Supreme XTE, St Paul, MN, USA) in A1 colors (30 samples). The samples were prepared by a silicon cylindrical mold (4 mm in diameter and 4 mm in height). The light curing process of the composite resin material was performed by Astralis 7 (Ivoclar Vivadent AG, FL-9494 Schaan/Liechtenstein) with 750 mW / cm2 power for 40 seconds and in two layers of 2 mm. After removing the samples from the molds, the exposure was performed on four sides of samples for 40 seconds. After finishing the composite resin samples, they were polished by the Sof-Lex system (3M, St Paul, MN, USA) with medium, soft, and very soft disks using a handpiece at speeds ranging from 7000 to 8000 rpm. The color of each sample, in the middle part of the cylinder, was determined four times and the average was recorded.

The aging process was done for all samples, which was 383 hours that equal one year of clinical performance. After these steps, the color of each sample in the middle part of the cylinder was determined four times and its average was recorded. The color of the samples was determined with a spectrophotometer (based on the CIE L*, a* and b* system) (base color for comparison). After the completion of the process, the samples were washed out and were put into distilled water. If the color difference between the before and after the initial aging was less than 3.3 (because it is not visually recognizable), the composite resin color used for restoration was the same as the A1 color; otherwise, the color was determined for composite resin repair was determined by spectrophotometer. The samples put in another cylindrical silicon model again (4 mm in diameter and 8 mm in height). The sample surface was marked in the outer cylindrical section by a marker to determine the initial composite resin. The sample surface in the internal cylindrical section was washed out with water for 20 seconds and dried with air for ten seconds. Then, 37% Etch-Rite phosphoric acid was applied to the surface of the samples for 15 seconds. Consequently, the acid was washed out with water for 15 seconds and dried for 10 seconds. Adper Single Bond (3M ESPE, St Paul, MN, USA) was applied to the etched surfaces with a micro-brush and was expelled by spray air for two seconds and eventually 30 seconds [12]. After the completion of this work, the aging process in the second step was followed for these samples by the protocols described below. The composite resin color in the initial and the repaired parts of each sample in the middle section of cylinder was determined by a spectrophotometer.

Aging Process

The aging solution was prepared with two teabags, placed in 500 mL of distilled water for ten minutes. The samples were immersed in this colored solution for 14 consecutive days (every 24 hours) for 20 minutes per day in order to simulate the clinical condition [6]. After the completion of this process, the samples were washed out with distilled water.

Sample Color Measurement

The color of the samples was determined after the preparation of the samples and after each aging process in both the initial and the repaired composite resin parts with a spectrophotometer (Spectro Shade, Niederhasli, Switzerland) on a white background. The color was determined in a 4 × 3 special room with gray walls with sunlight between 10 and 12 A.M. It should be noted that the spectrophotometer device was calibrated according to the manufacturer's instructions before the measurements were taken. The determination of the color of the samples was conducted after the initial aging to select the composite resin color for repairmen. Also, the color of the samples was evaluated with the help of the CIE L*, a* and b* system, which was done with the aid of a spectrophotometer. In this system, L* refers to the brightness level, a* refers to the red color in positive values and the green color in negative values and b* also refers to the yellow color in positive values and the blue color in negative values [10], all of which were automatically taken by the spectrophotometer [6].

Statistical Analysis

The data was analyzed by descriptive statistical methods (mean and standard deviation) using the SPSS Software (IBM Corp., Armonk, NY, USA), version 16. Meanwhile, the normalization of the samples was evaluated by the Kolmogorov-Smirnov test. The paired t-test was used to compare the color correction of the composite resin restorations before and after aging. In this study, a p-value <0.05 was considered as statistically significant.

Results

It observed that after each aging, the color deteriorated and therefore, we used inferential statistics for a more accurate evaluation and meaningful analysis of these differences.

As shown in Table 1, dE of the color of the original composite resins before the initial aging was 73.2, which decreased to 61.7 after the initial aging and got cloudy. This decrease is statistically significant (p<0.001). According to Table 1, the color of the restored composite resins before the second aging was 61.7, which decreased to 55.4 after aging. This decrease was statistically significant (p<0.001) too.

Table 1. Independent T-test results for the color of the composite resin samples before and after aging.

Composite Resin Restorations Type	Measurement Time	Mean and SD*	p-value
Initial	Before initial aging	73.2 ± 1.6	p<0.001
	After initial aging	61.7 ± 3.2	
Repaired	Before second aging	61.7 ± 3.2	p<0.001
	After second aging	55.4 ± 2.3	
Initial	After second aging	44.3 ± 5.8	p<0.001
Repaired	After second aging	55.4 ± 2.3	

*Standard Deviation.

According to Table 1, the comparison of the restoration color of the initial and repaired composite resin after the second stage of aging also shows that dE of the color of the initial restored composite resin after the second stage of aging is 44.3 while dE of the color of the repaired composite resins after the second stage of aging is 55.4, which is relatively large and statistically significant (p<0.001).

Discussion

The repair and restoration of composite resins is a more appropriate method than complete replacement. The process saves the remainder of the teeth, saves time and cost, and maintains the tissue. Since it is less invasive compared to the replacement method, it can increase the life span of the restorations. The switching method has several drawbacks: it takes a longer time and does more damage to the tooth pulp. Therefore, repairing unsuccessful composite resins is a suitable treatment for preventing damage to the tooth pulp and for protecting the healthy tissue [17].

We will first discuss the methodology of the study and will continue to do so as we take a look at the results. Various methods have been used to study the aging process such as boiling, thermocycling, storage of citric acid, sodium chloride, and distilled water. However, water is the most commonly maintained environment and its shelf life varies from six hours to 24 months, as ascertained in different studies. In this study, 30 composite resin samples were immersed in tea solution for 20 minutes per days (every 24 hours) for 14 consecutive days to simulate the clinical condition [6]. By storing samples in a wet environment, hydrolytic degradation and hydrolysis and oxidation reactions, such as those occurring in the oral environment, can be provided. In the present study, after the completion of the process, the samples were washed with distilled water. In the present study, a nanohybrid composite resin was used due to its aesthetic and mechanical properties [18].

Color measurement is a phenomenon that varies from person to person, at different times. Various factors such as lighting, translucency, opacity, light immersion, and human eyes can affect color assessment [19,20]. In this study, to solve the subjective errors, color evaluation was carried out by the spectrophotometer apparatus of the Dental and Periodontal Research Center, Faculty of Dentistry, Tabriz University of Medical Sciences. It is currently the most accurate tool for color examination [21] and also, has more objectivity than the visual method (in 93.3% of the cases) and higher accuracy (33% more) than the common techniques [22].

According to the findings of this study, it was observed that ΔE the color of the initial composite resin restorations after the original and secondary aging, as well as the ΔE color of the repaired composite resins, decreased significantly after the second stage of aging and actually became cloudy.

According to various studies, the internal and external factors associated with the patients' habits and medical history as well as the exposure time and concentration of the staining material may impact the color stability of the tooth and the restorative materials [22]. Color change in the composite resin restorations may be physiological, chemical, hydrophilic or hydrophobic reactions and may be caused by water absorption due to different reasons, such as composition (optical primer, actuator, resin matrix, and fillers). Other factors affecting the color stability of the composite resin materials include incomplete polymerization, curling time and application, porosity, abrasive resistance, oxygen permeation at the surface, and surface preparations like polishing and bonding [22,23].

The composite resin used in this study is the Supreme Filtek Universal nanocomposite resin, which has Bis-GMA (bisphenol A-diglycidyl ether methacrylate), Bis-EMA (bisphenol A ethoxylated glycol dimethacrylate) and UDMA (urethane dimethacrylate), and has a small amount of TEGDMA (triethylene glycol dimethacrylate). According to the previous studies, although Bis-GMA and TEGDMA are both hydrophilic monomers, Bis-GMA causes 3 to 6% water absorption and

TEGDMA also causes 0 to 1% water absorption [24,25]. In the composite resin used in this study, considering the high amounts of Bis-GMA in comparison to TEGDMA, one of the reasons for the lack of color can be the presence of these monomers in the composite resin structure.

The composite resin is composed of mineral fillers in the organic matrix and the composite resin can be damaged and colored in different environments. The simplest reaction that can occur at the contact surface of the environment and the composite resin after the material penetrates into it, will be the color change. The degree of polymerization and crosslinking of the composite resin are important factors determining the effects of the solutions on it [26]. The degree of polymerization depends on factors such as the type and intensity of the polymerization device, the color, the translucency, the opacity and the thickness of the composite resin [27-29]. In Bis-GMA-based composite resins, the degree of polymerization varies between 45% and 85% and it has been reported that the composite resins with Bis-GMA and UDMA base (similar to the composite resins used in this study) have a 20% lower degree of polymerization than the other monomers [30]; the low polymerization degree causes the materials to be more susceptible to degradation, resulting in reduced color stability and the release of products like methacrylic acid and formaldehyde can aggravate color change [26,30].

According to numerous articles, the human eye is able to detect a difference in color with $1 \leq$ E; but in dentistry, the usually acceptable value is $3.3 > \Delta E$ [3]. In the present study, the difference in the color of the original composite resin and the repair after the second aging was greater than the acceptable clinical value ($\Delta E = 11.1$).

In various studies, the bond strength of repaired composite resin to the initial composite resin is clinically acceptable if proper surface preparation was done [31,32]; however, the stability and color matching are vital especially in the anterior teeth. In this study, the color of the initial composite resin is adapted to the two stages of aging and the composite resin is used to repair an aging step and shows the results of poor color matching between the two composite resins. Therefore, despite the favorable bond strength of the new composite resin with the original composite resin, which has been proven in various studies, this discrepancy in color suggests the need for a complete replacement of the defective composite resin restorations. The reason for the poor color matching of the repaired and the initial composite resin can be the longer contact time of the original composite resin to the material (two stages of aging) and the inherent characteristics of the composite resin used.

A number of studies on the coloring of composite resins, with results similar to the present study, are noted. Evaluation of the aging effect on dental composite resins showed that the composite resin underwent an unacceptable change in color after aging ($\Delta E > 3$) [33]. Also another study on the stability of the three composite resin materials after accelerated artificial aging showed that the ΔE of the composite resins changed significantly after aging; the composite resins studied were similar to the current study and were selected from the Filtek brand [7]. The surface color change of three composite resins including the microhybrid composite resin and the five nanohybrid composite resin after staining and bleaching showed that composite resins change color over time [6].

The color of the original composite resin and the restored composite resins had a statistically significant difference after the second stage of aging. The results of one study showed that color change after aging in the microhybrid composite resin (Z250) was significantly less than in the supreme and the nanohybrid (Z250XT) composite resins and there was no statistically significant difference between the color change of the nano-field and the nanohybrid [7]. In a laboratory studyfound that the color stability of dental composite resins in colored solutions by spectrophotometry showed that all the composite resins change color after an exposure to tea and coffee solutions and this color change was not acceptable and damaged the aesthetic value; one of the composite resins used in this study was similar to the present study and this color change was due to the surface porosity resulting from the brief dissolution of materials, the physicochemical properties of resin matrix monomers, and the form of composite resin filler aggregation [8].

One study analyzed the color stability of nanocomposite resins and microhybrid composite resins in three solutions of tea, coffee, and cola, and concluded that the color stability of the nanocomposite resins was significantly higher than the microhybrid composite resins [9]. Other study showed that there was no significant difference after staining between the microhybrid and nano hybrid composite resin [6].

This study was carried out with a set of assumptions. In order to further elaborate the study, the compatibility of the original restorative color with the restored composite resins (conventional composite resins, ceramic composite resins, and nanocomposite resins) should be investigated in future. Additionally, the effects of the exposure to various solutions can also be evaluated, in addition to time. In the future studies, the effect of correct polishing of the original composite resin after the restoration step and the aging process can be evaluated for the final color matching. In addition, the effect of bleaching on the color compatibility of the original and the restored composite resins can also be assessed and the hypothesis is that bleaching improves the compatibility of the original and repaired composite resins.

Conclusion

Composite resins color change and deteriorate over time. Over time, the color changes in initial composite resins and the repaired ones are not the same and the color matching of them affected by the aging phenomenon.

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