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The effects of preheating on color values of polyacid-modified composite resins

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ABSTRACT

Objectives: Color stability is crucial to the esthetic success of restorative materials. Internal and external factors affect the coloring of these materials. Research carried out on the development of restorative materials draws attention to the advantages of methods such as preheating resins, reducing the viscosity and light cure time, increasing the marginal adaptation, and increasing the degree of monomer conversion. The aim of this study was to examine the *in vitro* effects of preheating polyacid-modified composite resins (PMCRs) on their color values and evaluate the obtained findings comparatively. **Materials and Methods:** Four main groups were formed by preparing discs from A2-colored PMCR material, which were kept at four different temperatures (4°C, 23°C, 39°C, and 55°C) before polymerization. The colors of the discs were measured according to the Commission on Illumination Laboratory system before and after they were kept in distilled water for 24 hours. The data were statistically analyzed using IBM Statistical Package for the Social Sciences V3. **Results:** It was seen that the preheating treatment did not significantly affect the color sensation (ΔE) and red-green (Δa) color values of the PMCRs. It was determined that this process was effective on the lightness (ΔL) and blue-yellow (Δb) color values of the materials. **Conclusion:** It should be considered that preheating applied to PMCRs may be beneficial for the longevity of the color stability of restorations, but different oral hygiene and dietary habits may have different effects on PMCRs.

Keywords: Commission on illumination laboratory, Color stability, Compomer, Heating device, Preheating

INTRODUCTION

Dental caries is an important oral health disease, especially in children. The World Health Organization reports that the prevalence of caries in the primary dentition period is between 60% and 90% worldwide.[1] The primary goal of treating dental caries is to restore function and esthetics. Factors such as the usage areas, esthetic properties, advantages, and disadvantages of materials are taken into consideration in the selection of the appropriate restorative materials in dentistry practice.[2] As a reflection of the increasing social awareness rate and interest in esthetics in the field of dentistry, it is seen that the parents of patients want longer-lasting and esthetic restorations for their children. For this reason, today, the usage of composites, polyacid-modified composite resins (PMCRs), and resin-modified glass ionomer cements, which are dental restorative materials with resin content compatible with tooth color, are frequently preferred in pediatric dentistry.[3]

Many studies have been carried out, and various methods have been developed to improve the physical properties of resin-containing restorative materials.[4] One of the methods evaluated for this purpose is the preheating of restorative materials.[4] It is a technique that became very popular in recent years due to its advantages, such as heating resin-containing dental restorative materials

before polymerization, reducing the viscosity of the material,[5] increasing the monomer conversion rate,[6] improving marginal compliance,[7] and reducing the light exposure time.[8] According to the review of the relevant literature, the effects of heating before polymerization on composite resins have been investigated, but it was seen that studies on the effects of preheating on PMCRs, which are esthetic restorative materials widely used in pediatric dentistry, are quite limited.[4] Our aim in this study is to present data that can be utilized in the literature on this topic by examining the effects of this method on the color values and discoloration rates of PMCRs under *in vitro* conditions as a result of applying the preheating process at different temperatures.

MATERIALS AND METHODS

In this *in vitro* study, discs prepared from A2 colored PMCRs (Dyract XP, Dentsply, Konstanz, Germany), which were kept at four different temperatures (4°C, 23°C, 39°C and 55°C), were used as a restorative material to be evaluated. In Group 1, the PMCR capsules were used after being kept in the refrigerator for 48 h to reach the desired 4°C before polymerization. For Group 2, the PMCR capsules that were used were kept at 23°C (room temperature) for 48 h without any preheating. A composite heating device (Micerium, Avegno GE, Italy) was used according to the manufacturer's instructions before polymerization to bring the other PMCR capsules to 39°C for Group 3 and to 55°C for Group 4. The PMCR samples were prepared at 10 × 2 size and polymerized for 20 s using a portable light-emitting-diode light device (Elipar S10, 3M ESPE, St. Paul, USA). The prepared samples were polished by applying coarse, medium, fine, and super fine discs in the same direction without water for 15 s, respectively. The prepared samples were kept in distilled water for 24 h to complete their polymerization.

A total of 40 samples were prepared (n = 10) for each of the four temperature groups. The color of the samples was measured with a digital spectrophotometer device (Vita Easyshade Advanced 4.0, Vita Zahnfabrik Bad Sackingen, Germany) before and after soaking them in distilled water for 24 h. Color measurements of the samples were made according to the Commission on Illumination (CIE) Laboratory color system. In the samples, the L, a, and b values were determined and recorded as the beginning measurement with a spectrophotometer device, allowing the three-dimensional color to be determined. Color differences (ΔE) were calculated with the following formula:

- $\Delta L^{\star} = L_{\text{distilled water}}{}^{\star} - L_{\text{beginning}}{}^{\star}$
- $\Delta a^{\star} = a_{\text{distilled water}}{}^{\star} - a_{\text{beginning}}{}^{\star}$
- $\Delta b^{\star} = b_{\text{distilled water}}{}^{\star} - b_{\text{beginning}}{}^{\star}$
- $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\ ]^{1/2}$

The obtained data were recorded, and statistical analyses were carried out. The analyses were carried out with the IBM Statistical Package for the Social Sciences (SPSS) V23 program. Compliance with normal distribution was evaluated with the Shapiro–Wilk test. One-way analysis of variance was used to compare the normally distributed findings among the groups, and multiple comparisons were carried out using Tamhane's T2 test. The Kruskal–Wallis test was used to compare the findings that did not show normal distribution among the groups, and multiple comparisons were carried out using the Dunn test. The results are presented as mean ± standard deviation and median (min. - max.). The level of statistical significance was accepted as $P < 0.050$.

RESULTS

The differences among the median values of color change (ΔE) in the samples prepared at 4°C, 23°C, 39°C, and 55°C were not statistically significant (P = 0.146) [Table 1]. The differences among the mean brightness change (ΔL) values of the samples prepared at 4°C, 23°C, 39°C, and 55°C were found to be statistically significant (P = 0.018). There was no statistically significant difference among the mean green-red color change (Δa) values of the samples prepared at 4°C, 23°C, 39°C, and 55°C (P = 0.093). There were statistically significant differences among the median blue-yellow color change (Δb) values of the samples prepared at 4°C, 23°C, 39°C, and 55°C (P = 0.018) [Table 2].

DISCUSSION

In pediatric dentistry, the expectations of patients from dental restorations include an ideal esthetic appearance and color match. However, the formation of color change is among the negative properties of resin materials.[9] The level of color change of resin restorations is related to many parameters such as incomplete polymerization, water absorption by the restoration, chemical reactions, surface properties of the restoration, and oral hygiene and dietary habits of the patient.[10] Resin-based materials can absorb water due to their hydrophilic properties. Due to this structure, they have, they can also absorb pigments and other liquids, and as a result, the discoloration can be seen in these restorations.[11] The preheating of resin restorations has become increasingly common in recent years. However, this process is generally applied in composite materials and canal-filling pastes in dentistry. Studies on heating PMCRs could not be found in the literature review that was carried out in this study. Studies evaluating the heating of glass ionomer cements, which constitute one of the basic contents of PMCR materials, are limited. These studies have reported that heat treatment was effective on properties such as microhardness, bond strength, and marginal adaptation of glass ionomers.[12]

To achieve the ideal polymerization depth, light transmission must be provided to the lower layers. Therefore, the color tone of the resin materials is important. Compared to light-colored resins, the light transmission of dark-colored ones

Table 1: Color change values.

	4°C	23°C	39°C	55°C	*P*
ΔE	1.45 (0.39–2.86)	2.22 (1.49–7.13)	0.80 (0.44–1.27)	1.53 (0.67–3.92)	0.146

ΔE: Color differences

Table 2: ΔL, Δa, and Δb values.

	Mean±s. deviation	Median (min. max.)	Test stats.	*P*
ΔL				
4°C	1.12±0.95[a]	1.08 (−0.17–2.47)	4.316	0.018*
23°C	0.61±2.84[ab]	0.75 (−3.30–5.90)		
39°C	0.10±0.50[b]	−0.08 (−0.93–0.97)		
55°C	−0.03±0.62[b]	−0.10 (−0.83–1.17)		
Δa				
4°C	−0.28±0.22	−0.30 (−0.57–0.13)	2.483	0.093*
23°C	−0.24±0.70	−0.23 (−1.17–0.80)		
39°C	−0.41±0.14	−0.43 (−0.67–0.20)		
55°C	−0.17±0.25	−0.12 (−0.73–0.10)		
Δb				
4°C	−0.55±0.74	−0.50[ab] (−1.97–0.80)	10.122	0.018**
23°C	−0.87±1.87	−0.75[ab] (−3.87–1.70)		
39°C	−0.33±0.51	−0.37[a] (−1.10–0.63)		
55°C	−1.55±0.94	−1.45[b] (−3.80–0.67)		

*One-way analysis of variance, **Kruskal–Wallis test. ΔL: Mean brightness change, Δa: Mean green-red color change, Δb: Median blue-yellow color change.

is weaker, which causes the hardening mechanism to be negatively affected.[13] In our study, the PMCRs used were selected in the lightest color of the manufacturer, A2, to prevent a negative effect on the polymerization mechanism. Many clinicians store dental materials in the refrigerator at 4°C to prevent deterioration. Manufacturers generally state that materials should be stored at room temperature at 23°C, and many clinicians keep the materials at room temperature.[14] 39°C and 55°C temperatures can also be reached with special heating devices. For this reason, 39°C and 55°C were selected in our study to examine the color stability of PMCRs at high temperatures. A situation that causes concern in preheating processes applied to materials is the effect of the high temperature of the material on the pulp tissue. Trujillo *et al.,* stated that pulp vitality could be compromised due to temperature increases higher than 5°C and it was observed that after the composite resin, whose temperature reached 54.5°C by preheating, was placed in the cavity, the temperature increase recorded by a thermocouple placed in the pulp chamber was only 2.4 ± 0.3°C.[15] It was observed that the material placed in the tooth at this temperature did not damage the pulp.[15] However, Knezevic *et al*., while evaluating the cellular toxicity caused by preheating resin-based materials at 68°C, suggested that this procedure may not be safe.[16] In our study, the material was preheated to a maximum of 55°C, considering the risk of pulpal irritation.

In our study, when the PMCRs prepared at different temperatures were compared in terms of color change (ΔE), no significant difference was found. It was observed that the preheating treatment did not have an effect on the coloration (ΔE) of the PMCR material. Similarly, in the study carried out by Mundim *et al.,* with composites that were preheated at 8°C, 25°C, and 60°C and aged for 384 h, no difference was observed in terms of color stability and opacity between the temperatures evaluated.[6] Moreover, in their study investigating the discoloration of composites prepared by preheating in distilled water for 30 days, Darabi *et al.,* reported that the coloration rates of the composites kept at room temperature (25°C) and those heated at 68°C were similar.[17] The coloration of restorative material depends not only on external factors but also on the hydrophilicity of the matrix structure of the material. As resin materials can absorb water, they can also absorb other liquids and pigments, which can cause these resins to be colored.[11]

In our study, when the color change values of the PMCRs prepared at different temperatures were analyzed by dividing them into the ΔL, Δa, and Δb color coordinate differences, significant differences were found among the temperature groups in terms of ΔL and Δb, but no significant difference was found in terms of Δa. It is thought that the preheating process may have an effect on the brightness and yellow-blue color values of the PMCR material, but not on the red-green color values. Gönülol and Karaman, who examined the color changes of preheated composite resins after 48 h of exposure to a coffee solution, found a statistically significant difference in ΔL and Δb values, similar to the results of our study, but no significant difference was observed between the groups in terms of their Δa values.[18] Furthermore, in the study in which they compared the color stability levels of 2 different composites in 18 patients, Setz and Engel reported that ΔL and Δa values did not change significantly, while the values of Δb and the total color change difference (ΔE) increased by approximately 2 units each year. It was reported that this increase in Δb values indicated that the material turned more yellow.[19] However, in the study performed by Vichi *et al.,* in which color values were examined by preparing discs from 3 different composites and keeping them in distilled water at 60°C for 30 days, it was observed that the most affected parameter was ΔL, the Δa value was slightly affected, and the Δb value was slightly increased in only one group and decreased in the other groups.[20] It was also stated that the

material in the group with an increase in Δb values turned yellow. In our study, it was observed that the a* value of the samples in all temperature groups decreased, but the degree of this change (Δa) was not statistically significant.

Lee and Powers, who prepared discs from four different composites and kept the discs in mucin, chlorhexidine, and tea solutions for three days after sealant application, observed a decrease in L* values, while an increase was observed in a* and b* values. It was reported that this decrease in L* values may cause a decrease in the gloss value of the material with the application of the surface sealant.[21] In the study by Paravina *et al.,* in which two different composites were subjected to aging, and 33 whitening shades were examined, it was observed that there was a decrease in L* and a* values due to aging and an increase in b* values. It was reported that the material became darker as the L* values decreased.[22] However, in the study by Mundim *et al.,* with composites that were preheated at 8°C, 25°C, and 60°C and aged for 384 h, there was no significant difference in terms of color stability and gloss-opacity between the temperatures that were evaluated.[6] According to the results of our study, the L* values of the discs prepared before polymerization at the temperatures of 4°C and 23°C increased, while the L* values decreased in the samples that were prepared at 39°C and 55°C. Considering that increasing the temperature of resins before polymerization increases the monomer-polymer conversion ratio and directly affects the chemical and color stability of the material,[6,8] it is thought that it may also affect the gloss (L*) value of the material, resulting in a decrease in gloss, that is, causing the material to appear opaque.

Considering the cause of an opaque white appearance, which is the characteristic feature of white spot lesions, it is known that there are changes in the optical structure with the loss of minerals in the body of the lesion, and the demineralized surface reflects less light.[23] Although it was reported that the thermal vibrations caused by heating resin materials before polymerization force the monomer and oligomer molecules to slide easily over each other,[24] there is no information in the literature on how they affect the inorganic fillers in the material structure.

Considering the increase in the L* values in the PMCR samples prepared at the temperatures of 4°C and 23°C in our study, it is thought that as a result of keeping the disc samples in distilled water for 24 h, the removal of the unreacted residual components in the material[25] and the completion of the polymerization mechanism by providing post-polymerization hardening[26] may have contributed positively to the gloss color value of the material. In our study, there was a significant difference in ΔL values between the 4°C and 39°C groups and between the 4°C and 55°C groups, but there was no significant difference between the other groups. In line with these results, it is thought that the difference between the temperatures should be large to create a significant difference in ΔL values between two different temperatures of PMCR material preheating before polymerization. Similar to the results of our study, in the study by Gönülol and Karaman investigating color changes that occurred as a result of the 48-h exposure of preheated composite resins to a coffee solution, while the difference between coloration values at 4°C and 23°C was not significant, the difference between coloration values at 4°C and those at 39°C and 55°C was significant.[18] This study supported the findings that for a significant difference in the ΔL value to be observed, the difference between the temperatures must be large.

In our study, it was observed that b* values decreased in all temperature groups, in contrast to the results obtained in some previous studies.[22] In other words, no yellowing was observed in the PMCR disc samples prepared in all preheating temperature groups. The causes of discoloration of resin-containing dental restorative materials depend on many factors, including internal and external sources. While internal factors include factors in the resin matrix in the deep layers of the restoration material and the chemical structure at the matrix/particle interface, different coloring substances in food and/or beverages consumed during the day are considered external factors.[6] Considering that coloration may occur not only due to internal factors such as insufficient polymerization but also due to the structural characteristics of the food and beverages that are consumed daily,[27-29] it is thought that the pH of the preferred solution was not acidic, and it did not contain coloring pigments, so that no increase in the b* value, that is, no yellowing of the material, was observed in any group in our study.

There are some limitations to our study. Traditional statistical tests are often referred to as parametric tests. Parametric tests are used more frequently than nonparametric tests in many medical articles because most medical researchers are familiar with them, and statistical software packages strongly support parametric tests. In our study, we used SPSS V3, a powerful statistical software package widely used by researchers, but it can have difficulty dealing with very large data sets. In addition, they state that non-parametric analysis methods are not always the best choice for cases with small sample sizes because they have less statistical power than parametric techniques and have difficulty calculating the "95% confidence interval" that helps readers understand.[28]

CONCLUSION

According to the results of our study, although it is thought that heating PMCRs before polymerization affects the inorganic components and refractive index of the material and causes a decrease in its gloss value, causing it to appear more opaque, depending on the increase in the degree of monomer conversion, it does not cause an increase in the b* value, namely, yellowing, which has a significant effect on ΔE, and this method may be beneficial in reducing the discoloration that may occur in restorations. Furthermore, the level of discoloration in esthetic restorations depends on many factors,

including internal and external factors such as oral hygiene and dietary habits, the surface smoothness of the restoration, water absorption, chemical reactions, and incomplete polymerization. Although the results showed that the preheating process was effective on the color values of the PMCR material, and the preheating process applied to the PMCRs can be beneficial in increasing the color stability performance of restorations, it should be considered that different oral hygiene and nutritional habits may have different effects on PMCRs.

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