

Research Article

Color Stability of Provisional Restorative Materials in Different Mouthwash Solutions

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Purpose. This study is a comparison of the effects of temporary restorative materials (PRMs) on the color change that occurs due to the use of different mouthwash solutions in two time periods. **Material and Methods.** One hundred fifty disc-shaped specimens (10 mm × 2 mm) were fabricated with three PRMs chemically polymerized PMMA (Imident-I), chemically polymerized bisacrylic composite resin (Acrytemp-A), and CAD/CAM PMMA-based polymer (TelioCAD-T) according to manufacturers' instruction and using a CAD/CAM milling system ($n = 10$). CIE L * a * b * values of specimens were recorded before immersion. Samples were immersed in solutions (Distilled water-DW, Kloroben-CHX, Listerine Advanced White-LAW, Listerine Total Care-TC, and Listerine Zero-TCZ) in two time periods (t_1, t_2). Color measurements of the samples were made with the help of a spectrophotometer before and after they were removed in mouthwashes (VITA Easyshade V). **Results.** According to the statistical analysis results, significant differences were observed between the results obtained in our study. The highest roughness values in $\Delta E1$ were seen in A-LAW (1.83) and the lowest in T-DW (0.61). In $\Delta E2$, the highest roughness values were observed in I-LAW (2.70), and the lowest in T-DW (1.05). ΔE values of all obtained groups were found within clinically acceptable limits ($\Delta E < 3.7$). **Conclusions.** The content of temporary restorative materials, the production technique, the type of mouthwash, and the immersion time of the restoration affect the color stability. Mouthwash with a whitening effect caused the most discoloration. Among the temporary restorative materials, it was the CAD/CAM material that best preserved its color stability.

1. Introduction

The use of provisional restorations in prosthetic applications significantly affects the success of the treatment and patient comfort. Provisional restorations are always preferred before restorations such as crowns, implant-supported prostheses, laminate veneers, and inlay-onlays. As a result of temporary restorations to be applied for treatment, many studies have shown that it protects the pulp against thermal and bacterial harmful factors. In line with these, studies have revealed that it stabilizes the teeth prepared during the function as a disadvantage [1]. It is important in shaping soft tissue, evaluating the final shape, and coloring permanent restorations. Provisional restorations must be resistant to

breakage and abrasion, as well as satisfying esthetic expectations [2]. Especially in anterior region restorations, the color stability of the material from which provisional restorations with a long time in the mouth will be produced becomes important. Some of the materials used in the production of fixed temporary restorations are polymethyl methacrylate (PMMA), polyethylene methacrylate, urethane dimethacrylate, and bisacrylate resins [3]. The polymerization of these materials can either be chemical or light-cured and can be both chemical and light-cured [4]. As a result of recent changes, it contributes to the production of temporary restorations by shaping acrylic resin blocks that are prepolymerized with some computer-aided design and manufacturing (CAD/CAM) [1]. Similar to other polymers

used in dentistry, acrylic resins used as temporary materials also tend to absorb liquid and undergo a color change [5]. Surface roughness, plaque accumulation, chemical degradation, consumption of coloring beverages, and use of mouthwash can affect the color of the restorative material over time [6]. Mouthwash solutions usually consist of water, antimicrobial agents, coloring agents, and salts [7]. Alcohol is mostly used as a solvent and preservative. Hydrogen peroxide or different bleaching agents in concentrations of about 3% to 6% may be used in some solutions [7–9].

Mouthwashes are auxiliary chemical therapeutic agents in terms of preventing cavities and gingivitis. In dentistry, these therapeutic agents are also recommended for patients who will have fixed dentures. Mouthwashes consist mainly of water, antimicrobial agents, colorants, and salts. Sometimes it may also contain alcohol as solvent and preservative, or bleaching agents such as hydrogen peroxide and carbamide peroxide in different concentrations. Since the contact time of mouthwashes with the tooth surface is limited, their whitening capacity is controversial. In addition, chlorhexidine digluconate (CHX) is a widely used therapeutic agent to help reduce periodontal problems and prevent caries [5]. It has side effects such as the formation of calculus and coloring of enamel and restorative materials [9].

The coloring effects of colorants such as mouthwashes on enamel or restorations can be evaluated by different methods. This evaluation can be done using visual evaluation or color measuring devices. Visual evaluation, which is a subjective method, may vary depending on the physiological and psychological conditions of the person doing it [7]. Colorimetric color analyzes are objective and color measurement devices provide numerical values. Evaluations with these devices are so sensitive that even small color changes can be identified [10]. Colorimetric color analysis is a quantitative technique in which color differences in dental materials can be examined. $L^* a^* b^*$ is a three-coordinate color system that is frequently used in color analysis [10–12]. The L^* coordinate represents the lightness value of the color, and the a^* and b^* coordinates represent the positions on the red/green and yellow/blue axes. On the other hand, the $+a^*$ axis represents the red intensity of the color, the $-a^*$ axis represents the green intensity of the color, the $+b^*$ axis represents the yellow intensity of the color, and the $-b^*$ axis represents the blue intensity of the color. Color difference (ΔE) is the mathematical calculation of the direction and magnitude of the difference between two points in a three-dimensional color space [11, 12].

In this study, it was aimed to compare the effect of chlorhexidine digluconate-containing, alcoholic/nonalcoholic, and whitening effective mouthwash solutions on the discoloration of temporary restoration materials under immersion conditions equivalent to 1 month and 6 months of clinical use. The null hypothesis of this study is that there will be no difference in the color changes that the different mouthwash solutions will cause in the temporary restoration materials.

2. Materials and Methods

In the study, three different PRMs chemically polymerized PMMA (Imident), chemically polymerized bisacrylic

composite resin (Acrytemp), and CAD/CAM PMMA-based polymer (TelioCAD) were used in A1 shade (VITA classical A1-D4, VITA Zahnfabrik, Bad Säckingen, Germany). Detailed information about the temporary materials used is shown in Table 1. For this purpose, 50 disc-shaped samples of each material were prepared with the help of perforated metal sheets with a height of 2 mm and an inner diameter of 10 mm.

For the samples of the TelioCAD group, one of the samples produced with the help of molds was scanned with a 3D scanner (Ceramill Map 400; Amann Girrbach, Koblach, Austria), and a milling device (Ceramill Motion 2; Amann Girrbach) was used for the milling process.

A standard polishing process was applied to all the prepared samples. All surfaces were polished with silicon carbide (600–800–1000 grit) to obtain surfaces of equal roughness. The surfaces of the samples to be measured were polished with felt and pumice water. After the preparation of all samples was completed, they were kept in distilled water at 37°C for 24 hours and dried with blotting paper before being put into mouthwash solutions. The samples were randomly divided into 5 subgroups ($n = 10$) to be placed in four different types of mouthwash Chlorhexidine (CHX), Listerine Advanced White (LAW), Listerine Total Care (TC), Listerine Zero (TCZ), and the control group distilled water (DW).

$L^* a^* b^*$ values before samples were placed in solutions were recorded using a spectrophotometer (VITA Easyshade V; VitaZahnfabrik) (t_0). Measurements were made on a white background by calibrating the device in accordance with the manufacturer's instructions to CIE standard illuminant D65 at baseline. For each sample, the measurements were repeated three times and the average $L^* a^* b^*$ values were recorded. Considering that mouthwash solutions are used for one minute twice a day, 1 month of use was simulated with 1 hour of soaking (t_1), and 6 months of use with 6 hours of soaking (t_2). Only the samples belonging to Group LAW were kept two times compared to other groups in accordance with the manufacturer's instructions. Color measurements of all samples were repeated at the end of the specified time. The color changes were measured and recorded in $L^* a^* b^*$. CIEDE2000 formula was used to calculate color changes (ΔE). According to the CIEDE 2000 color system of the samples, $TP00 = ((\Delta L/KL.SL)^2 + (\Delta C/KC.SC)^2 + (\Delta H/KH.SH)^2 + RT \cdot (CSCB/KC.SC) \cdot (HS-HB/KH.SH))^{1/2}$ was calculated with the formula developed by Sharma et al. [13] where ΔL (LS-LB), ΔC (CS-CB), and ΔH (HS-HB) are the lightness, color, and hue differences in the samples, respectively; SL, SC, and SH are weighting functions for the lightness, chroma, and tone components, respectively; RT shows the interaction between color and hue differences in the blue region. KL, KC, and KH are parametric factors for changes in operating conditions. In this study, the parametric factors were determined as 1.

The mean color change of the samples at the end of t_1 time was recorded as ΔE_1 , and the mean color change at the end of t_2 time was recorded as ΔE_2 .

2.1. Statistical Analysis. Kolmogorov-Smirnov test was used to determine whether the obtained data showed a normal

TABLE 1: ΔE values of the materials after immersion in solutions and mean (\pm standard deviation) values ($p < 0.05$).

Groups	Imident		Acrytemp		TelioCAD		Total	
	ΔE_1	ΔE_2	ΔE_1	ΔE_2	ΔE_1	ΔE_2	ΔE_1	ΔE_2
DW	0,88 ($\pm 0,47$)	1,06 ($\pm 0,45$)	1,06 ($\pm 0,58$)	1,36 ($\pm 0,64$)	0,61 ($\pm 0,25$)	1,05 ($\pm 0,53$)	0,85 ($\pm 0,47$)	1,16 ($\pm 0,54$)
CHX	1,23 ($\pm 0,59$)*	1,89 ($\pm 0,63$)*	0,94 ($\pm 0,46$)	1,35 ($\pm 0,62$)	0,80 ($\pm 0,30$) ^A	1,09 ($\pm 0,24$) ^X	0,99 ($\pm 0,48$)	1,44 ($\pm 0,60$)
LAW	1,75 ($\pm 0,36$) ^{ab*}	2,70 ($\pm 0,65$) ^{ab*}	1,83 ($\pm 0,49$) ^{ab*}	2,48 ($\pm 0,44$) ^{ab*}	0,71 ($\pm 0,45$) ^{AB}	1,07 ($\pm 0,46$) ^{XY}	1,43 ($\pm 0,67$) ^{ab}	2,08 ($\pm 0,89$) ^{ab}
TC	1,05 ($\pm 0,33$) ^{c*}	1,44 ($\pm 0,52$) ^{c*}	1,34 ($\pm 0,50$)	1,83 ($\pm 0,74$) ^c	0,82 ($\pm 0,58$) ^B	0,89 ($\pm 0,48$) ^Y	1,07 ($\pm 0,51$) ^c	1,39 ($\pm 0,69$) ^c
TCZ	1,28 ($\pm 0,37$) ^c	1,73 ($\pm 0,48$) ^{ac}	0,84 ($\pm 0,62$) ^{c*}	1,07 ($\pm 0,55$) ^{cd*}	1,13 ($\pm 0,38$)	1,27 ($\pm 0,45$)	1,08 ($\pm 0,49$) ^c	1,36 ($\pm 0,55$) ^c
TOTAL							1,08 ($\pm 0,55$) [*]	1,49 ($\pm 0,73$) [*]

a, b, c, and d significate the difference from other solutions for DW, CHX, LAW, and TC, respectively. A and B significate the difference from TelioCAD material in ΔE_1 for Imident and Acrytemp, respectively. X and Y significate the difference from TelioCAD material in ΔE_2 for Imident and Acrytemp, respectively. *significates the difference between ΔE_1 and ΔE_2 in the same material and same solution.

TABLE 2: Materials used in the study.

Products	Material type or effective content	Fabrication method	Manufacturer
Imident	PMMA	Powder/liquid	Imicryl, Konya, Turkey
Acrytemp	Bisacryl methacrylate composite resin	2 pastes auto-mix syringe	Zhermack, Badia Polesine, Italy
TelioCAD	PMMA block	Milling disk	Ivoclar Vivadent AG, Schaan, Liechtenstein
Listerine Advanced White	Whitening effective		Johnson & Johnson, UK
Listerine Total Care	Alcohol-containing		Johnson & Johnson, UK
Listerine Total Care Zero	Nonalcohol-containing		Johnson & Johnson, UK
Kloroben	%0, 12 chlorhexidine digluconate		Drogosan, Ankara, Turkey

distribution. After seeing that the distribution was normal in the direction of the data obtained as a result of the application, the application was made by using the multidirectional analysis of variance (MANOVA) analysis to reveal the possible differences between the data. In order to show the color changes at the end of the t_1 and t_2 times, the analysis was made using the ANOVA test. In addition, the LSD post hoc test was applied to find the source of the difference between the groups we obtained. In order to compare the results of the same material at different times in line with the data obtained, the t -test, which is called dependent variables, was used. All statistical analyzes of all data obtained except power analysis were performed with SPSS, which was used in accordance with the Windows program. (SPSS for Windows, Version 26.0; SPSS, Inc., Chicago, IL, USA). The significance level was defined as 0.05 ($p < 0.05$).

3. Results

As a result of the MANOVA test, it was determined that the difference between the ΔE values of the samples kept in different mouthwash solutions was significant ($p < 0.05$). The statistical analysis results obtained with the mean ΔE_1 at time t_1 and ΔE_2 at the end of t_2 time, which were determined as a result of immersion of each PRM in different solutions, are shown in Table 2. Box plot graphs of the results are shown in Figures 1 and 2.

In Imident material, Group LAW showed the highest ΔE_1 values compared to other solutions at the end of t_1 . No statistical difference was observed between the ΔE_1 values of Group DW, CHX, LAW, and TC. Group LAW showed the highest ΔE_2 values at time t_2 in Imident material. No statistical difference was observed between Group CHX, TC,

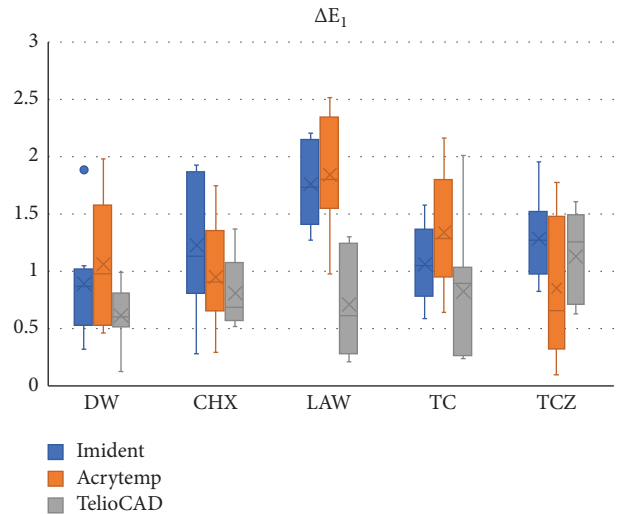


FIGURE 1: ΔE_1 values after immersion.

and TCZ. At time t_2 , Group DW showed the lowest ΔE_2 values, but no statistical difference was observed between Group DW and Group TC. In Imident material, ΔE_2 values were higher than ΔE_1 in all solutions, but a statistically significant difference was found between ΔE_1 and ΔE_2 in Group CHX, LAW, and TC.

In Acrytemp material, the highest value in ΔE_1 was seen in Group LAW. Group LAW showed statistically higher values than other solutions. However, no statistically significant difference was found between Group LAW and Group TC. Group LAW showed the highest values in ΔE_2 and was significantly higher than other solutions in ΔE_2 . In Acrytemp material, ΔE_2 values were higher than ΔE_1 in all

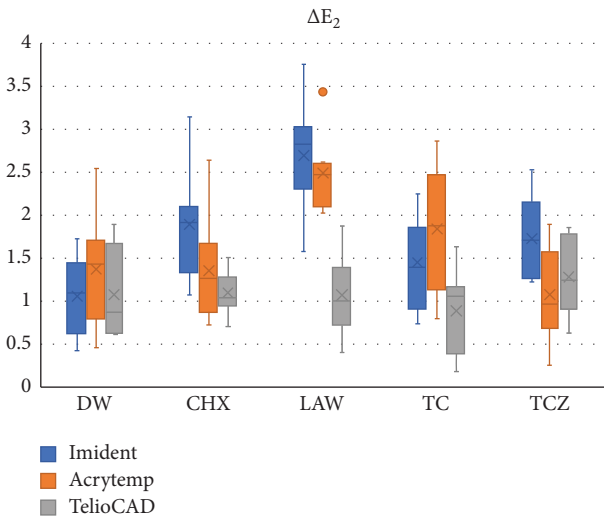


FIGURE 2: ΔE_2 values after immersion.

solutions, but a statistically significant difference between ΔE_1 and ΔE_2 times was observed only in Group LAW and Group TCZ solutions.

In TelioCAD material, there was no statistically significant difference between solutions in both ΔE_1 and ΔE_2 values. In addition, there was no significant difference between ΔE_1 and ΔE_2 , which describes the increase in color difference over time, despite the increase in all solutions.

When the ΔE_1 and ΔE_2 values of the materials are compared, significant differences were shown in Group CHX, LAW, and TC in the Imident material. In Acrytemp material, significant differences were shown in Group LAW and TCZ. In TelioCAD material, there was no statistically significant difference between ΔE_1 and ΔE_2 values in all solutions.

ΔE_1 and ΔE_2 values of TelioCAD among PRMs have shown that DW and TCZ solutions are not statistically different compared to Imident and Acrytemp, but lower ΔE values in CHX, LAW, and TC solutions.

It was shown that there was no statistical difference between the Imident and Acrytemp groups for all solutions. Both ΔE_1 and ΔE_2 values of TelioCAD material differed statistically from Imident material in the CHX solution group, Acrytemp material in TC solution group, and from both Imident and Acrytemp groups in LAW solution groups. Among the materials, the one with the least ΔE averages was determined in the prefabricated TelioCAD material.

Regardless of the material variable, it was determined that the LAW group, which had a bleaching-effective mouthwash solution, showed statistically significantly more color change than the other groups at both times.

4. Discussion

According to the statistical analysis results, significant differences were observed between the results obtained in our study. The null hypothesis that there would be no difference

in color changes caused by different mouthwash solutions in PRMs was rejected.

The ΔE value is generally used to evaluate the color change of restorative materials. In order for the color change to be perceived by an observer, it is more meaningful to use the ΔE value, which expresses the change, instead of considering the L , a , and b values one by one. Various studies have reported different thresholds of color difference values at which color change can be perceived by the human eye. [3]. In our study, the clinical acceptability limit of the ΔE value was taken as "3.7" [14]. When the ΔE values obtained as a result of this study were examined, clinically acceptable results were obtained in all solutions and all materials at both times.

PRMs continue to change color throughout their lifetime [3, 15]. In our study, it was observed that the amount of color change increased over time, independent of the material and solution variable.

The lowest color change in all groups was detected in the PMMA-based TelioCAD material, which was previously polymerized under industrial conditions. There was no significant color change in TelioCAD material depending on time and solution. These results can be explained by the polymerization of millable PMMA blocks under ideal production conditions [1]. Temporary restorations produced with CAD/CAM blocks have been reported to exhibit superior mechanical properties and compatibility compared to PMMA temporary restorations produced by the traditional method, in addition to their color stability [16]. For these reasons, it can be said that temporary restoration materials produced with CAD/CAM technology are an ideal option, especially for long-term temporary restorations.

It was shown that there was no statistical difference between Imident and Acrytemp for all solutions. Contrary to our study, in a similar study on the effect of mouthwash on the color change of temporary restorative materials, bisacryl-based temporary materials were found to exhibit more discoloration than PMMA-based materials [17]. In addition, in the study of Sham et al. in which PMMA and bisacryl composite resin group temporary restorative materials were compared, the effects of distilled water on the color stability of coffee were investigated. According to the results of the study, it was found that the PMMA group samples showed more coloration in distilled water than the bisacryl methacrylate group samples, and on the contrary, the bisacryl composite resin group samples showed more color change than the PMMA group samples in the samples kept in coffee. It was thought that this was due to the coloring coffee contents accumulated in the small pits [17]. In a similar study, no difference was found between PMMA and bisacryl composite resin groups for samples kept in water, and the bisacryl composite resin group showed a higher degree of coloration in samples kept in coffee and tea [15]. In our study, there was no statistically significant difference between PMMA and bisacryl composite resin groups for all solutions, including the distilled water group. This result suggests that mouthwashes do not contain high levels of colorants.

According to CIE $L^*a^*b^*$ measurements, increased lightness (increased L^*) and decreased yellowness (decreased b^*) are the main inducers of teeth whitening. Reduction of redness (reduction of a^*) affects whitening less [18]. There are studies showing that whitening mouthwashes cause more color changes than other mouthwashes [19]. In our study, it was determined that Group LAW caused the most color change.

It has been reported that the water content of mouthwashes can affect color change, so the effects of mouthwashes can be seen in the same way in the distilled water (control) group [20]. In this study, the color change was observed in all materials stored in distilled water. In addition, there was a color change in distilled water and alcohol-free TCZ solution, but there was no statistically significant difference between the materials.

Ingredients such as high levels of ethanol and phosphoric acid found in some mouthwashes can affect the surface properties of restoration materials [21]. Listerine can cause polymer matrix precipitation, dissolution of residual monomers, and erosion in resin materials. Low pH and alcohol can affect the surface integrity of resin-based materials and predispose them to discoloration [22, 23].

It is known that mouthwashes containing chlorhexidine gluconate cause discoloration of esthetic restorations [24]. This discoloration occurs even in teeth and oral mucosa [25]. In the current study, the CHX and LAW mouthwash groups showed clinically significant color change. Mouthwashes are commercially available in two forms based on their alcohol content. Alcohol acts mainly as a solvent in these solutions [26]. In our study, no significant difference was found between the alcohol-free mouthwash group (TCZ) and the other groups except group LAW at both times. This finding is consistent with other studies examining the color changes of mouthwash solutions on restorative materials [27–31]. However; Soygun et al. reported that mouthwashes with high alcohol content increased color change in restorative materials [32]. Differences between different reports can be attributed to the types of materials exposed to mouthwash solutions, contact time with solutions following different surface treatments, and surface texture is thought to be caused by [19, 31].

The in vitro conditions in which our study was conducted differ from the intraoral environment due to factors such as nutritional diversity and saliva. Moran reported that the resulting effects of mouthwashes containing chlorhexidine may vary with consumed food and drink [8, 33]. This difference constitutes the limitation of our study. In addition, long follow-up time and ethical requirements limit clinical studies [34]. Saliva, temperature changes, and pH levels in the oral environment can also affect the long-term color stability and translucency values of materials. No simulator was used for rinsing in this study, only immersion was performed. These limitations may affect the results of the study.

5. Conclusions

Within the limitations of the present in vitro study, the following conclusions were drawn:

- (i) Prefabricated polymerized CAD/CAM discs have been shown to be the most successful temporary restoration material in terms of color stability
- (ii) LAW with whitening effect showed more color change in temporary restorative materials compared to other mouthwashes
- (iii) The color change of temporary restorative materials increases with time

Data Availability

All generated data were used and presented in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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