Evaluation of the color stability of different temporary re-storative materials

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ABSTRACT
This study aimed to evaluate the color stability of different temporary restorative materials in contact with staining solutions, as well as to verify which one presents the highest resistance to staining. In this laboratory study, five types of temporary restorative materials were evaluated: self-curing acrylic resin, bis-acrylic resin, light-curing acrylic resin, CAD/CAM machinable, and 3D printed resin. Thirty samples of each material were produced in a circular mold measuring 10 mm in diameter and 2 mm in thickness. The materials were divided into subgroups (n=10) and immersed in solutions: Coffee, Coca-cola®, and distilled water (control). Color measurements were carried out at baseline, 1, 7, and 14 days using a digital spectrophotometer and the color parameters were calculated according to the CIEDE00 system. The color change data were subjected to two-way ANOVA (temporary material vs time) and posthoc Tukey test ($\alpha = 0.05$). The materials showed a color change only comparing baseline vs. one day, according to acceptability standard $\Delta E00 > 1.8$. Thus, we concluded that there was a difference in color stability already on the first day of immersion. In ad-dition, the coffee solution showed the highest color variation when compared to the other solutions.

Keywords: Temporary Dental Restoration, Color, Prosthesis Coloring.

1 INTRODUCTION

Temporary restorations are used in prosthesis treatments to reach pulp protection, marginal integrity, aesthetics, health, and comfort, and mainly to restore the masticatory function over some time. [1] In addition, they are of great importance for diagnostic evaluation, planning of final restorations, and insertion of the definitive prosthesis. [1,2] The material life span in the mouth is variable and can be extended beyond the time expected, it is also relevant to consider adequate biomechanics and aesthetic aspects. [2] Another factor to be considered is the stability of the material in the buccal environment.

These materials are exposed to an environment where various chemical substances, food, and dying solutions pass through and may change their characteristics. [3] Residual polymers can absorb liquids that enter the oral cavity and tend to change their color over time, and this can influence patients' satisfaction with the treatment.[2] The intensity of color change is affected by endogenous factors including initiator systems, polymerization, matrix composition, particle size, hardness, water sorption, hydrolysis, oxidation of unreacted carbon double bonds, and surface roughness, and the intensity of color change usually depends on the staining substances and the material involved.[3]

Many temporary dental materials are available, from materials with easy-to-handle techniques to digital computer-aided materials. All of those have different characteristics and indications, as well as production costs. [1,4] They are widely used in dental routine and although several studies cover the issue of color stability of temporary restorations over time, the results are still contradictory. [5] The results of color change can be measured by visual scales, being a subjective measurement, or by colorimetric instruments, such as the digital spectrophotometer, which ensures greater accuracy and clarity in the analysis. However, we have not found studies reporting the use of such equipment.

The temporary material chosen needs to present aesthetic quality and should approximate every shape and color of natural teeth, being fundamental to ensure patients' satisfaction.[3] Thus, the objective of this study was to evaluate the color stability of acrylic resin, bis-acrylic, light-curing acrylic resin, and CAD/CAM when in contact with staining solutions. We also aimed to determine which resin demonstrates the highest stain resistance. The null hypothesis of the study was the non-pigmentation of the sample.

2 MATERIALS AND METHODS

2.1 TEMPORARY MATERIALS

Five types of temporary materials (Table 1) were evaluated. For each temporary material analyzed, a total of 30 specimens were manufactured. The acrylic, bis-acrylic, and light-curing acrylic resin samples were manufactured according to the manufacturers' information using a stainless circular metal mold measuring 10 mm in diameter and 2 mm in thickness. Polymerization was performed according to the manufacturer's recommendations.

Two glass plates were placed over the steel mold to promote the removal of excess material and ensure a parallel surface to facilitate the reading of the samples. The specimens of the EVOLUX resin (Evolux, Curitiba, Brazil) were milled in a Ceramill Motion 2 (Amann Girrbach, Curitiba, Brazil) milling machine using the Ceramill Mind software, and those of the Cosmos TEMP resin (Yller, Pelotas, Brazil) were printed on the FlashForge Hunter 3D Printer (FlashForge, São Paulo, Brazil).

After the samples were prepared, they were manually polished using silicon carbide abrasive discs (3M ESPE, St. Paul, MN, USA), in descending order of grains # 320, # 600, # 800, and #1200. Polishing was performed for 30 seconds on each abrasive paper, under water cooling. The samples were washed for 30 seconds between each sandpaper to remove possible residues present on the surface.

All specimens were immersed in distilled water at 37 °C for 24 hours before baseline color measurement. This measurement was taken after washing and drying the specimens and performed on a white background with a digital spectrophotometer (VITA Easyshade Advance 4.0 Model DEASYAS4). After that, the specimens were placed in their respective staining solutions.

Table 1. Temporary materials used.

PRODUCT	MATERIAL	COMPOSITION
Dencôr Lay (Clássico/ São Paulo – SP, Brazil)	Self-curing acrylic resin	Copolymer, methyl ethyl
STRUCTUR 2 SC (Voco/ Cuxhaven, Germany)	Bis-acrylic resin	Methacrylate, peroxide, pigment
REVOTEK™ LC (GC Dental Products, Aichi, Japan)	Light-curing acrylic resin	Urethane Dimethacrylate
Cosmos TEMP (Yller, Pelotas, Brazil)	3D printed resin	Oligomers, monomers, photoinitiators, stabilizers, pigment.
EVOLUX (Evolux, Curitiba, Brazil)	CAD/CAM machinable blocks	PMMA and biocompatible components

2.2 STAINING SOLUTIONS

The specimens were randomized and immersed in three different solutions (three subgroups n=10): distilled water (Cinoad Sudeste, Serrana, Brazil); cola soft drink (Coca-cola®, São Paulo, Brazil; and coffee (Pilão Tradicional, São Paulo, Brazil) - 90g powder to 1 liter of water. The solutions were replaced after each measurement.

2.3 COLOR CHANGE ASSESSMENT

The color assessment was carried out at baseline, and after 1, 7, and 14 days of immersion using a digital spectrophotometer (VITA Easyshade Advance 4.0 Model DEASYAS4). Before the measurements, the specimens were manually cleaned with a P-40 soft bristle brush (ORAL-B) for 30 seconds followed by washing in water to remove sediment remaining from immersion solutions. The color change (ΔE) calculations were performed using the CIEDE$_{00}$ System, established by the "Commission Internationale de l'Eclairage" (International Illumination Commission) CIE, ΔE_{00} =

$[(\Delta L/kLSL)^2 + (\Delta C/kCSC)^2 + (\Delta H/kHSH)^2 + RT(\Delta C^*\Delta H/SC^*SH)]^{1/2}$.[7] Color changes were considered significant when the differences at baseline and the period of evaluation present $\Delta E_{00} > 1.8$.[8]

2.4 STATISTICAL ANALYSIS

Data were analyzed using the Kolmogorov-Smirnov test to assess the normality and the Barlett test for equality of variance (data not shown). As the data showed normality, the color change data in (ΔE_{00}) in each solution were subjected to two-way ANOVA (temporary material vs time) and Tukey's posthoc test to compare different materials and different times. Statistical significance was fixed at ($\alpha = 0.05$).

3 RESULTS

Table 2 presents the data of the temporary materials immersed in distilled water. In these materials, there was no significant difference in the intersection of factors ($p = 0.61$). However, there was a difference between the times alone ($p = 0.003$) and also for the different materials ($p > 0.0001$). Only the materials Light-curing acrylic resin, Acrylic-resin, and 3D Printed resin showed color changes. However, it is important to observe that these changes already happened on the first day (24h) of measurement, being higher than the acceptability standard ($\Delta E_{00} > 1.8$). Regarding the other periods, the color was still higher than the acceptability threshold in comparison to the baseline for both materials, however, without statistically significant difference between the periods (24h, 7 days, and 14 days).

The results of the temporary materials submitted to the Coca-cola® solution did not show a significant difference in the intersection of the factors ($p = 0.99$). There was no difference between the times alone ($p = 0.94$), but a difference was observed for different materials ($p > 0.0001$). In addition, all materials showed color changes already occurred on the first day (24h) of measurement, which was higher than the acceptability standard ($\Delta E_{00} > 1.8$) (Table 3). As regards the other periods, the color was still higher than the acceptability threshold when compared to the baseline, however, without a statistically significant difference between the periods (24h, 7 days, 14 days).

When the temporary materials were subjected to the coffee solution, there was no significant difference in the intersection of the factors ($p = 0.99$). There was no difference between the times alone ($p = 0.94$), but a difference was observed for the different materials ($p > 0.0001$). All materials showed changes already on the first day (24h) of measurement (Table 4), being also higher than the acceptability standard ($\Delta E_{00} > 1.8$). When considering the other periods, the color was still higher than the acceptability threshold in comparison to the baseline, however,r without statistically significant difference between the periods (24h, 7 days, 14 days).

Table 2. Means ± standard deviations of different temporary materials submitted to distilled water at times of 1, 7, and 14 days in CIEDE units (ΔE_{00}).

Material	Time		
	Baseline vs. 1 day	Baseline vs. 7 days	Baseline vs. 14 days
Light-curing acrylic resin	2.6 ± 1.6 Ad	3.0 ± 1.4 ABd	3.8 ± 1.2 Bd
Bis-acrylic resin	1.2 ± 0.6 Ab	1.2 ± 0.5 ABb	1.5 ± 0.5 Bb
Acrylic resin	1.9 ± 0.5 Ac	2.3 ± 0.6 ABC	2.3 ± 0.9 Bc
3D Printed resin	2.2 ± 0.9 Acd	2.9 ± 1.2 ABcd	3.1 ± 1.1 Bcd
CAD/CAM machinable resin	0.5 ± 0.3 Aa	0.4 ± 0.2 ABa	0.7 ± 0.4 Ba

Two-way ANOVA p = 0.61. The same small letters in the same individual column indicate no significant difference (P > 0.05).
The same capital letters within individual rows indicate no significant difference (P > 0.05).

Table 3. Means ± standard deviations of different temporary materials subjected to Coca-Cola® at times of 1, 7, and 14 days in CIEDE units (ΔE_{00}).

Material	Time		
	Baseline vs. 1 day	Baseline vs. 7 days	Baseline vs. 14 days
Light-curing acrylic resin	3.8 ± 1.2 Aab	3.9 ± 1.1 Aab	3.9 ± 1.2 Aab
Bis-acrylic resin	4.2 ± 1.5 Abc	4.1 ± 0.9 Abc	4.2 ± 1.0 Abc
Acrylic resin	2.9 ± 0.7 Aa	2.7 ± 0.9 Aa	2.5 ± 1.0 Aa
3D Printed resin	4.3 ± 0.6 Abc	4.5 ± 1.1 Abc	4.7 ± 0.7 Abc
CAD/CAM machinable resin	4.8 ± 2.0 Ac	5.1 ± 3.1 Ac	5.2 ± 2.9 Ac

Two-way ANOVA p = 0.99. The same small letters in the same individual column indicate no significant difference (P > 0.05).
The same capital letters within individual rows indicate no significant difference (P > 0.05).

Table 4. Means ± standard deviations of different temporary materials subjected to coffee at times of 1, 7, and 14 days in CIEDE units (ΔE_{00}).

Material	Time		
	Baseline vs. 1 day	Baseline vs. 7 days	Baseline vs. 14 days
Light-curing acrylic resin	5.0 ± 1.7 Aa	5.2 ± 1.7 ABa	5.1 ± 1.4 Ba
Bis-acrylic resin	14. 9 ± 4.0 Ac	14.8 ± 4.2 ABc	15.9 ± 3.8 Bc
Acrylic resin	6.4 ± 1.9 Aa	6.6 ± 2.5 ABa	7.5 ± 2.3 Ba
3D Printed resin	7.8 ± 2.0 Ab	8.7 ± 2.8 ABb	12.7 ± 3.3 Bb
CAD/CAM machinable resin	6.0 ± 3.9 Aa	6.1 ± 4.2 ABa	6.5 ± 4.4 Ba

Two way-ANOVA (materials vs time) p = 0.37, time p = 0.033 material p > 0.0001. Same small letters in the same individual column indicate no significant difference (P > 0.05). Same capital letters within individual rows indicate no significant difference (P > 0.05).

4 DISCUSSION

In dentistry, color is an important aesthetic parameter, being responsible for the harmony of the smile and patients' satisfaction with the treatment.[9,20] Since the oral cavity and temporary restorations are subject to different staining solutions, this study aimed to evaluate the main temporary materials in contact with commonly consumed and used solutions, not only subjectively, but with the use of a spectrophotometer.[1]

There are two thresholds for evaluating color, namely the perceptibility threshold (PT) and the acceptability threshold (AT). These thresholds are tools that can be used as quality control to guide the selection of dental materials.[8] The acceptability threshold is the most common value used to evaluate color in dentistry and refers to a broader value describing the acceptability difference of color in a situation according to clinical acceptance, where the standard value is $\Delta E_{00} > 1.8$. [10] In this study, we evaluated color change according to acceptability parameters.

Although there are studies in the literature that evaluate the color stability of temporary materials, no studies were found that evaluated all these materials together. [11] The joint evaluation of these materials is important because each one has its different characteristics, advantages, and disadvantages concerning material and clinical applicability. Therefore, this is an interesting comparison for providing an overview of another factor in the clinicians' choice. [12] Some studies evaluated different resins, such as Structor (bis-acrylic) in comparison to Revotek (light-cure resin)[13], or comparison to Dencorlay (acrylic resin)[1], and they had already found differences in color stability. However, no color stability studies were found for CADCAM resin or Printed 3D resin (EVOLUX and Cosmos TEMP).

Given the hypothesis of the study, the non-pigmentation of the samples was rejected, since there was variation in the color assessment of the specimens. In this study, the comparison between the liquids showed that the staining solution influenced the color change of the specimens, and it seems relevant to mention that the change occurred already on the first contact between the staining solution and the temporary material.

Regarding the color variation of specimens in distilled water, some studies reported that water absorption can be influenced by factors such as unreacted monomers, the inclusion of air, and incomplete polymerization. [5,14,15,16] For this reason, it might provoke a decrease in the material physical properties, increased microleakage and solubility, and color change. [5,14,15,16] In the distilled water, bis-acrylic and CADCAM resins did not reach $\Delta E_{00} > 1.8$, while the other materials showed significant color variation. Therefore, they may be more susceptible to changes due to their composition and other interactions.

When analyzing the behavior of resins in Coca-Cola, we could conclude that all the resins were influenced by the staining liquid, being more affected on the first day of measurement. The acrylic resin was the less affected among all. Among the materials tested, the one that showed the best color stability in the Coca-Cola solution was the acrylic resin, followed by light-cured resin, bis-acrylic resin, 3D Printed, and CADCAM.

However, the coffee solution showed a higher color variation of the specimens when compared to the Coca-Cola solution. Previous studies already showed higher variation in the color of the temporary materials exposed to this solution. [2,4,17] Regarding the coffee solution, the light-cured resin showed the highest resistance to color change, followed by the milled CADCAM. The bis-acrylic and 3D Printed showed the highest vulnerability.

Despite the lower color stability shown by the 3D Printed version, it has advantages over bis-acrylic, such as the elimination of traditional molding steps, and the reducing possible inaccuracies resulting from contraction, expansion, or deformation of the material. In addition, it promotes greater patient comfort and reduced chair time for the dentist. It also has the advantages of low consumption and economical use of the material. [18,19] Besides that, even though acrylic resin, light-cured and CADCAM showed less color change in different staining solutions, they present less favorable characteristics for the agility of the clinical procedure.

This study demonstrated that both staining solutions interfere with the staining of the resins since the first day of contact, decreasing the intensity from the second day onwards to the end of the study, but still clinically significant and visible. Because of these characteristics, it is very important to consider the function and application of the material in the clinical routine, and properly analyze the characteristics of the materials and their advantages and disadvantages to achieve a successful treatment.

5 CONCLUSIONS

Within the limitations of this study, we concluded that there was a difference in the color stability of the materials, but some remained within the acceptability limit. In addition, the coffee solution showed the highest color variation when compared to the other solutions.

CLINICAL APPLICABILITY

Temporary restorations are widely used in prosthetic treatments and can remain in the mouth for a considerable period. They are responsible for aesthetic and func-tional maintenance during the rehabilitation process. In addition, they provide data for the definitive prosthesis and should assure comfort and confidence to the patient. Thus, these materials must be resistant and present such color stability that does not compromise the aes-thetics during the treatment phase.

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CONFLICT OF INTEREST

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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