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Research Article

The Effect of Chlorhexidine Gluconate Mouthrinse on the Color Stability of Different Permanent Prosthetic Resin Materials

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KEYWORDS

3D printed resin, CAD-CAM block, color stability, dental resin material, indirect composite, mouthrinse

ABSTRACT

Introduction: Color stability is a crucial aspect in the longevity and aesthetics of dental prosthetics. Understanding how different materials respond to common oral hygiene practices, such as chlorhexidine mouthrinse, is essential for informed clinical decision-making. This research aims to provide valuable knowledge about the potential effects of chlorhexidine gluconate on the color stability of prosthetic resin materials, contributing to a comprehensive understanding of their performance in actual oral care prognoses. **Objective**: The aim of this in vitro study was to evaluate the effect of mouthrinse on the color stability of two different laboratory-processed resin composite systems, a resin nanoceramic CAD-CAM material and a 3D printed resin material. **Methods:** Forty-eight specimens were prepared from two different indirect composite systems (SR Adoro, Ivoclar Vivadent and Tescera ATL, Bisco); a resin nano-ceramic (Lava Ultimate, 3M ESPE) and a 3D printed permanent crown material (Permanent Crown, Formlabs). Surfaces were ground using carbide grinding paper (Grids 600, 800, 1000) followed by a 50µm Al_2O_3 sandblasting. Then universal polishing paste was applied to the surfaces. The color before and after immersion was measured according to Comission Internationale de L'Eclairage (CIED2000) System and ΔL, Δa, Δb, and ΔE values were calculated. All specimens were immersed in the mouthrinse solution for 24h. Changes in colors (ΔE_{00}) was assessed before and after immersion by a digital spectrophotometer (Vita Easyshade, Vita). Data was analyzed with a one-way ANOVA and a Shapiro–Wilk test of normality was performed. **Results:** After conducting a one-way ANOVA test, it was found that there was no statistically significant difference between the mean values of ΔE_{00} in the test groups ($p=0.105$). The chlorhexidine gluconate mouthrinse did not affect the color change of resin materials manufactured by different methods. **Conclusion:** Within the limitations of the study, the color stability of the tested resin materials in the chlorhexidine gluconate mouthrinse was not affected.

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INTRODUCTION

There has been a growing importance on the aesthetic aspect of teeth and dental treatments among dentists and patients. As a result, there is an increased demand for restorative procedures that not only restore function but also mimic the natural shape, shade and the color of the patient's teeth. The ability to maintain the selected color throughout the functional lifetime of the restoration is an important consideration in achieving a satisfying aesthetic outcome for patients[1]. As more patients request dental treatments that focus on appearance, there is growing need for researchers to develop new more aesthetic alternatives to traditional metal restorations[2]. The natural appearance of teeth is achieved through their optical properties of color, translucency and opalescence. In recent years, advancements in technology have led to the development of dental resin composites that use nano fillers to achieve an optimal balance between strength, wear resistance and translucency, thus improving the clinical performance of the restorative materials[1,3].

The longevity of color stability of the materials plays a crucial role in achieving long term aesthetic success. There are various factors that can be responsible for the discoloration of dental materials in the oral environment. One important aspect to consider is the color stability of composite materials, which can be affected by both external and internal factors. External factors, such as exposure to staining agents like coffee, juice, tea, red wine or mouthrinse can contribute to discoloration. The discoloration of dental materials in the oral environment can also be influenced by internal factors like the type of photoinitiator utilized, duration of polymerization, resin matrix composition, matrix monomers conversion, material hardness and size of particles , and unreacted carbon double bonds oxidation, can also play a role[4-6]. The color stability of resin composites can be improved by using materials that have low water absorption, high filler to resin ratio, smaller particle size, reduced hardness, and an optimal filler matrix coupling system. In addition, indirect composite materials are typically considered to have better color stability than direct resin composites due to their higher degree of conversion[7].

A significant clinical challenge associated with the dental material is the accumulation of dental plaque on the restoration surface, which provides a suitable environment for oral microorganisms to thrive[8]. Maintaining oral hygiene is crucial and this can be achieved through regular mechanical remove of plaque or dentists often prescribe chemical plaque control agents. Mouthrinse typically contain a combination of ingredients such as antibacterial agents, alcohol, essential oils, salt, dyes and organic acids. Chlorhexidine gluconate (CHX) is well known antibacterial agent that is commonly administered as a spray, gel or mouthrinse. However, the use of CHX can also result in some adverse effect such as discoloration on the restorative materials, formation of calculus and unpleasant taste in the mouth[9].

The development of novel composite materials that incorporate nano ceramic particles within a resin matrix that has undergone a high degree of curing has been made possible by the latest advances in computer-aided design/computer-aided manufacturing (CAD-CAM) technology[10]. Digital manufacturing encompasses both subtractive and additive techniques, such as computer-aided milling and 3D printing, respectively. The use of CAD-CAM systems has led to the rise in popularity of three dimensional (3D) printing or additive manufacturing in dentistry[11]. The utilization of 3D printing technology in dentistry enables the creation of prosthetic devices such as surgical guides, crown restorations, dental bridges, and dentures using 3D printing resins[12]. One of the key benefits of 3D printing technology is the ability to print objects with small size and high precision. The high level of precision is one of the most significant advantages of dental 3D printing[13].

Despite the growing popularity of 3D printing technology in the manufacture of dental restorations, there is a lack of researches to guide the use of 3D printing resins for intraoral applications. This study aimed to assess and compare the color stability of more recent, more advanced dental materials and materials with different contents of each other, particularly the color stability of modern restorative materials and 3D printed permanent crown material when exposed to chlorhexidine gluconate mouthrinse. In the current study, the null hypothesis was that the color stability of the all tested resin materials would remain unaffected after immersed into the CHX mouthrinse.

MATERIALS AND METHODS

Four different permanent prosthetic resin materials and chlorhexidine gluconate mouthrinse were used in the current study, and their details are listed in Table 1. In this study, total of 48 specimens were fabricated from each material (n=12). To create the laboratory processed indirect composite specimens, Adoro (ADR) and Tescera (TSC) materials were placed into a metal mold of standard dimensions. The composite resin-filled mold was then sandwiched between two glass slides and compressed to eliminate any excess material. For TSC material light cup and heat cup were utilized during polymerization to produce the composite specimens. These cups are filled with water and used during the curing process. The curing process was performed in Tescera Procesing Base Unit under pressure and light for 2 minutes, final curing process was done under pressure, light and heat for 13 minutes. ADR specimens were polymerized using a Targis Power-Upgrade system with heat and light for 25 minutes.

To produce the specimens from Formlabs Permanent Crown material (FMLB), the slicing software (Chitubox 64, Chitu Systems, GD, China) was used to import the digital file, which was saved in the .STL format and then printed using a 3D-printer (Form3, Formlabs Inc., Sommerville, MA, USA). The 3D-printing resin was poured into the printer and the specimens were set to be printed on layer thickness of 50 µm , with the orientation set at 0 °, and predetermined dimensions for the specimens. The 3D printing process was performed using a Stereolithography 3D printer that utilized a 405-nm UV LED and a laser power of 250 mW. The printed specimens were then cleaned to eliminate any uncured monomers remaining on the surface for 10 minutes in a ultrasonic washing machine (Wash and Cure 2.0, Anycubic Technology, Shenzen, China) using 99,9% isopropyl alcohol.

The post-curing process was done for 3 minutes in accordance with the instructions provided by the manufacturer of the unit for post-curing 3D-printed resin (Wash and Cure 2.0, Anycubic Technology, Shenzen, China). The resin nano ceramics CAD-CAM specimens were fabricated by cutting the block with the thickness of 2 mm (IsoMet 5000, Buehler, Illinois, USA). In order to maintain uniformity across all specimens, a metal mold was employed to mark the diameters of the discs, which were subsequently cut to a standardized size using a diamond bur (Table 1).

The fabricated total specimens were finished on both sides using a carbide grinding papers (Grids 600,800,1000) under water cooling and subjected to a blasting process using 50 µm aluminum oxide abrasive at a distance of 10 mm, with a pressure of 0,2 MPa, for 10 seconds. All specimens were then polished on the both sides with universal polishing paste (Ivoclar Vivadent AG, Liechtenstein). To ensure consistency in the results, all specimens were finished and polished by a single person in order to standardize the process.

The specimens produced from each material were separated into four groups, each containing 12 specimens. At first, baseline color measurement (T0) was performed before immersion into CHX mouthrinse. The baseline colors were assessed on a CIED2000 color system using a spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen, Germany) on white baseline. The CIED2000 color system was selected as it is particularly effective for detecting small variations in color differences. Also provides a more accurate indication of color perceptibility and acceptability. Before measuring the specimens were dried and were in contact with the measuring probe of the spectrophotometer during measuring. The color measurements were conducted on several occasions, and the mean value was documented. The CIED2000 formula was used as a reference, proposed by the Comission Internationale de L'Eclairage (CIE) also commonly used in the large number of publications (17). Formula is as follows:

$$\Delta E00=\sqrt{(\Delta L' KLSL)2+(\Delta C' KCSC)2+(\Delta H' KHSH)2+RT(\Delta C' KCSC)(\Delta H' KHSH)}$$

Table 1. Summary of tested materials and mouthrinse compositions and manufacturers

Material Group	Material	Composition	Manufacturer
Indirect composite material	SR Adoro	Dimethacrylate (17–19 wt.%); copolymer and silicon dioxide (82–83 wt.%). Content of inorganic fillers: 64–65 wt.% / 46– 47 vol.%. Particle size: 10–100 nm.	İvoclar, Vivadent, Schaan, Liechtenstein
Indirect composite material	Tescera ATL	Amorphous silica, Glass frit TEGDMA, BisGMA Camphoroquinone Tertiary amine TBPZ	Bisco, Schaumburg, Illinois, USA
CAD/CAM resin nano-ceramic block	Lava Ultimate	Bis-GMA, UDMA, Bis-EMA, TEGDMA SiO2 (20 nm), ZrO2 (4–11 nm), aggregated ZrO2/SiO2 cluster (SiO2 = 20 nm, ZrO2 = 4–11 nm) is 80 % by mass	3M ESPE, St Paul, MN, USA
3D printed permanent crown resin material	Permanent Crown	4,4'-isoprop<ylidiphenol, ethoxylated and 2-methylprop- 2enoic acid. Silanized dental glass, methyl benzoylformate, diphenyl(2,4,6-trimethylbenzoyl) phosphine oxide. Total content of inorganic fillers (particle size 0.7 µm) is 30–50% by mass	Formlabs, Sommerville, MA, USA
Mouthrinse	Kloroben	0.12% Chlorhexidine gluconat 0.15% Benzydamine hydrochloride, Lutrol F36 Sorbitol Ethanol	Drogsan Medical, Turkey

Afterward, specimens were immersed in 20 ml of 0,12% CHX mouthrinse at room temperature. The immersion period of 12 hours is equivalent to the use of mouthrinse for 1 minute twice a day for 1 year. In order to stimulate a longer period of exposure, the specimens were kept in the solution for 24 hours in this study, which simulates 2 years of mouthrinse use at a rate of 1 minute twice a day[14]. Following a 24-hour interval, the specimens were rinsed with distilled water, dried, and the color measurement process was repeated accordingly. (T1). To evaluate the color change, data was analyzed using SPSS version 23 software (IBM SPSS, Chicago, IL, USA.). One-way ANOVA analysis of variance was used, to compare the normally distributed ΔE00 values between the groups and Shapiro-Wilk test of normality was conducted. The results were displayed in both mean and standart deviation. A significance level $p<0.05$ was used to determine statistical significance for all tests.

RESULTS

The color changes of all groups studied, before and after immersing into CHX mouthrinse are presented in Table 2.

Table 2. ΔE00 values (mean and standart deviation) of tested materials

	Mean ±SD	SE	T	p
Formlabs	1,81±0,68	1,82 (0,84 -2,97)	2,173	0,105
Adoro	1,6 ± 0,98	1,62 (0,36 -3,40)		
Lava Ultimate	1,1 ± 0,49	1,01 (0,64 -2,09)		
Tescera	1,3 ± 0,58	1,20 (0,56 -2,36)		

Comparison of ΔE00 values between groups were done with one-way ANOVA and the results indicated that there was no statistically significant difference ($p=0.105$). The average mean of group Formlabs was 1,81, the average mean of group Adoro was 1,66, the average mean of group Lava Ultimate was 1,15 and the average mean of group Tescera was 1,33.

All restorative materials colors that were observed were within clinically acceptable limits. The results revealed that the mouthrinse did not have any impact on color change on resin materials that were manufactured using different methods.

DISCUSSION

One of the challenges associated with the failure of aesthetic restorations is their inconsistent stainability and color stability. In this study, the discoloration was objectively evaluated using digital analysis with a spectrophotometer before and after immersion into chlorhexidine gluconate mouthrinse. The spectrophotometer measures the color change quantitatively and objectively. This method is commonly used in the dental field for color evaluation of restorative materials[15,16].

The correct use of a color difference formula is important in order to achieve a better correlation between perceptibility and acceptability. There is ongoing debate about what the threshold level for color difference should be in order to be considered visually acceptable. In dentistry, visual perceptibility and acceptability threshold are important concepts when it comes to color change. The point at which the color difference becomes perceptible to 50% of the observers is referred to as the perceptibility threshold, and the acceptability threshold is when the color difference is considered acceptable by 50% of observers. The best fit on average 50:50% acceptability and perceptability thresholds to be achieved were ΔE00=2.23 and ΔE00=1.25, respectively (18). As shown in the results section of this study, all dental materials immersed into mouthrinse solution resulted within clinically acceptable limits. It was observed that there was little variations in color shift between trademark and shades, which resulted in no significant impact of the color coordinates of the materials.

Our results support the idea that increased proportion of resin matrix and a lower proportion of filler particles can result in increased water absorption. As smaller filler particles cannot absorb water, higher amount of matrix can lead to debonding between the filler and matrix or even degradation due to hydrolysis. It is evident that the water sorption properties are closely tied to the chemical composition of the monomer used. Color change is greater in materials with low filler content and high resin content[19-21].

Additionally, difference in matrix structures also has an effect on the color change of restorative materials. The color changes may be attributed to the composition of resin matrix used, such as the types of monomers and their proportions. The specific properties of the monomers and their interactions with other materials can affect the color stability of the composite. The presence of Bis-GMA, Bis-EMA or TEGDMA in matrix structure also is known to increase materials hydrophilic properties and due to the fact that TEGDMA has a higher water sorption capability. On the other hand, UDMA is more resistant to staining as it has a lower water uptake and is less sensitive to changes in color and water absorption. However, it is not known exactly what effects the monomers related to the color change of composite materials[22-24]. Therefore, materials that are more hydrophilic tend to have greater discoloration tenseness compared to those that are more hydrophobic. Our findings suggests that the presence of Bis-GMA, Bis-EMA and TEGDMA in studied materials structure was not a significant factor in color change.

The other factors that can affect the restorative materials are the degree of polymerization of composite resins including the technical characteristics of the light-curing unit, the conditions of photopolymerization, and the post curing period and temperature. These elements, such as light intensity, wavelength range, and thermal emission, as well as the application mode and exposure time, all play role in determining the degree of polymerization[25-27]. Materials such as Adoro and Tescera are produced though high temperature, light and high-pressure polymerization, resulting in high polymerization rates and compact structures. Therefore, they showed a significant low color change and low $\Delta E00$ values.

Additionally, 3D printing resins compared to other materials has a low polymerization rate which is a contributing factor to their low color stability. 3D printing resins, despite undergoing post-curing process, have relatively low polymerization rates, which can negatively affect their mechanical properties, biological activity and increase the likelihood of discoloration caused by surface integrity and residual monomers (28). The presence of residual monomers and additives can lead to diffusion of cured materials over time. This can cause potential negative effect on the properties and performance of the final restoration. The photoinitiators were identified as a significant contributor to this release, during extraction process of resin-based materials. The choice of an appropriate photoinitiator is crucial in the photopolymerization process. It should have a correlation between its absorption characteristics and the emission characteristics with those of the light source used, and must not be toxic or lead to discoloration[29,30].

Kim et al. (2022) evaluated 3 different photoinitiators and evaluated the color stability and citotoxicity by preparing experimental 3D printing resin materials. Among tested photoinitiators, ethyl (2,4,6-trimethylbenzoyl) phenylphosphinate (TPO-L) and diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide (TPO) groups presented low discoloration in all of the condition compensations[31]. The Formlabs permanent resin material used in this study, also contains TPO, which may have contributed to the color stability results observed. Apart from the constituents of the 3D printing resin, the processing parameters used to fabricate the specimens in this study could also impact the surface texture. Therefore, further follow-up research is needed to enhance the techniques used for printing, post-cure treatments, and the materials themselves.

Some elements are added to mouthrinse such as zinc and is intended to provide benefits such as plaque control, reduction of bad breath, and preventing of tarata buildup. However, this element can remain present in plaque and saliva for extended periods, potentially leading to noticeable discoloration of resin composite materials. Cengiz at al., evaluated the effect of four different mouthrinse and suggested that noticeable discoloration of the specimens was likely caused by the zinc chloride content of the mouthrinse[32].

Additionally, mothrinses containing alcohol substance can lead to dissolution of the organic matrix, and make the composite more susceptible to staining[14]. It was found in previous research that using mouthrinse with high alcohol content may have an effect on softening composite resin materials. A research conducted by Asmussen showed that ethanol specifically has a softening effect on BIS-GMA- based materials[33]. A study by Ulusoy et al., reported that composite resin exposed to mouthrinse containing alcohol did not exhibit any noticeable color change when compared to those exposed to non-alcoholic mouthrinse[34]. Our finding also showed that ethanol containing mouthrinse Kloroben did not caused color variation unacceptable in a clinical way.

It is important to note that in a clinical setting, the oral environment is different from the laboratory conditions used in this research. Factors such as the variety of saliva, the effect of different foods, and their interaction can contribute to discoloration. The success of the restoration is determined by the appropriate choice and utilization of the right material for the specific clinic situation.

CONCLUSION

The outcome of this in-vitro study suggest that the microstructure of different permanent restorative materials immersed into chlorhexidine gluconate mouthrinse demonstrated no color change as visually perceptible. It can be concluded short term exposure of restorative materials to mouthrinse may not affects their appearance. The results suggest that these types of mouthrinses are safe for use with tested materials. However, it is important to take into account the potential for color change when selecting and matching the shade of aesthetic restorative materials before they are used in clinical cases. Additionally, it is recommended that further research be conducted to examine the effect of extended immersion periods, in order to gain more detailed understanding on discoloration.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interest regarding the publication of this paper.

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