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Color Stability of Vita 3D-Master Shade Tabs Following Repeated Disinfection: An In Vitro Study

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ABSTRACT

Objectives: To evaluate the color stability of VITA 3D-Master shade tabs following repeated disinfection with Peroxan 6% and Desomed 0.5%, compared to a distilled water control.

Materials and Methods: Ninety VITA 3D-Master shade tabs representing 10 shades were divided into 3 groups (n = 30): Control, Peroxan 6%, and Desomed 0.5%. Each tab was immersed for 10 minutes per cycle and subjected to 200 disinfection cycles. Color measurements were performed at baseline, 50, 100, 150, and 200 cycles using a VITA Easyshade V spectrophotometer. Color differences were calculated using the CIEDE2000 formula. Data was analyzed using repeated-measures ANOVA and Tukey's test ($\alpha = 0.05$).

Results: At 200 cycles, mean ΔE00 values were 0.9 ± 0.2 for Control, 2.8 ± 0.4 for Peroxan, and 3.6 ± 0.5 for Desomed tabs. 20% of Peroxan tabs and 100% of Desomed tabs exceeded the clinical acceptability threshold of $\Delta E00 > 2.7$. Repeated-measures two-way ANOVA showed significant main effects for group ($p < 0.001$), time ($p < 0.001$) and group × time interaction ($p<0.001$). Mauchly's test indicated that the assumption of sphericity was violated for the factor time, $\chi^2(9) = 45.23$, $p < 0.001$; therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates $\varepsilon = 0.72$. Post-hoc analysis using Tukey's test showed significant differences between all groups at each post-disinfection time point ($p < 0.001$).

Conclusions: Repeated disinfection with Peroxan 6% and Desomed 0.5% solutions caused color changes in VITA 3D-Master shade tabs. Desomed 0.5% solutions reached the clinical acceptability threshold of $\Delta E00 = 2.7$ at 100 cycles and exceeded it thereafter, while Peroxan 6% solutions caused unacceptable changes in 20% of tabs at 200 cycles. These findings suggest that alternative disinfection protocols should be considered to preserve shade matching accuracy in clinical practice.

Keywords: Color stability, VITA 3D-Master, Disinfection, Peroxan, Desomed, CIEDE2000.

1. Introduction

Accurate shade matching is a fundamental determinant of aesthetic success in restorative and prosthetic dentistry. Discrepancies between the selected shade and the final restoration can lead to patient dissatisfaction, increased chair time, and economic burden due to remakes (1,2). The VITA 3D-Master shade system was introduced to overcome the limitations of the VITA classical system by providing a more systematic arrangement based on value, chroma, and hue, thereby improving shade selection accuracy (1-3). However, the reliability of shade selection depends not only on the system used, but also on the physical integrity and color stability of the shade tabs themselves.

Infection-control guidelines recommend appropriate cleaning and disinfection of reusable dental items between patients to prevent cross-contamination (4,5). Chemical disinfection remains a practical method in clinical settings due to its efficacy and ease of use.

The impact of disinfectants on dental materials has been widely investigated. Several studies have reported that repeated chemical exposure can alter the surface roughness, microhardness, and color stability of resin-based materials (6-9). Porto et al. in their systematic review concluded that disinfectants have a cumulative effect on the color stability of dental materials, with changes becoming clinically relevant after multiple cycles (6). Similarly, Barilli et al. found that oxidative disinfectants led to progressive degradation of resin-based materials over time due to polymer chain scission (7).

Specifically, hydrogen peroxide and peracetic acid are strong oxidizing agents. Giti et al. demonstrated that hydrogen peroxide causes bleaching effects on resin-based materials through the breakdown of chromophores, leading to increased ΔE values with prolonged exposure (15). Kim et al. further reported that peracetic acid can induce both color changes and reductions in mechanical properties of dental polymers (16). On the other hand, phenolic compounds, such as those in Desomed solutions, are known for their antimicrobial efficacy, but may also cause staining and plasticization of polymer matrices, potentially accelerating discoloration (14).

Despite this body of evidence on restorative and denture materials, research focusing specifically on shade guides is limited. Singh et al. reviewed current shade guide disinfection protocols and highlighted the potential for cumulative effects, but noted a lack of quantitative data on color change after repeated cycles (10). Shade tabs are unique, because they are handled multiple times daily, exposed to saliva, light, and disinfectants, and serve as the reference standard for shade selection. Even minor color shifts can propagate errors to the final restoration.

To date, no study has quantitatively evaluated the color stability of VITA 3D-Master shade tabs following repeated exposure to high-level disinfectants, such as Peroxan 6% and Desomed 0.5% solutions over an extended number of cycles. Most available data is based on single exposures or on different material types. Given that the clinical acceptability threshold for color difference is $\Delta E00 > 2.7$ (11), it is critical to determine at what point repeated disinfection causes shade tabs to exceed this threshold.

Therefore, the aim of this in vitro study was to evaluate and compare the color stability of VITA 3D-Master shade tabs following repeated exposure to Peroxan 6% and Desomed 0.5%, solution relative to a distilled water control, over 200 disinfection cycles.

2. Materials and Methods

Ninety VITA 3D-Master shade tabs (VITA Zahnfabrik, Bad Säckingen, Germany) representing 10 shades (1M1, 1M2, 2M1, 2M2, 2M3, 3M1, 3M2, 3M3, 4M1, 4M2) were selected. Three tabs of each shade were used, with one tab randomly allocated to each of the three groups, resulting in 30 tabs per group (n = 30). All tabs were tracked longitudinally across all cycles.

Two disinfectants were used; namely: Peroxan 6% (Peroxan Company, Tehran, Iran), and Desomed 0.5% (Kolodent, Cologne, Germany) solution. Chemical composition of disinfectants employed is presented in Table 1. The control group was immersed in distilled water.

Table 1. Composition of the disinfectant solutions used

Ingredients	Generic name	Ingredients	Manufacturer	Concentration
Peroxan 6%	Hydrogen peroxide + Peracetic acid	H2O2, CH3COOOH, CH3COOH	Peroxan, Company, Tehran, Iran	6%
Desomed 0.5%	Phenolic derivative	C6H5OH 0.5% w/v, Aqua	Kolodent, Cologne, Gernany	0.5% w/v

Each tab was immersed in the assigned solution for 10 minutes per cycle at room temperature (23 ± 2°C). The specimens underwent 200 disinfection cycles. Between cycles, tabs were rinsed thoroughly with distilled water for 30 seconds and air-dried.

Color measurements were performed using a VITA

Easyshade V spectrophotometer (VITA Zahnfabrik, Bad Säckingen, Germany) in Specular Component Included (SCI) mode. The device was calibrated before each measurement according to the manufacturer's instructions. Measurements were taken at baseline, and after 50, 100, 150, and 200 cycles. The probe tip was placed perpendicular to the middle third of the labial surface of each tab. Three readings were taken and averaged.

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{\frac{1}{2}}$$

Where Δ *L*', Δ *C*', Δ *H*' are the differences in lightness, chroma, and hue. S_L, S_C and S_H are the weighing functions for the lightness, chroma, and hue components, respectively. R_T is a function that accounts for the interaction between chroma and hue differences in the blue region. K_H, K_C and K_L are the parametric factors to be adjusted according to different viewing parameters and were set to 1. The clinical acceptability threshold was set at ΔE00 = 2.7 (11).

Statistical analysis was performed using SPSS, version 26.0 (IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro-Wilk test. A repeated-measures two-way ANOVA was conducted to evaluate the effects of disinfectant as the between-subjects factor with 3 levels, and number of cycles as the within-subjects factor with 5 levels: baseline, 50, 100, 150, and 200 cycles, time, and their interaction on ΔE00 values. Repeated-measures ANOVA was conducted with group as the between-subjects factor and time as the within-subjects factor. Mauchly's test indicated violation of sphericity for time, $\chi^2(9) = 45.23$, $p<0.001$. Therefore, Greenhouse-Geisser correction was applied, $\varepsilon = 0.72$. There were significant main effects of group, $F(2, 87) = 125.3$, $p < 0.001$, time, $F(2.88, 250.56) = 98.2$, $p < 0.001$, and group × time interaction, $F(5.76, 250.56) = 52.1$, $p<0.001$. Post-hoc pairwise comparisons were performed using Tukey's test. A p-value less than 0.05 was considered statistically significant.

3. Results

At 150 cycles, 60% of tabs immersed in (18/30) exceeded acceptability value ΔE00 > 2.7, while at 200 cycles, 20% of tabs immersed in Peroxan tabs (6/30) and 100% of those immersed in Desomed solutions (30/30) exceeded the threshold acceptability threshold.

The number and percentage of tabs exceeding the clinical acceptability threshold are shown in Table 2. The mean ΔE00 values at each time point are summarized in Table 3. The trends in color change across all disinfection cycles are illustrated in Figure 1. Representative shade tabs after 200 cycles are shown in Figure 2.

A repeated-measures two-ways ANOVA revealed significant main effects for disinfectant group $F(2, 87) = 125.3$, $p < 0.001$, time $F(2.88, 250.56) = 98.2$, $p < 0.001$, and group × time interaction $F(5.76, 250.56) = 52.1$, $p < 0.001$. Mauchly's test indicated that the assumption of sphericity was violated for the factor time, $\chi^2(9) = 45.23$, $p < 0.001$; therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates $\varepsilon = 0.72$. Post-hoc analysis using Tukey's test showed significant differences between all groups at each post-disinfection time point (50, 100, 150, and 200 cycles; $p < 0.001$).

Table 2. Number and percentage of VITA 3D-Master shade tabs exceeding clinical acceptability threshold ΔE00 > 2.7

Cycles	Control n=30	Peroxan n=30	Desomed n=30.	P- value
150 cycles	0 (0%)[a]	0 (0%) [a]	18 (60%) [b]	<0.001
200 cycles	0 (0%)[a]	6 (20%) [b]	30 (100%) [c]	<0.001

Different superscript letters within the same row indicate statistically significant differences between groups, $p < 0.05$.

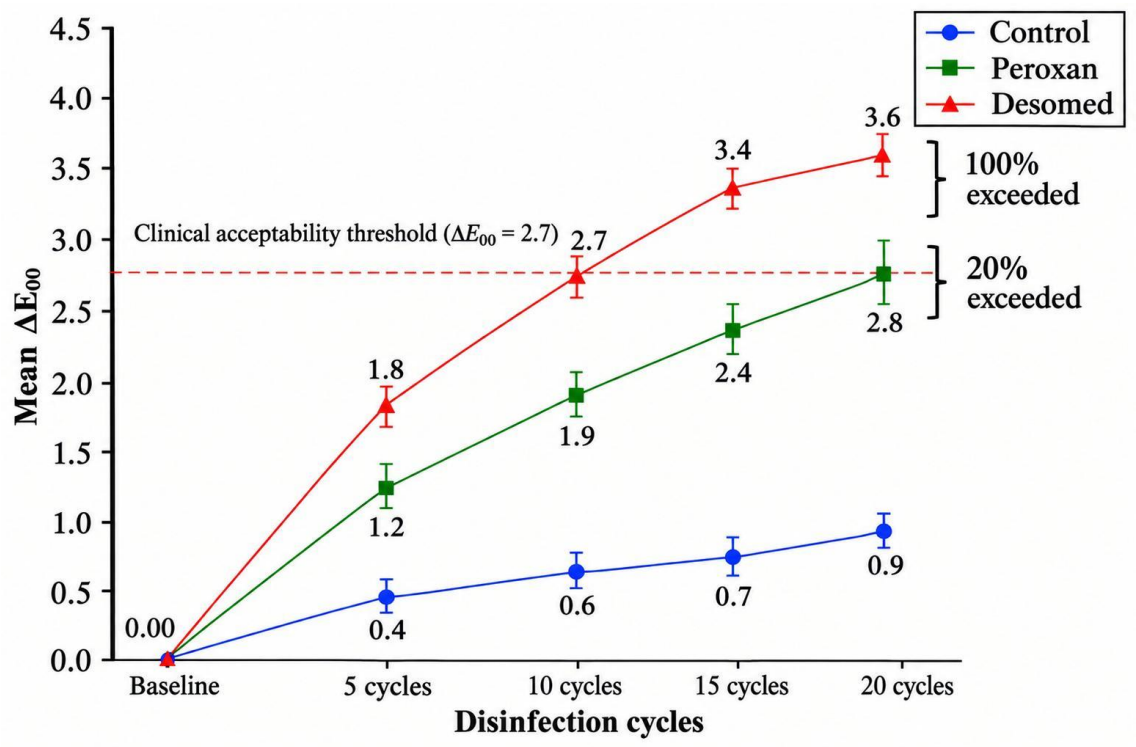


Figure 1. Mean ΔE00 changes of VITA 3D-Master shade tabs across 200 disinfection cycles. Error bars represent ±1 standard deviation. The red dashed line indicates the clinical acceptability threshold of ΔE00 = 2.7

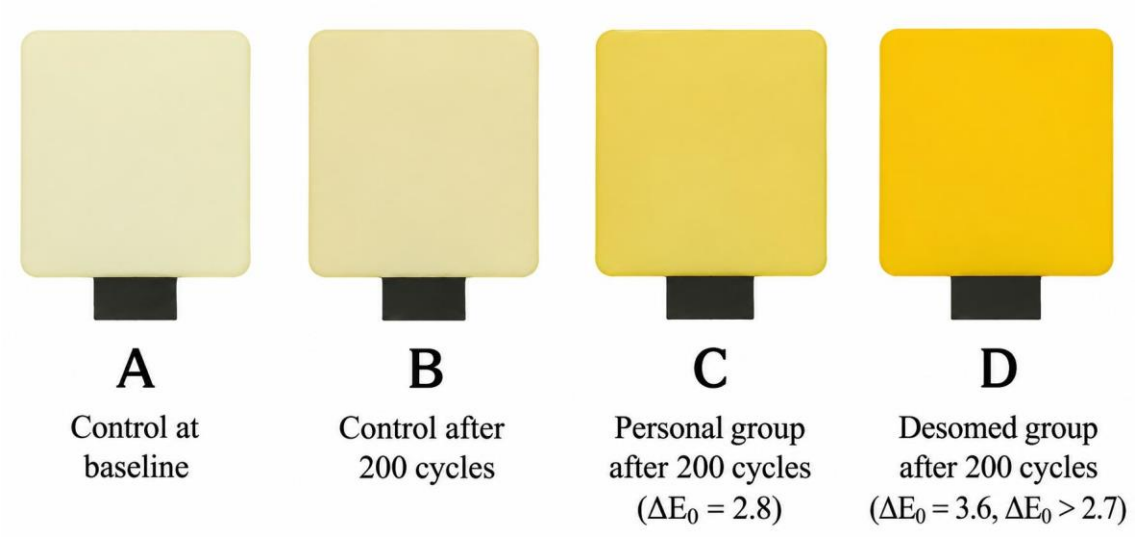


Figure 2. Representative VITA 3D-Master shade tabs after 200 disinfection cycles. (a) Control at baseline. (b) Control after 200 cycles. (c) Peroxan group after 200 cycles (ΔE00 = 2.8). (d) Desomed group after 200 cycles (ΔE00 = 3.6, ΔE00 > 2.7)

Table 3. Mean ΔE00 values and standard deviations of VITA 3D-Master shade tabs across disinfection cycles

Cycles	Control n=30	Peroxan n=30	Desomed n=30
Baseline	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
50 cycles	0.4 ± 0.1^{a}	1.2 ± 0.3^{b}	1.8 ± 0.4^{c}
100 cycles	0.6 ± 0.2^{a}	1.9 ± 0.3^{b}	2.7 ± 0.4^{c}
150 cycles	0.7 ± 0.2^{a}	2.4 ± 0.4^{b}	3.4 ± 0.5^{c}
200 cycles	0.9 ± 0.2^{a}	2.8 ± 0.4^{b}	3.6 ± 0.5^{c}

Different superscript letters within the same row indicate statistically significant differences between groups, $p < 0.05$.

4. Discussion

The results of this study rejected the null hypothesis, as Desomed 0.5% disinfectant caused a color change that exceeded the clinical acceptability threshold of ΔE00 = 2.7 at 100 cycles, while Peroxan 6% caused unacceptable changes in 20% of tabs after 200 cycles. At 200 cycles, 100% of shade tabs disinfected using Desmond exceeded the clinical acceptability threshold, while the control group remained well below this threshold. These findings suggest that repeated exposure to the disinfectant solutions contributed substantially to the observed color changes, beyond the effects of water alone.

The color instability observed in the Peroxan group may be related to its oxidizing composition. Peroxan 6% contains active ingredients including hydrogen peroxide and peracetic acid, as reported by the manufacturer (13). Peracetic acid is a highly reactive oxidizing agent used in dentistry for surface disinfection (14). However, repeated immersion for 200 cycles represents an extreme challenge that may lead to oxidative degradation and bleaching of polymer matrices (15,16). Hydrogen peroxide is known to cause bleaching effects on resin-based materials through the breakdown of chromophores (15), which likely explains the progressive and cumulative increase in ΔE00 values observed at 50, 100, 150, and 200 cycles.

Desomed 0.5%, a phenolic-based disinfectant, caused more pronounced color changes. The results showed that Desomed produced a higher ΔE00 than Peroxan at 200 cycles (3.6 vs. 2.8), and reached the threshold earlier at 100 cycles, suggesting that phenolic disinfectants may pose a greater risk to the long-term color stability of shade guides compared to oxidizing agents.

When comparing the two disinfectants, Desomed 0.5% demonstrated a significantly greater detrimental effect on color stability than Peroxan 6%. This is consistent with the chemical nature of phenolic compounds, which are known to interact with polymer matrices through sorption and plasticization, leading to accelerated pigment uptake and discoloration (14). In contrast, the oxidative action of Peroxan 6% appears to cause a slower, more progressive bleaching effect that required 200 cycles to produce clinically unacceptable changes in only 20% of tabs. These findings align with Barilli et al. who reported that phenolic-based disinfectants induced more rapid surface and optical alterations in resin-based materials compared to oxidizing agents (7). From a clinical standpoint, this suggests that if chemical disinfection of shade guides is unavoidable, oxidizing agents such as Peroxan 6% may be preferable to phenolic agents like Desomed 0.5% to minimize cumulative color shifts. However, both agents exceeded acceptable thresholds with repeated use, reinforcing the need for alternative strategies such as barrier protection or UV disinfection that do not involve direct chemical immersion.

These results indicate that repeated disinfection cycles may be detrimental to the optical properties of polymer-based shade guides. Alshiddi and Al-Mogbel reported that chemical disinfectants caused significant color changes in acrylic resin denture base materials after repeated cycles (8). Porto et al. in their systematic review concluded that disinfectants have a cumulative effect on the color stability of dental materials (6). Menezes et al. also observed increased surface roughness and color change following disinfection protocols (9). Singh et al. reviewed current shade guide disinfection protocols and highlighted the potential for cumulative effects on shade guides (10). Menezes et al. also observed increased surface roughness and color change following disinfection protocols (9). Singh et al. reviewed current shade guide disinfection protocols and

highlighted the potential for cumulative effects on shade guides (10). These results support our findings that repeated disinfection cycles may be detrimental to the optical properties of polymer-based shade guides.

The clinical acceptability threshold of ΔE00 = 2.7 was used in this study (11). It should be noted that other studies have suggested lower thresholds for perceptibility, such as ΔE00 ≈ 1.8, which may further increase the clinical relevance of the observed changes. Using the threshold of 2.7, the mean ΔE00 value in the Desomed group reached 2.7 at 100 cycles, whereas the Peroxan group reached 2.8 at 200 cycles, further emphasizing the progressive effect of repeated disinfection.

From a clinical perspective, accurate shade selection is critical for esthetic restorations (3). Any shift in the color of the shade tab can lead to a mismatch between the selected shade and the final restoration, resulting in patient dissatisfaction and remakes. The results of this study indicate that frequent disinfection of shade guides with strong oxidizing or phenolic agents may compromise shade matching accuracy. Dental professionals should consider using disposable barrier sleeves for shade guides during patient contact, or limiting direct immersion to the minimum time required by the manufacturer. Previous studies have also emphasized the importance of accurate shade matching for patient satisfaction (17,18) and the influence of surface properties on color perception (19,20) and the cumulative effect of sterilization on the shade guide color (21, 22). However, as this is an in vitro study, clinical or long-term validation is needed before recommending routine implementation of alternative protocols.

Though, despite the relevant results obtained from the current study, it should be noted that it has several limitations. It was an in vitro study and may not fully replicate intraoral conditions, such as exposure to saliva, food pigments, and lighting variations. Only two disinfectants were evaluated, and the 10-minute immersion for 200 cycles exceeds typical clinical protocols, but was designed to simulate long-term use (10). Future studies should evaluate other dental-specific disinfectants, different immersion times, and the effect on other shade guide systems, such as VITA Classical (17). Frequent immersion of shade guides in strong oxidizing or phenolic disinfectants may compromise shade matching accuracy.

5. Conclusions

Within the limitations of this in vitro study, repeated disinfection of VITA 3D-Master shade tabs using Peroxan 6% and Desomed 0.5% for 200 cycles resulted in color changes. Desomed 0.5% reached the clinical acceptability threshold of ΔE00 = 2.7 at 100 cycles and exceeded it thereafter, while Peroxan 6% caused unacceptable changes in 20% of tabs at 200 cycles. Clinicians should exercise caution when disinfecting shade guides and consider alternative disinfection methods to preserve color accuracy.

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