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Effect of Different Bleaching Methods on Color Stability of Two Laminate Veneer Materials

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ABSTRACT

Background: Laminate veneer restorations should maintain their color and translucency as long as possible. Patients seeking whiter teeth are liable for color changes of pre-existing laminate veneers. Therefore, searching for the best method of bleaching and the laminate veneer material that can provide good color stability is a prime requisite.

Objective: This study evaluated the effect of different bleaching methods on the color stability of different laminate veneer materials.

Materials and methods: Twenty samples were divided into two main groups: 10 discs of lithium disilicate glass-ceramic (IPS E Max CAD), representing group E and 10 discs of nanoceramic composite, representing group C. Each main group was divided into two subgroups (n=5), where subgroup (O) received chemical in-office bleaching, and subgroup (L) received diode laser-activated bleaching. Color measurement of each group was assessed at baseline, after their accelerated coffee staining for one week, and finally after bleaching agent application. The color of the samples was evaluated according to the CIE L*C*H color parameters using a Vita Easy-Shade Spectrophotometer. Colors were compared using the ΔH*, ΔC*, ΔL*, and ΔE at baseline, after accelerated coffee staining, and after bleaching.

Results: There were statistically significant differences among study groups for all color parameters after accelerated staining with coffee. After bleaching, there were statistically significant differences among study groups for all color parameters. The lowest mean color change value of ΔE was revealed by the IPS E Max CAD samples that are treated with in-office bleaching (EL), followed by EO, then CL, and the greatest mean color change value was revealed by CO.

Conclusions: IPS E Max CAD ceramic can provide the best choice for a color-stable veneer that can preserve its color even after diode laser-activated bleaching.

KEYWORDS: Chemical in-office bleaching, Diode laser-activated bleaching, IPS E Max CAD, Nano-ceramic composite, Color measurement.

1. INTRODUCTION

An important obstacle facing contemporary dentistry is replicating the ideal optical characteristics of real teeth with synthetic materials [1]. Newer bleaching products have started to appear due to the growing demand for teeth whitening. Dental bleaching is recommended because it can fulfill the needs of both patients and professionals and is affordable, easy to accomplish, and less invasive [2]. The application of bleaching agents on dentition with pre-existing laminate veneers has gained attention due to the increasing demand for the best possible aesthetic appearance. Patients' demand for aesthetically pleasing healthy smiles drives ongoing research and development of composite restorative materials. Composite resin should have color stability and match the natural tooth to be aesthetically pleasing.

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One of the major challenges in this regard is color stability, particularly when restoring anterior teeth. Assessment of color stability and staining is a commonly employed metric for measuring the effectiveness and shortcomings of composite restorative materials in clinical performance [3, 4]. Glazed glass ceramics such as IPS E max CAD are known for their good color stability even when compared to polished resin ceramics [5]. They have excellent optical properties with high translucency. Silica or quartz (in the form of a silicon-dioxide matrix), together with other additional crystals that are contained inside the glassy matrix, can retard and inhibit the propagation of cracks, strengthen the ceramic, and add to the final optical characteristics as well as color stability [6 - 8]. However, previous studies investigating the influence of various bleaching agents on ceramic optical properties have reported a controversy. Many have claimed an unfavorable color change that leads to restoration replacement eventually [9-13]. While other studies have concluded that bleaching was effective in the removal of stains without any significant change in the basic color of ceramic restorations. [14 - 17]. Therefore, the present study aimed to evaluate the effect of regular chemical in-office bleaching and laser bleaching procedures on the color stability of direct nano-ceramic composite veneers and IPS Max CAD ceramic veneers after their accelerated coffee staining.

2. MATERIALS AND METHODS

This study was approved by the Research Ethics Committee, by the code (REC-PD-24-16), and complied with the fundamentals of the Helsinki Declaration. The calculation of sample size was guided in regard to a previous study by Alrabeah *et al*. [18], using the G-power statistical power analysis software (version 3197, Franz Faul, Kiel University, Germany). A total of 20 samples were divided into two main groups: 10 discs of lithium disilicate glass-ceramic (IPS E Max CAD), representing group E, and 10 discs of nanoceramic composite, representing group C.

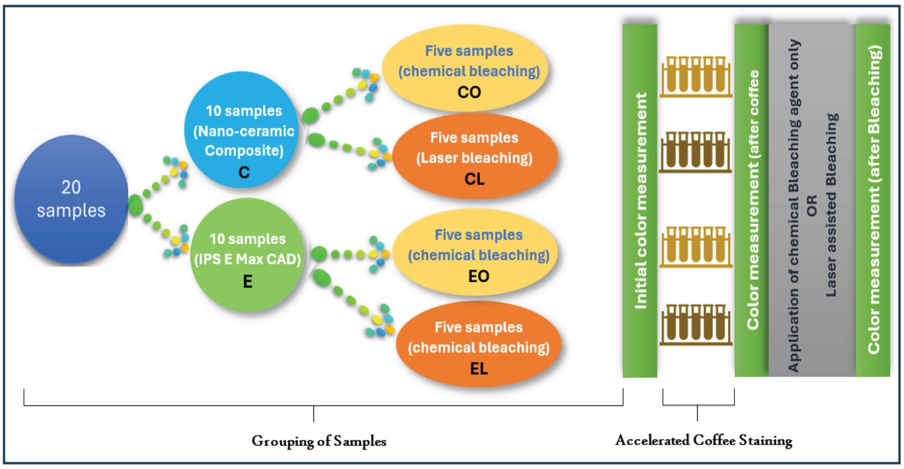

Fig. 1: Diagrammatic Illustration of the study plan

Each main group was subdivided into two subgroups (n=5) according to the type of surface treatment applied, where subgroup (O) samples had chemically in-office bleached surface, and subgroup (L) had diode laser-activated bleached surfaces. Color measurement of each group was assessed at baseline, after their accelerated coffee staining for one week, and finally, after bleaching agent application, to assess the color stability of each restorative

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laminate veneer material at different time intervals. A diagrammatic illustration of the study plan is shown in Fig.1.

2.1. Sample Preparation

Commercially available nano-ceramic composite (Olico Xp, Olident Co., St. Christo Botewa 1b 30-798 Kraków, Poland) was used in preparing the disc samples. The discs were prepared using a circular Teflon mold of 10 mm diameter and one-millimeter thickness. The mold was filled with composite, covered with celluloid paper, and packed between two clear and clean glass slabs to prevent oxygen and ensure the smooth surface of the discs. The curing process was done using an LED light curing device (TY309 LED Root Toye) for 60 seconds (light intensity of 1500 mW/cm^2). Circular discs of 10 mm diameter and one-millimeter thickness of lithium disilicate glass-ceramic (IPS E Max CAD) blocks were ground using a diamond micro-saw set at a cutting speed of 2500 rpm and a 0.7 mm thick diamond disk in a water coolant with an anticorrosive agent (30:1) cooling system (at China (Mainland) Guilin Measuring & Cutting Tool Co., Ltd). Samples were sintered by the manufacturer's guidelines. A crystallization cycle was carried out using the Programate furnace (Ivoclar Vivadent, Schaan, Liechtenstein) [19].

2.2. Initial Color Measurement

Color measurement was performed before any surface treatment (baseline) of both composite and E Max CAD samples. VITA Easyshade Spectrophotometer (Vita Easyshade Advance ver. 4.0, VITA Zahnfabric, Bad Sackingen, Germany) was utilized for measuring color and recording different color parameters. [20-22] Calibration of the device was performed before each color measurement recording through the use of a white table supplied by the manufacturer (figure 2: b). Sample color was measured by holding the device tip perpendicular to the disc surface (figure 2: c). The values were measured and recorded according to the CIELCH (Commission Internationale de I'Eclairage L* C* and H*) color space system (figure 2: d). The following mathematical equation was used to calculate the overall color difference ($\Delta\boldsymbol{E}$):

$$\Delta\boldsymbol{E} = \sqrt{(\Delta\boldsymbol{L})^2 + (\Delta\boldsymbol{C})^2 + (\Delta\boldsymbol{H})^2} \tag{1}$$

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Fig. 2. Color measurement procedure: a) Vita Easy Shade device, b) a sample inside the white calibration table, c) the device tip is held perpendicular to the disc surface, and d) different color parameters (ΔL, ΔC, and ΔH) recordings on the device screen after color assessment.

2.3. Staining Procedure

Each sample was kept separately in a 3 mL coffee solution (Nescafe RED MUG, Nestle) at room temperature for a week (24 hours each day) in order to follow the accelerated staining process. The coffee solution was refreshed each day. The samples were rinsed under tap water and dried after the end of the staining period.[23] The colour measurement was done as previously for all the samples.

2.4. Bleaching Procedures

The discs of group I were covered with the chemically activated in-office bleaching agent D.M. White® (which is composed of a blend of peroxides (hydrogen peroxide 37%, carbamide peroxide 10% in addition to benzoyl peroxide & sodium perborate). The whole content of one of the D.M. White gel base syringes was evacuated in one of the D.M. White powder jars and was mixed gently for 20 seconds using the supplied micro-applicator brush to achieve a homogeneous effervescence mixture. A uniform (1-2 mm thickness) layer of the mix was applied to the disc surface using the supplied micro-applicator brush, left for 30 minutes, then wiped off and rinsed thoroughly under tap water for one minute**.** The discs of group II were covered with a uniform layer of laser-activated bleaching gel (Crystal Whites Bleaching Kit, Crystal Whites®, China) of 1.5 mm thickness. A 450 nm wavelength diode laser (LX 16 Plus, Woodpecker, Industrial Park, Guilin, Guangxi, 541004 P.R. China) was then used for radiation for 60 seconds in three cycles from a distance of 2 mm at a peak and average power of 3 W, 450 nm wavelength, 180 J energy, and using continuous emission mode. The delivery system was a fiber optic tip with a light transmission glass tip. No water irrigation nor aspirating airflow was used. The bleaching agent was then left on the disc surface for 10 min. Then the bleaching gel was wiped off, followed by irrigation with tap water to remove the bleaching gel completely [24]. After bleaching, color measurement was recorded again for all study groups.

2.5. Statistical analysis

Microsoft Excel 365 and IBM® SPSS® (Version 28.0; IBM Corp) were used for statistical analysis. The Shapiro-Wilk test was used to examine all quantitative data for

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normality. The data were shown as mean and standard deviation (SD) values after being determined to be parametric (**Table 1, 2)**. The mean color change between the study groups was compared using One-way ANOVA and Tukey HSD tests, while pairwise comparisons between each group's pre- and post-bleaching at each color parameter (ΔH, ΔC, ΔL, and ΔE) were conducted using paired t-tests. The levels of significance have been set at (p≤0.05).

3. RESULTS

Using One-way ANOVA and Tukey HSD tests, it was observed that there were statistically significant differences among study groups in the mean color change of all color parameters after accelerated staining with coffee (**Table 1)**. After bleaching, there were statistically significant differences among study groups in the mean color change of all color parameters (**Table 2)**. Using a paired *t*-test for a pairwise comparison between the mean color changes pre-and post-bleaching in each treatment group at ΔH color parameter (**Table 3)** revealed that there were statistically significant differences between pre-bleaching and post-bleaching mean color change results in all study groups. At the mean color change of (ΔC), there were statistically significant differences between CO "*pre-bleaching*" and CO "*post-bleaching*", p=0.001. The same case was observed for CL "*pre-bleaching*" and CL "*post-bleaching*"; p=0.000.

Table 1. Descriptive statistics and comparison of mean colour change after staining among different treatment groups in all colour parameters, using One-way ANOVA and Tukey HSD tests.

Color parameter	GROUPS	After staining					
		Mean	SD	Minimum	Maximum	*F*	*P-value*
ΔH	EO	-.12[c]	.13	-.20	.10	49.6	0.000*
	CO	-2.36[b]	.54	-3.00	-1.90		
	EL	-.080[c]	.25	-.40	.10		
	CL	-3.64[a]	.93	-4.20	-2.00		
ΔC	EO	.48[a]	.04	.40	.50	227.7	0.000*
	CO	9.32[b]	1.41	8.00	10.80		
	EL	.52[a]	.40	.10	.90		
	CL	12.24[c]	1.03	10.50	13.00		
ΔL	EO	-.64[c]	.33	-1.00	-.40	145.9	0.000*
	CO	-4.24[b]	.42	-4.70	-3.90		
	EL	-.34[c]	.15	-.50	-.20		
	CL	-7.16[a]	1.06	-7.90	-5.60		
ΔE	EO	.92[a]	.11	.80	1.00	4.3	0.05*
	CO	2.06[a]	1.44	.40	3.40		
	EL	.68[a]	.084	.60	.80		
	CL	1.98[a]	.49	1.20	2.50		

*The mean difference is significant at $p \leq 0.05$.

Table 2. Descriptive statistics and comparison of mean colour change after bleaching among different treatment groups in all color parameters, using One-way ANOVA and Tukey HSD tests.

Color parameter	GROUPS	After Bleaching					
		Mean	SD	Minimum	Maximum	*F*	*P-value*
ΔH	EO	-.54 [b]	.18	-.70	-.30	25.9	0.000*
	CO	-.24 [c]	.11	-.40	-.10		
	EL	-.40 [b c]	.10	-.50	-.30		
	CL	-.90 [a]	.07	-1.0	-.80		
ΔC	EO	.46 [b]	.49	.10	1.00	8.1	0.002*
	CO	-4.52 [a]	3.90	-9.30	-.70		
	EL	.74 [b]	.05	.70	.80		
	CL	-2.92 [ab]	.93	-3.70	-1.90		
ΔL	EO	-.42 [a]	.11	-.50	-.30	16.1	0.000*
	CO	-.06 [a]	.52	-.80	.40		
	EL	-.68 [a]	.19	-.90	-.40		
	CL	2.16 [b]	1.33	1.10	4.10		
ΔE	EO	-.22 [bc]	.08	-.30	-.10	115.8	0.000*
	CO	-.32 [b]	.25	-.50	.10		
	EL	.00 [c]	.00	.00	.00		
	CL	-1.48 [a]	.084	-1.60	-1.40		

*The mean difference is significant at $p \leq 0.05$.

There were no statistically significant differences for EO and EL; p=0.930 and 0.313, respectively. Besides, at the mean color change (ΔL), there were no statistically significant differences between pre- and post-bleaching mean color change results in all study groups except for the CO group, where P=0.001. Finally, at the mean color change (ΔE), there were statistically significant differences between pre-bleaching and post-bleaching mean color change results in all study groups.

Table 3. Pairwise comparison between the mean color changes pre- and post-bleaching in each treatment group, using a paired *t*-test.

Color parameter	Groups	Mean color change ± SD	*p* Value
ΔH	EO (pre)	-.12±0.13	0.000*
	EO (post)	-.54±0.18	

	CO (pre)	-2.36±0.54	0.000*
	CO (post)	-.24±0.11	
	EL (pre)	-.08±0.24	0.030*
	EL (post)	-.40±0.10	
	CL (pre)	-3.64±0.93	0.003*
	CL (post)	-.90±0.07	
ΔC	EO (pre)	.48±0.44	0.930
	EO (post)	.46±0.49	
	CO (pre)	9.32±1.4	0.001*
	CO (post)	-4.52±3.9	
	EL (pre)	.52±0.40	0.313
	EL (post)	.74±0.05	
	CL (pre)	12.24±1.03	0.000*
	CL (post)	-2.92±0.93	
ΔL	EO (pre)	-.64±0.328	0.247
	EO (post)	-.42±0.109	
	CO (pre)	-4.52±0.42	0.001*
	CO (post)	-4.24±0.53	
	EL (pre)	-.34±0.15	0.077
	EL (post)	-.68±0.192	
	CL (pre)	-7.16±1.06	0.001*
	CL (post)	2.16±1.33	
ΔE	EO (pre)	.92±0.109	0.000*
	EO (post)	-.22±0.083	
	CO (pre)	2.06±1.44	0.029*
	CO (post)	-.32±0.23	
	EL (pre)	.68±0.83	0.000*
	EL (post)	.00±0.00	
	CL (pre)	1.98±0.49	0.000*
	CL (post)	-1.48±0.08	

*The mean difference is significant at $p \leq 0.05$.

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4. DISCUSSION

Whitening products have become more widespread as a result of growing aesthetic standards and dissatisfaction with teeth discoloration. In the present study, the authors evaluated the influence of regular chemical in-office bleaching and laser bleaching procedures on the color stability of direct nanoceramic composite veneers and IPS E Max CAD ceramic veneers after their accelerated coffee staining for one week. The null hypothesis presumes that chemical in-office bleaching and laser bleaching would not affect the color stability of direct nanoceramic composite veneers and IPS E Max CAD ceramic veneers. Bleaching agents have been shown to have detrimental effects on many ceramic and resin composite materials [25-27]. However, there was a controversy over the bleaching agent's impact on ceramic materials [28-30].

The main explanation for color variations seen during staining and bleaching among the examined materials is the variation in their composition and structural configuration. The most color-stable ceramics were those made of extremely dense materials like feldspar or lithium disilicate. These findings are consistent with two previous studies [31-32]. On the other hand, the organic matrix of composite resin materials was shown to be the reason for their color instability as these materials contain a higher organic matrix content than the denser ceramics [33]. A wide variety of external coloring factors, such as cola, coffee, and tea, can cause discoloration of offending dental restorations, especially in anterior teeth with subsequent esthetic derangement and patient dissatisfaction. In the present study, the samples were immersed in a coffee solution for one week, which equals seven months of coffee ingestion (i.e., for a patient who drinks three cups of coffee per day on average) [17]. The apparent color change of the composite after accelerated staining is attributed to the organic matrix phase that absorbs the coloring agent after being adsorbed upon the surface of the composite disc [34-35].

In the present study, two different types of bleaching procedures were used: regular chemical bleaching (in-office) and diode laser aided bleaching. Hydrogen peroxide, in the in-office bleaching, is the active ingredient and is used in higher concentrations. This brings about the breakdown of pigmented ring structures into non-pigmented single-carbon bonds. Photo-oxidation of the double bonds in the chromophore will result in their disruption and bring about the bleaching process. Hence, lasers have been utilized to raise the temperature of the bleaching material, which in turn enhances the penetration of the bleaching gel into the tooth structures and promotes the effect of the bleaching agent as usually observed in all chemical reactions. It has been revealed that increasing the temperature of hydrogen peroxide by ten degrees can fasten its decomposition by a factor of 2.2 [32-34]. In the present study, the gel was activated using the diode laser of 980 nm. The laser activation was carried out for 30 seconds in four sessions. This is shown to have no detrimental effects on pulp and was thus preferred. Color changes can be assessed by several methods, such as visual method, colorimeter, and spectrophotometer. VITA Easyshade provides objective and reliable color measurements of natural teeth. It is efficient and reproducible and helps in digital communication. Various studies have shown that VITA Easyshade spectrophotometers show significantly accurate results compared to the visual method [20]. There were statistically significant differences between pre- and post-bleaching mean color change results in all study groups at all color parameters except for IPS E Max ceramic groups at ΔC and ΔL color parameters. It may be attributed to the dense architecture of this type of restorative material as well as having lesser

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porosity and minimal structural flaws. All these criteria result in more resistance to color change.

The results showed that (ΔE) for the (CL) group after laser bleaching is significantly high. This may be attributed to the deep penetration of the bleaching material due to laser application. The utilization of only one kind of coloring solution (i.e., coffee) may be considered one of the limitations of the current study. An additional limitation is obtaining the data under in vitro conditions due to the difficulty of simulating of intra oral conditions. Patients will always request bleaching as a treatment option. So, it is important to fully understand how different bleaching techniques affect the characteristics of each restorative material to determine which bleaching technique is safe to apply for each type of material.

5. CONCLUSIONS

Since bleaching procedures have varying effects on laminate materials, it is best to assess each material separately and provide the safest bleaching approach. Composite laminates are affected by coffee staining more than IPS E Max CAD laminates. The laser bleaching significantly affects composite laminates more than the chemical office bleaching.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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