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COLOR CHANGE AND STAINING ABILITY OF LITHIUM DISILICATE, FELDSPATHIC AND TWO COMPOSITE RESIN LAMINATES IN COFFEE AND COLA IMMERSIONS: AN IN VITRO STUDY

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ABSTRACT

Objective: This study measured the color change of lithium disilicate (E. max CAD), micro-hybrid resin composite (Coltene C bright, Filtek Z250) and feldspathic ceramic (Vita Mark II) laminates after putting them in coffee, Cola and artificial saliva staining solutions for seven days.

Materials and Methods: Sixty freshly extracted sound upper central incisors were randomly divided into four groups (n=15) according to the material used for laminate veneer fabrication; E. max CAD (Group I), VitaMark II (Group II), Coltene C Bright blocks (Group III) and Filtek Z250 composite resin (Group IV). Teeth were all prepared to receive a prepared sample of a squared-shaped laminate of different materials in a dimension of 7x7 mm. Cementation, finishing and polishing procedures were performed followed by color change measurement using a spectrophotometer. Measurements were all recorded before and after immersion for seven days.

Results: Time, material type and immersion medium had a statistically significant effect on mean color change ($p<0.001$). Intra-group comparisons displayed that E. max CAD showed the lowest color change, whereas Coltene C bright blocks were the greatest to show color change. Vita Mark II showed a higher color change in artificial saliva than Filtek Z250, however, the latter demonstrated a surpassing change in color in the other solutions.

Conclusion: Material type, external source of stain, and staining time are important factors that affect the degree of color change, which in turn could affect patient satisfaction. E. max showed the best results in all solutions regardless the exposure time.

KEYWORDS: Color change, laminate, dental ceramics, esthetics.

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INTRODUCTION

Esthetics have gained wide significance over the last years not only among dentists but also among patients. The main concern nowadays is delivering an esthetic restoration that symmetrically blends with the patient's adjacent teeth [(1)]. Besides, paradigm-shifting from GV Black's principle toward minimally invasive dentistry has put dental tooth-colored restorations at a high value. Therefore, both the esthetic demands from patients and the paradigm shift in philosophies of conservative dentistry have put dental materials in a continuous state of update regarding color stability, which is often ignored over other properties such as physical and mechanical properties [(2)].

Shade match and stability of the matched color for the entire life service are two of the most desirable properties of an esthetic restorative material [(3)]. Color stability, which is defined as the ability of a dental material to keep and retain its original color may determine the success or failure of the restoration. This property may turn out to be compromised in the dynamic environment of the oral cavity, due to the continuous presence of microflora, saliva, and the frequent intake of colored food (chromogens) [(4)].

Color change of dental composite resin restorations may take place due to intrinsic and extrinsic factors during their clinical service. Chemical alterations of the resin matrix, as oxidation of unpolymerized monomers and amine accelerators, percentage of incorporated filler and its particle size distribution, photo-initiator type, and the remaining double bonds, may be considered intrinsic factors, while accumulation of plaque and sorption of staining materials from diet or smoking are extrinsic factors for color change [(5)]. The color change of composites improved dramatically by the enhancement of the physicochemical properties of the material, such as filler/matrix ratio, reduced particle size, and optimal filler matrix coupling agents [(6)].

Dental ceramics are known to be the most esthetic and biocompatible dental material. The intrinsic color stability of dental ceramics relies on their composition and the presence of the glaze layer, while the extrinsic color stability is often linked to surface smoothness that hinders plaque accumulation [(7,8)]. Owing to the limited evidence-based data in the literature concerning the color stability of dental tooth-colored restorations, it was found that it will be goal-directed to assess the color change of lithium disilicate, feldspathic, Coltene resin composite and Filtek Z250 composite paste before and after immersion in coffee, cola and artificial saliva solutions.

MATERIALS AND METHODS

Teeth Preparation

Sixty freshly extracted upper central incisors free of caries, attrition, abrasion, cracking or previous restoration were obtained and prepared for the current study. The teeth were thoroughly cleaned and stored in artificial saliva at room temperature until use. The roots of all teeth were sectioned and removed using carborundum discs (One New Bond St., Worcester, MA), and the crown part was inserted into a putty rubber base condensation silicone impression material (Zetaplus Putty, Zhermack, Italy) using a custom made acrylic mold with a fixed diameter exposing the labial surface upwards.

The 60 specimens were randomly divided into four groups (n=15) according to the material used for laminate veneer fabrication; Group I represented the lithium disilicate glass-ceramic (E. max CAD; Ivoclar Vivadent AG) with shade A2 LT "block size 14", Group II represented monochromatic fine structured feldspar ceramic blocks material (VitaMark II, VITA Zahnfabrik) with shade 2M2-T "block size 14", Group III Coltene C Bright (COLTENE Group) with white opaque shade layered with A2 composite and Group IV of composite laminate veneer (Filtek Z250, 3M Ltd, USA).

The facial surfaces of the teeth were initially prepared by placing depth-orientation grooves (one mm in depth) with a depth preparation bur. (Microdont, Rodovia Fernao Dias, Sao Paulo, Brazil). Then, the teeth were prepared without exceeding the depth-orientation grooves to provide a flat enamel surface area, 7x7 mm in dimension, measured by a periodontal probe, for luting the prepared veneer to the middle third of the facial surface.

Sample Preparation

All samples of different restorative materials were sectioned and prepared in the form of laminate sections of dimensions of 7x7 mm and 1 mm thickness each. The thickness of the specimens was confirmed using a digital caliper (Guanglu Instruments, Guilin, China). For the E. max CAD, fifteen samples of the material were designed and obtained using autodesk meshmixer software to create 3D blocks and were then saved in STL file format and delivered to the CAD/CAM 5-axis milling machine (SHERA Eco-mill 5X, Bimedis, Germany). The milling procedure was carried out under water irrigation. While as for the VitaMark II group, 15 samples were sectioned using a cutting machine (T210 Mecatome, PRESI Trade, Shanghai, China).

A diamond disk-cutting machine (Accutom 5, Struers, Ballerup, Denmark) was used at 1000 rpm at 0.100 mm/s while being cooled by water to section Coltene C Bright blocks into 15 laminate sections as well. Filtek Z250's samples were prepared by inserting composite into the teflon mold. To compact and remove the excess material from the sample surfaces, the mold containing the resin was covered by a polyester strip and a glass plate was placed on top of it with a four kg weight for 30 seconds. The weight and the glass plate were removed and the composite resin was light-cured through the polymer strip for 40 seconds (KM 200R, DMC Equipment, a QTH unit, 450-600 mW/cm2 9 mm tip diameter).

Cementation

The following cementation procedure was performed by the same operator to avoid any human variation. Before starting the cementation procedure, a try-in of all specimens was carried out to check the fit of the restorations on the flatly prepared tooth surface by visual inspection and using tactile sensation. The cementation protocol started by preparing the fitting surface of the samples and the tooth surface. Firstly, samples were prepared by cleaning them with water from the try-in step and drying them thoroughly with an air syringe. Before applying the acid etchant, the samples were temporarily attached to a sticky holder by an adhesive.

For E. max CAD and Vita Mark II samples a 5% concentration of hydrofluoric acid (DentoBond Porcelain Etch; iTENA™ , France) was applied by a disposable plastic brush only on the fitting surface of the samples for 20 seconds and 60 seconds to the E. max and Vita Mark II samples, respectively as the latter has more glass content. Rinsing was done thoroughly for 60 seconds to make sure that all the acid was removed and then dried for 20 seconds until the etched surfaces appeared white and opaque. A silane coupling agent (DentoBond Porcelain Silane; iTENA™ , France) was applied using a disposable brush for 60 seconds until completely evaporated. Etched surfaces were further dried with oil-free air for 60 seconds.

Regarding the Coltene C bright samples, the fitting surfaces were sandblasted with 25 μm alumina (Cobra 25μm sand; Renfert™ , Germany), followed by the application of one layer of Scotchbond universal adhesive (3M™ , USA) and the surface was rubbed for 20 seconds right prior to cementation. The adhesive was then left uncured, as advised by the manufacturer and any excess adhesive was removed gently by oil-free compressed air for 20 seconds. While the Filtek Z250 indirect veneers prepared were slightly roughened by fine diamond burs and rinsed with an air/water syringe.

Then a thin coat of Scotchbond Universal Adhesive was applied and air-thinned.

All teeth were first cleaned and etched following the total-etch technique prior to cementing the prepared laminate sections. Total-etching of the enamel surface of each tooth was performed as recommended by the cement manufacturer; with a 35% phosphoric acid gel for 20 seconds (MetaBiomed, South Korea), followed by the application of Scotchbond Universal adhesive (3M, ESPE, USA) for 20 seconds.

The cementation of all veneers was done by applying a considerable amount of cement using the light-cured adhesive resin cement RelyX Ultimate (3M ESPE, USA) to the etched and silanated veneer's fitting surface. The restorations were seated on their corresponding teeth, with maximum finger pressure for uniform pressure distribution. For curing, brief curing for 1-2 seconds was done. Next, the margins were coated with glycerin gel and light curing was carried out to all restoration margins for 40 seconds at a zero distance with a second-generation LED polymerization unit (5W LED chips and a lamp power of 1000 mW/cm2). The glycerin gel was rinsed off with water after complete polymerization.

Finishing and polishing

After cementation, finishing and polishing were performed for all the specimens of the four material groups, using a universal polishing kit (Optra Gloss) (Ivoclar Vivadent, Switzerland), following the manufacturer's instructions. To ensure standardization, the same operator performed the finishing and polishing steps for all specimens in a fixed time of 30 seconds using fine diamond finishing stones (40 μm Sof-lex "red") at a speed of 15,000 rpm with light pressure and sufficient coolant application. Then, a two-step polishing procedure was performed using rubber cups at a lower speed (5,000-10,000 rpm) with slight pressure for all samples, according to the manufacturers' recommendations. Then, the polishing was finalized by occlubrush (Kerr, USA).

Staining process

According to Gupta et al. (2005) (9) the samples of each group were randomly divided into three subgroups (n=5) depending on the staining solutions Coffee (Nescafe Classic, Nestle, Egypt), Coca-Cola (Cairo, Egypt) or artificial saliva (control group). The coffee staining solution was prepared by adding 15 g of coffee powder to 250 ml of boiled distilled water. Each sample was immersed in a15 ml of the tested solution in a closed container stored in a dark place, at room temperature (37 ±10 °C). The tested solutions were changed every day and stirred once every 12 hours. Specimens were kept in the immersions for 7 days then were removed and wiped dry with tissues after being rinsed with distilled water.

Outcome measurement:

A Cary 5000 spectrophotometer (Agilent Technologies, California, USA) was used to measure the color change of each specimen. All measurements were recorded by one of the authors before and after immersion for one day and seven days. CIE (Commission Internationale d'Eclairage22) L*a*b relative to standard illuminant against a white background was used to detect any change in color. Color changes were calculated by using the following formula: Change in color (ΔE) $\Delta E = (\Delta L2 + \Delta b2 + \Delta a2)$ ½.

Statistical Method

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Color change (ΔE) data showed a normal (parametric) distribution. The data were presented as mean and standard deviation (SD) values. Repeated measures ANOVA test was used to study the effect of material type, immersion medium, time and their interactions on ΔE. Bonferroni's post-hoc test was used for pair-wise comparisons when the ANOVA test was significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with

IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY:IBM Corp.

RESULTS

Results of the study (Table 1) showed that after immersion in saliva for one day as well as Seven days; there was a statistically significant difference between mean ΔE of different materials (P-value <0.001, Effect size = 0.494 and 0.432, respectively). Pair-wise comparisons revealed that there was no statistically significant difference between Vita Mark II and Coltene; both showed the statistically significantly highest mean values. Filtek showed a statistically significantly lower mean value and E. max showed the statistically significantly the least mean ΔE after one day of immersion while both showed no statistically significant difference after 7 days of immersion having the least mean ΔE values.

After immersion in Cola for one day; there was a statistically significant difference between the mean ΔE of different materials (P-value <0.001, Effect size = 0.649). Pair-wise comparisons revealed that Coltene showed the statistically significantly highest mean ΔE. There was no statistically significant difference between Filtek and Vita Mark II; both showed statistically significantly lower mean values. E. max showed the statistically significantly least mean ΔE.

TABLE (1). The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between ΔE of different interactions of variables.

Time	Immersion medium	E. max (n = 5)		Filtek (n = 5)		Vita Mark (n = 5)		Coltene (n = 5)		*P*-value	Effect size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		
One day	Artificial saliva	1.95^{C}	0.27	2.4^{BF}	0.41	2.92^{A}	0.24	2.92^{AF}	0.52	<0.001*	0.494
	Cola	2^{C}	0.07	3.1^{BE}	0.26	2.89^{B}	0.26	3.53^{AE}	0.09	<0.001*	0.649
	Coffee	2.18^{D}	0.13	3.25^{BE}	0.18	2.83^{C}	0.19	3.66^{AE}	0.17	<0.001*	0.642
	P-value	0.372		<0.001*		0.866		<0.001*			
	Effect size	0.04		0.378		0.006		0.319			
Seven days	Artificial saliva	2.23^{BF}	0.55	2.59^{BF}	0.55	3.47^{A}	0.6	3.04^{AF}	0.51	<0.001*	0.432
	Cola	2.88^{CE}	0.09	4.45^{AE}	0.18	3.86^{B}	0.16	4.83^{AE}	0.11	<0.001*	0.654
	Coffee	2.96^{CE}	0.07	4.66^{AE}	0.12	3.73^{B}	0.25	4.79^{AE}	0.2	<0.001*	0.658
	P-value	0.003*		<0.001*		0.195		<0.001*			
	Effect size	0.218		0.694		0.066		0.645			

		E. max (n = 5)		Filtek (n = 5)		Vita Mark (n = 5)		Coltene (n = 5)	
		P-value	Effect size	*P*-value	Effect size	*P*-value	Effect size	*P*-value	Effect size
Effect of time	Artificial saliva	0.022*	0.105	0.121	0.049	<0.001*	0.308	0.303	0.022
	Cola	<0.001*	0.533	<0.001*	0.729	<0.001*	0.581	<0.001*	0.714
	Coffee	<0.001*	0.472	<0.001*	0.744	<0.001*	0.545	<0.001*	0.65

: Significant at P ≤ 0.05, Effect size: Partial eta squared, A,B,C,D superscripts in the same row indicate statistically significant difference between material types, E,F superscripts in the same column indicate statistically significant difference between immersion media

After immersion in Cola or coffee for seven days; there was a statistically significant difference between the mean ΔE of different materials (P-value <0.001, Effect size = 0.654) and (P-value <0.001, Effect size = 0.658), respectively. Pair-wise comparisons revealed that there was no statistically significant difference between Filtek and Coltene; both showed the statistically significantly highest mean values. Vita Mark showed statistically significantly lower mean ΔE. E. max showed the statistically significantly least mean ΔE.

DISCUSSION

A variety of tooth colored restorations have been developed as a result of the enhancement of Computer-Aided Design/Computer-Aided manufacturing (CAD/CAM) and the rise in patients' demands for aesthetics [10]. For the success and durability of aesthetic restorations, color stability is thought to be a crucial factor [2]. New ceramic and composite restorative materials showed excellent mechanical properties, yet they are still prone to internal or external factors that change their color. It is noteworthy that the oral environment is warm, moist, and subjected to significant pH changes as a result of exposure to various extrinsic factors, such as colored and hot beverages. The material composition, type of solution, and exposure time all play a role in the degree of discoloration of the restoration [11]. The current study measured the color stability of different restorative materials in different immersions.

The current analysis was an in vitro study that provided a standardized and controlled method of fabrication, which is crucial to provide data that is more consistent with the clinical situation. In our study, IPS E. max CAD, Coltene C Bright, Vita Mark II and Filtek Z250 were examined for color stability. Our study tested mainly A2 shade and LT translucency since they are the most commonly used for crown fabrication as claimed by the authors [12].

The results of the current study showed a statistically significant effect on the mean ΔE. For the material type factor alone, Coltene C bright showed the highest color change results, while E. max CAD showed the least value. Because of the heightened resin content found in Coltene C blocks, hydrophilic degradation could have occurred, which causes particles to detach from the material structure. Thus, a decline in the physical and optical characteristics of the material takes place [13]. Further, Filtek Z250 paste exhibited less color change in comparison to Coltene C blocks which contradicted what was demonstrated in a previous study which considered that composite blocks have a higher degree of conversion, allowing minimal color changes [6]. This conflicting finding may be attributed to the thermocycling step done in the past study.

Different immersion protocols were developed in order to determine the effect of external factors on the color stability of the restoration. Various solutions have been used to examine color stability such as coffee, tea, orange juice, distilled water, and red wine. Our study utilized staining solutions of coffee and Coca-Cola since they are routinely used by patients compared to artificial saliva as a control group. Irrespective to other factors, coffee and Cola solutions lead to greater color change than artificial saliva especially the coffee solution, owing to the presence of yellow stain particles within the solution [14]. Immersion time also has a substantial influence on the color of the restoration. In this study, up to seven days of staining was performed which is considered the least duration required for a composite material to stain where it was proved earlier that composites needed from 7 to 30 days to get saturated by the staining solution [15,16].

Upon assessing the interaction of all factors, the findings highlighted that E. max was the least likely to experience color change after one day and seven days immersion periods. This may be attributed to the high physical and optical properties of the material in addition to its surface smoothness preventing the attachment of the stains found in the staining solutions [17]. On the other hand, Vita Mark II showed higher changes in color after seven days than E. max which might be due to probable ceramics' surface degeneration that is influenced by the material composition, manufacturing processes, surface finishing, and measurement techniques used [18].

Regarding the color stability of the resin-based restorations, in accordance with the current results, a study showed a marked increase in discoloration of Filtek Z 250, which may be related to the composites' characteristics. The filler particles of Filtek Z 250 are not silane treated and the chance of a slow breakdown at the matrix-filler interface due to water sorption could not be completely ruled out [9].

Another study showed that the used indirect composites (Dentocolor, VisioGem, Brilliant D. I.) exposed to coffee for 48 hours were strongly stained which was consistent with our results [19]. Filtek Z250 and Coltene C showed higher changes in color than the ceramic group. A possible explanation is that the ceramic glass fillers do not absorb water. Moreover, it was also observed that composite resins with lesser amounts of inorganic fillers displayed more color change [20]. Greater water sorption may reduce the resilience of composite resins by hydrolyzing the silane, expanding and plasticizing the organic matrix [21].

CONCLUSION

Stain resistance is an essential quality for any restoration to have, in order to retain its optical properties. Material type, external source of stain, and staining time are important factors that affect the degree of color change, which in turn affects patient satisfaction. E. max showed the lowest change in color among various immersion solutions due to its microstructure and physical properties. However, a Coltene C block was found to have the highest change in color among the other groups because of its great resin content. Further investigations are needed to study the effect of different restoration thicknesses and the influence of different finishing and polishing protocols on the color of the restorations. Also, long-term clinical trials are mandatory to assess and validate the change in color of different restorative materials in the oral cavity.

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