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EFFECT OF ELECTRONIC CIGARETTES SMOKING ON COLOR STABILITY OF LITHIUM DISILICATE GLASS CERAMIC VENEERS

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ABSTRACT

Objectives: This study aimed to investigate the effects of ECIG smoking on color stability of simulated veneers made from lithium disilicate glass ceramics.

Materials and methods: 24 specimens of lithium disilicate glass ceramic veneers were exposed to aerosols which are flavored and non-flavored with nicotine content (0, 6 and 12 mg). Six specimens were prepared for each group IPS E.Max press high translucent ceramic discs. Vacuum Induction Device was used to simulate smoking in vivo. Color measurement was performed on the specimens before and after exposure to ECIG aerosol using a calibrated spectrophotometer.

Results: According to Two Way ANOVA, both flavor and nicotine contents have significant effect on color change (P <0.0001). Regarding specimens exposed to e-liquid, flavorless 0 mg. nicotine group showed the lowest value 1.044 (±0.044), while flavored 12 mg. nicotine group showed the highest values 2.369 (±0.034). As for specimens which exposed to e-liquid, flavorless group lowest value 1.197 was found, while flavored group showed the highest values 1.868. Regarding specimens which exposed to e-liquid, group which exposed to 0 mg nicotine showed the lowest value 1.268 (±0.233), while group exposed to 12 mg nicotine showed the highest values 1.868 (±0.524).

Conclusion: Study showed that exposure to flavored and non-flavored ECIG aerosol of different nicotine concentrations has a significant effect on the color of lithium disilicate glass ceramic veneers. Higher concentrations of flavored nicotine had visually perceptible color changes and were deemed clinically unacceptable.

KEYWORDS: E-cigarettes, Vape smoking, lithium disilicate glass ceramic veneers, Color change.

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INTRODUCTION

In recent years, ECIG use has become more and more prevalent. Since the beginning of the 2000s, they have been offered on the market. Electronic cigarettes refer to a variety of device types.[1, 2]

The majority of an ECIG is made up of a battery and an electric heater that is used to aerosolize an e-liquid into a vapor that the user inhales. Initially shaped like conventional cigarettes, ECIG's shape was later modified to make advantage of more complex and cutting-edge technologies. Rechargeable batteries, temperature controls, and refillable tanks are all features of more recent devices.[3]

The first generation of ECIG devices, commonly known as "cigalikes," resembled regular cigarettes in both size and shape. Cigalikes are not meant to have their tanks replaced, batteries recharged, or liquid refilled in them.[4,5]

Second-generation ECIG devices are bigger and have a modified form from regular cigarettes. They resemble a medium-sized pen or a tank (larger size). They have stronger, rechargeable batteries as well as an electronic circuit for adjusting the duration and frequency of buffs. This generation's tanks can be replenished again.[6,7] While third generation ECIG devices have a similar appearance to second generation devices, they are more customizable, have better batteries, and offer a wide range of tank replacement options.[8]

The e-liquid is made up of nicotine, flavorings (including neutral, tobacco, menthol, candy, and more), and a solvent (often propylene glycol and/or vegetable glycerin). It is offered with various nicotine doses or without nicotine. While being marketed as a harmless substitute to traditional cigarettes, ECIG nevertheless contains dangerous ingredients. According to published research, ECIG aerosol and e-liquid ingredients cause and incite chronic inflammatory diseases.[5,8]

According to a study by Chotimah et al.[9], cigarette smoke has an impact on the color of acrylic artificial teeth. Yet, the impact of an electric cigarette on the color of acrylic teeth is minimal. Therefore, the color of artificial teeth could change depending on whether they were exposed to cigarette or electronic cigarette smoke.[9]

Rocha et al. claimed that oral behaviors including consuming alcohol and smoking cigarettes can cause resin composites to discolor. This in-vitro investigation revealed that the combination of these behaviors, particularly when translucent hues are utilized, can aggravate color shifts in composites.[10,11]

Since its inception in 1983, veneers have been regarded as one of the most effective treatment techniques due to their durability, strength, conservatism, biocompatibility, and aesthetics.[12] As materials and processes have advanced, veneers have become one of the most predictable, most beautiful, and least invasive forms of treatment. Attractive veneers made of ceramic materials have great clinical performance. For this reason, both materials and techniques give the dentist and patient a chance to improve the patient's smile in a way that requires little to no invasive procedures.[13]

Porcelain laminate veneers, which were first utilized to treat different types of tooth discoloration, have been gradually phased out in favor of more conservative therapy techniques like whitening and enamel microabrasion.[14] As long as new materials and methods are discovered, this evolution has not resulted in a drop in the indications for veneers. Because they almost entirely preserve the enamel before the veneer is applied, ceramic veneers are regarded as the best choice for a traditional aesthetic approach.[15]

When exposed to stains like coffee, tea, or cigarette smoke, dental materials can get discolored[16]. Thus, their impact on the color stability of dental materials was the subject of several investigations. The purpose of this study is to investigate the effects of ECIG smoking on the color stability of lithium disilicate glass-ceramic veneers when the veneers are exposed to aerosols of non-flavored and flavored with a nicotine content of 0 mg, 6 mg, and 12 mg.

The null hypothesis is that ECIG smoking has no effect on the color change of lithium disilicate glass-ceramic veneers.

MATERIALS AND METHODS

This study is an in-vitro experimental study that was approved by the Local Research Ethics Committee, faculty of dentistry, Alexandria university.

For the fabrication of veneers, IPS E-max CAD HT blocks (Ivoclar, Vivadent) using CAD/CAM technology (CEREC 3D CAD/CAM; Sirona Dental Systems LLC, Charlotte, North Carolina) were milled of 2 mm thickness. (**Fig. 1**)

Fig. (1): CAD/CAM emax veneers

E-Liquid preparation

Propylene glycol: vegetable glycerin formulations containing 0, 6, and 12 mg/mL of nicotine were created, both with and without flavor.

For the flavorless 0 mg. group, propylene glycol (PG) and glycerin (G) were mixed in equal proportions by volume. The liquid was stirred at 50°C (Celsius degrees) and 300 RPM for 15 minutes and sonicated for 15 minutes until being visually homogenous. For other flavorless groups, nicotine was added to the propylene glycol and glycerin. As nicotine is dissolved in a propylene glycol base, the proportion of nicotine was deducted from the amount of propylene glycol. As well, for the flavored groups, the proportion of flavor was subtracted from the amount of propylene glycol as the flavor is also dissolved in a propylene glycol base.

Vacuum Induction Device (VID)

The design of the introduced device was submitted to the Egyptian Patency Office and is still under evaluation, although it is allowed to publish the idea as long as it was already submitted patency.

The device is in a form of a modified portable suction machine (H003-c, Folee, China) in which the specimens were placed to receive the omitted aerosol simulating the smoking in vivo. A modification was designed for the device to allow the specimens to receive aerosol exposure. The modified design was milled from metal for ease of cleaning and durability.

This modification involved a perforated metal base to place the specimens. The perforated base allows a metal pipe, which is attached to a negative pressure of the suction machine, to go through it. The inlet parts of the suction machine were attached from inside with a distributor that is custom fabricated with openings that orient the aerosols' fumes directly to the specimens. (**Fig. 2**)

Fig. (2) A designed perforated metal base to place the specimens

Specimens were exposed to 20 cycles of aerosol emitted by a same ECIG device using the smoking chamber. The ECIG device contains a cartridge of volume 1.6 mL that was filled entirely with e-liquids and its batteries were being fully charged before exposing each experimental group. The ECIG was then attached to the smoking machine device via a silicon tube. Inside the chamber, specimens were fixed at a 1.5 cm distance in front of the aerosol inlet of the ECIG. The top of the chamber was connected to a vacuum system, which applies a negative pressure. (**Fig. 3**)

Fig. (3) A single EC device omitting aerosol to expose the specimens to the fumes for 20 cycles

Each cycle consisted of 10 puffs of 4 seconds puff duration and an inter-puff interval of 20 seconds giving a total of 220 seconds for each cycle. After completing 10 puffs for each cycle, the liquid is refilled to avoid overheating. Cycles were repeated into 20 cycles giving a total of 200 puffs.

Color measurement was performed on the specimens before and after exposure to ECIG aerosol using a UV/Visible spectrophotometer (EVOLUTION 300, Thermo fisher scientific, Madison WI53711, USA). After 200 puffs, specimens were gently washed with distilled water for 1 minute, dried with absorbent paper and finally the color was remeasured. (Fig 4)

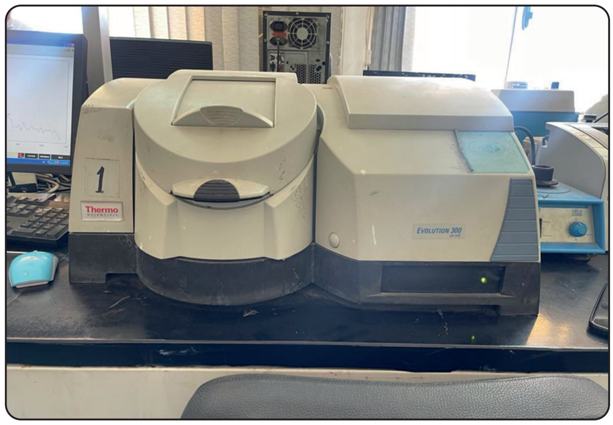

Fig. (4) A spectrophotometer used for color measurements

It should point out that adopting a power of 80% to detect a standardized effect size in delta E (color stability) (primary outcome) of 1.84 (this is not a value of clinical color change, this is what is called in statistics: The standardized effect size (Cohan d) and this is calculated to estimate the required sample size. On the other hand, the present study resulted in statistical significance in the primary outcome (colour stability), so the post hoc power of the study is > 80% and the estimated sample size is enough. If you would like to instruct us to carry statistical post hoc power analysis officially, additions can be made…. Please do).

Fig. (5) CAD/CAM e-max veneers being placed for color analysis in the spectrophotometer

Post-hoc power analysis was done in University of Alexandria, Medical Research Institute, Department of Biomedical Informatics and Medical Statistics and revealed that the power achieved by a sample size of 18 specimen patients per group (number of groups = 2) for t-test (Means: Differences between two independent means (two groups)) based on absorbance in the No Flavour group (1.197±0.139) versus Flavour group (1.868±0.382, resulted in two-tails standardized effect size (d) of 2.334.(1)

Power (1-b error probability) = 0.9999 = 99.99%

The absorbance was also statistically significant when comparing three subgroups (n=12) for each group (p=.002), indicating power over 80%. Also statistically significant when comparing seven subgroups (n=6) for each group (p<.0001), indicating power over 80%.

We will send a scan of the official paper signed by the Professor who carried the post-hoc power analysis and a level of significance 5% (α error accepted =0.05) was considered in this study based on Wasilewski et al. results[17]. The minimum required sample size was found to **6 specimens** per each type of veneer.[18] Any sample was withdrawn from the study due to any reason and replaced to maintain the sample size.[19] The sample size was calculated using GPower version 3.1.9.2.[20]

Data analysis

As indicated by Shapiro Wilk test, the data was normally distributed and presented using Mean and Standard deviation (SD). To evaluate the impact of flavor, nicotine content, and their interactions on color change, a two-way ANOVA was used. Values for estimated marginal means and adjusted R squared were computed. To determine the variations in delta E between the groups, pairwise comparisons were conducted. The P value for the significance level was chosen at 0.05. Every test had two tails. Data were analyzed using SPSS for windows version 23.

RESULTS

The data presented in **Table 1** shows the mean ΔE and standard deviation of the lithium disilicate glass-ceramic veneers according to both flavor and nicotine content. Regarding specimens exposed to e-liquid, the flavorless and 0 mg nicotine group showed the lowest significant value of 1.044 (±0.044). The flavored 12 mg and nicotine group showed the highest significant value of 2.369 (±0.034). (**Fig. 6**).

TABLE (1) Mean ΔE and Standard deviation of the *lithium disilicate glass-ceramic* veneers according to flavor and nicotine content.

	Group	
	No Flavour	**Flavour**
n	18	18
Min-Max	0.980-1.405	1.471-2.419
Mean±SD	1.197±0.139	1.868±0.382
SE of Mean	0.033	0.090
95.0% Lower CL for Mean	1.128	1.678
95.0% Upper CL for Mean	1.267	2.058
25^{th} Percentile – 75^{th} Percentile	1.090-1.352	1.488-2.338
Test of significance	$t_{(W)(df=21.440)}$=7.000 *p*<.0001*	

n: number of samples
Min-Max: Minimum to Maximum
SD: Standard deviation ***CL: Confidence Limit***
W : Welch's t-test ***df= degree of freedom***
NS: Statistically not significant (p≥.05)
****: Statistically significant (p<.05)***

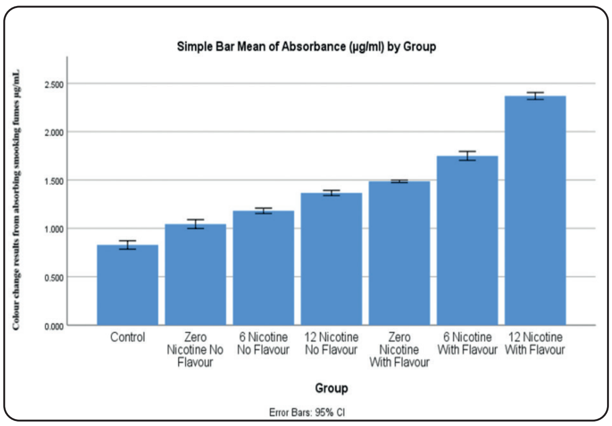

Fig. (6) Bar chart showing color change of dental veneers using different e liquid concentrations

The data presented in **Table 2** shows the mean ΔE and standard deviation of the lithium disilicate glass-ceramic veneers according to flavor content. Regarding specimens that were exposed to e-liquid, the flavorless group showed the lowest significant value of 1.197±0.139, while the flavored group showed the highest significant value of 1.868±0.382.

While **Table 3** shows the mean ΔE and standard deviation of the lithium disilicate glass-ceramic veneers according to nicotine content as we have three groups according to nicotine content (0,6 and 12 mg). In terms of specimens exposed to e-liquid, the group subjected to 0 mg of nicotine had the lowest significant value of 1.268 (±0.233), while the group exposed to 12 mg of nicotine exhibited the highest significant value of 1.868 (±0.524).

Both the flavor and high nicotine contents (12mg) had a significant impact on the color change of the lithium disilicate glass-ceramic veneers, according to Two Way ANOVA (p=.002*).

TABLE (2) Mean ΔE and Standard deviation of the *lithium disilicate glass-ceramic* veneers according to flavor and no flavor content.

	Group	
	No Flavour	**Flavour**
n	18	18
Min-Max	0.980-1.405	1.471-2.419
Mean±SD	1.197±0.139	1.868±0.382
SE of Mean	0.033	0.090
95.0% Lower CL for Mean	1.128	1.678
95.0% Upper CL for Mean	1.267	2.058
25^{th} Percentile – 75^{th} Percentile	1.090-1.352	1.488-2.338
Test of significance	$t_{(W)(df=21.440)}=7.000$ $p<.001$*	

n: number of samples
Min-Max: Minimum to Maximum
SD: Standard deviation CL: Confidence Limit
W : Welch's t-test df= degree of freedom
NS: Statistically not significant (p>.05)
****: Statistically significant (p<.05)***

TABLE (3) Mean ΔE and Standard deviation of the *lithium disilicate glass-ceramic* veneers according to nicotine content.

Absorbance (A)	**Nicotine**		
	Zero Nicotine	**6 Nicotine**	**12 Nicotine**
n	12	12	12
Min-Max	0.980-1.507	1.147-.811	1.341-2.419
Mean±SD	1.265±0.233	1.466±0.299	1.868±0.524
95.0% Lower CL for Mean	1.117	1.276	1.534
95.0% Upper CL for Mean	1.413	1.655	2.201
25^{th} Percentile – 75^{th} Percentile	1.041-1.485	1.178-1.732	1.355-2.362
Test of significance		$F_{(BF)(df=2)}=8.100$ $p=.002$*	
	Zero Nicotine	6 Nicotine	12 Nicotine
Zero Nicotine		.184	.006
6 Nicotine	.184		.081
12 Nicotine	.006	.081	

n: number of samples ***Min-Max: Minimum to Maximum*** ***SD: Standard deviation***
CL: Confidence Li mit BF = Brown-Forsythe df= degree of freedom
NS: Statistically not significant ($p\geq .05$)
****: Statistically significant (p<.05)***

DISCUSSION

In this study, propylene glycol and vegetable glycerin were mixed 50:50 with and without flavor to create nicotine e-liquid formulations at 0, 6, and 12 mg/mL. Since the tobacco flavor is one of the most popular ones among ECIG users, it was chosen for our study.[21]

The present study utilized computer-aided design/computer-aided manufacturing of lithium disilicate glass ceramic veneers because they had superior physical and mechanical attributes over traditional veneers.[22]

On the evaluation of the effects of ECIG in laboratory trials, specimens were exposed to 200 puffs in a pattern of 20 cycles of aerosol, each cycle consisting of 10 puffs with a puff duration of 4 seconds and an inter-puff interval of 20 seconds.[23]

Dental materials become discolored when they come into contact with stains like cigarette smoke, tea, or coffee.[6] Both external stains brought on by food and drink as well as intrinsic factors like the chemical make-up of the substance can have an impact on the color and surface roughness of the resin.[24-26] All lithium disilicate glass-ceramic veneer specimens, on the other hand, showed a modest color change after exposure to different e-liquid formulations, which was regarded as clinically acceptable. The color difference (ΔE) values >0.4 may be perceivable by a trained human observer and clinically unacceptable.[27]

standard cigarettes more than 4000 compounds are found in smoke, some of which could alter the surface and color of both natural teeth and dental implants.[6] As a traditional cigarette burn to produce smoke, an ECIG heats the e-liquid to make vapor; however, toxin levels in ECIG vapors are 9–450 times lower than in regular cigarette smoke.[28]

Both the flavor and nicotine contents had a substantial impact on color change. Although nicotine is white when in its neutral state; however, oxidized nicotine causes tooth discolouration.[29] These findings explained by the studies that used a tobacco flavor with a dark color. This also could interpret why the color shift in the investigated flavored groups was more pronounced.

The findings of our investigation were in line with a study conducted by Pintado-Palomino K., et al.[30] that reported the impact of electronic cigarettes on the color of tooth enamel. Moreover, Chotimah C., et al. who confirmed the effect of ECIG aerosol on the acrylic teeth's color.[31] Alnasser H., et al. concluded that ECIG smoking changes the color of composite resins.[32]

Additionally, in the investigation of Vohra F. et al. [33], they found that ECIG aerosol discolors both ceramic and composite specimens. Composite specimens displayed significantly higher ΔE value while ceramic specimens displayed ΔE value like those in present study. However, results may vary depending on the type of material utilized, the amount of nicotine in the e-liquid, the flavor employed, or how the specimens were exposed to ECIG aerosols.

The fact that the experimental specimens were not subjected to any cleaning procedures, such as brushing and mouthwash, which are cleaning procedures frequently used by patients due to their efficiency in eliminating stains and deposits, is a limitation of the current study. Furthermore, stains and debris may be cleared by moving the lips, saliva, and cheeks. Therefore, further clinical studies should be assessed to evaluate the effect of cleaning protocols and saliva nature on color stability values.

As the presented results showed, the null hypothesis was accepted for flavorless groups. but rejected for flavored ones.

CONCLUSION

Given the constraints of this investigation, it was determined that exposure to ECIG aerosol, both flavored and unflavored, at various nicotine concentrations, significantly affects the color of lithium disilicate glass-ceramic veneers. Although significance difference in colour changes were found in all groups but still within the acceptable clinical threshold value.

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