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INFLUENCE OF STAINING BEVERAGES AND SURFACE FINISHING ON COLOR STABILITY AND SURFACE ROUGHNESS OF ALL CERAMIC RESTORATIONS: LABORATORY STUDY

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ABSTRACT

Purpose: Objectives of this study were to assess and compare the impact of coloring beverages and surface finishing on color stability and surface roughness of dental ceramics.

Material and methods: Twenty-eight identical cuboids (14*12*1mm) were cut from zirconia-reinforced lithium silicate blocks (suprinity) using a precision cutting machine. Another 28 identical cuboids with the same dimensions were milled from high translucent zirconia ceramic blank (zolid fx). The specimens of each ceramic material were divided into 2 main groups (n=14) according to the finishing technique used; group G: specimens were glazed. group P: specimens were polished. Each subgroup was subdivided into 2 subgroups (n=7) according to the immersion solution used; Tea or Cola. Color measurements and surface roughness of all specimens were measured at the beginning and after 28 days of immersion in the staining beverages.

Results: Tea possessed the highest color changes in all tested groups, and these changes were statistically significant compared with those of Cola in both surface finishing groups and in both types of ceramics. The color changes of Tea were not clinically acceptable in the zirconia ceramic groups ($\Delta E > 3.3$).

While Cola possessed the highest mean Ra in all tested groups, and these changes were statistically significant compared with those of Tea in both surface finishing groups and in both types of ceramics.

Conclusions: Tea showed the highest impact on color of polished and glazed types of used ceramics, while Cola significantly increased the surface roughness of both polished and glazed types of used ceramics.

KEYWORDS: Ceramic, Color stability, Surface finishing, Acidic solution, Staining drinks.

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INTRODUCTION

Esthetic dentistry is now the main demand for most dentists and patients to obtain a wonderful smile and to restore the natural appearance. These esthetic objectives are influenced by several factors for example color, shape, position, and accuracy of existing restorations. [1]

Dental ceramics are the most well-known esthetic restorative materials in dentistry in view of their esthetic advantages, biocompatibility to the health of soft tissues and ability to provide smooth shiny surface which reduces plaque accumulation and subsequent periodontal disorders.[2] Ceramics should provide natural tooth characteristics, such as color, smooth surface properties, and translucency. [3, 4]

To gain the high esthetic and superior optical properties of glass ceramics and the improved mechanical properties of zirconia, lithium silicate glass ceramic material strengthened with approximately 10% by weight zirconia crystals ceramic (ZLS, Suprinity) was introduced. [5,6]

Zirconia ceramics possessed high mechanical properties but lower esthetic due to its lower translucency, pure zirconia is translucent, but additives such as oxides result in yellow or black colors after a reduction baking.[7] However, new translucent zirconia material has been introduced, according to the manufacturer, this material offers the high mechanical properties (700±150 MPa) presented by zirconia with the high translucency presented by lithium disilicates.[8] Currently, monolithic ceramic restorations have acquired increasing salability because of their improved manufacturing procedures and lowered functional problems, for example, chipping and delamination of the veneering ceramics.[7] Zolid fx ceramic is a polychromatic super-high translucent zirconia with incorporated concealed translucency gradients that provides naturalistic tooth appearance.[9]

The achievement of good esthetics and color constancy of a restoration throughout its functional lifetime is a significant factor to obtain successful dental ceramic restorations. Subsequently, restorative materials ought to have great color stability to keep up its color from changes occurring because of plaque aggregation, stains from everyday drinks, surface irregularities, and chemical degradation.[10]

In general, color results from the interaction of three main determinants: a) source of light, b) physical properties of the object, and c) the spectator. Any discrepancy in any of the three factors can change the perception of color.[11] Although dental ceramic shows color stability, however it might undergo some staining that might be grouped into endogenous or exogenous. Endogenous discoloration may result from chemical instability of the material and its glazed layer.[12] While exogenous shade changes may result from extrinsic factors like smoking, food, and colorant beverages that could be adsorbed on the restoration surface and this discoloration can be enhanced by surface roughness of the restoration. [13]

Surface degradation of dental ceramics occurs when they are exposed to aqueous solutions as well as pH changes.[14] Moreover, this interaction can be accentuated by fluctuation in temperature [15] and has unfortunate consequences on the restoration, for example, collection of microbial plaque and change of restoration shading and surface criteria.[16]

The increased consumption of hot and cold beverages has brought up questions about their impacts on the clinical degradation of new kinds of dental ceramic restorative materials regarding shading stainability and surface hardness. [17]

Various techniques can be used for evaluation of esthetic restoration appearance and natural color of teeth such as spectrophotometers or colorimeters.[18,19] Spectrophotometers measure the wavelength that is reflected or transmitted from one object at a time, without being influenced by the subjective interferences of the color [20] whereas colorimeters give a general estimation of the light retained [21]. The Commission International de l'Eclairage L*a*b* (CIELab) system estimates chromaticity and characterizes the shade of an object in a uniform 3-dimensional space. Color difference (ΔE) is determined through contrasts in the color coordinates L*, a*, and b*.[22] Color analysis which can be performed by computerized strategies permits color estimation of dental restorative materials without the subjectivity of human examination.[23, 24]

Glazing procedure before permanent placement of the restoration is essential to provide stable color and resistance to various staining [20, 25] and any changes performed after ceramic restoration cementation causing destruction of the outer layer may increase the surface irregularities,[26] which subsequently decrease the amount of reflected light and thus influence shade of ceramic restoration [22] while enhancing staining deposition.[27]

It was suggested that polished surfaces after chair-side modification might be as satisfactory as those glazed.[28-30] Furthermore, polishing shows additional benefits in that the crack durability of glazed porcelain was less than that of polished one.[31]

Until now, little thoughts consider the long-life span of dental ceramic regarding stain susceptibility as an impact of different beverages. Therefore, this study was done to evaluate and compare the impact of usually utilized coloring beverages and surface finishing on the color stability of zirconia ceramics and surface irregularities.

The null hypothesis of this *in-Vitro* study was that the tested beverages (black Tea and Cola) were not able to stimulate alterations in the color stability and surface properties of the tested zirconia reinforced lithium silicate (vita-Suprinity) and zirconia ceramic (Zolid fx).

MATERIALS AND METHODS

Construction of zirconia reinforced lithium silicate (Suprinity) specimens:

Twenty-eight identical cuboids (14*12*1mm) were cut from zirconia-reinforced lithium silicate blocks (Suprinity, VITA Zahnfabrik, Bad S¨ackingen, Germany) using a precision cutting machine (Isomet 4000, buchler ltd, Lake Bluff, IL, USA) under water cooling (Figure 1). Crystallization firing of the specimens was done according to the manufacturer's instructions. Then, the Suprinity Specimens (S) were coated with its special glaze (VITA AKZENT Plus GLAZE LT) and fired according to the manufacturer's recommendations. The S specimens were randomly divided into 2 equal groups (n=14); group G (glazed): Specimens were left glazed, group P (polished): specimens were ground with 40 µm diamond grinding stones then polished with the special finishing kit (Vita Suprinity Polishing Set Clinical Vita Zahnfabrik, Bad S¨ackingen, Germany) recommended by the manufacturer.

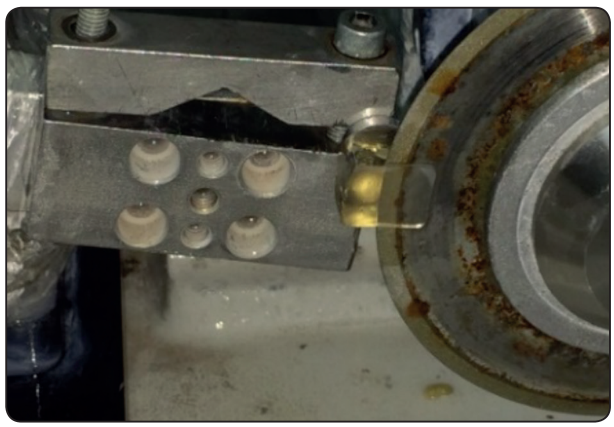

Fig. (1) Cutting of the Suprinty specimens with Isomet precision cutting machine.

Construction of zirconia (Zolid fx) specimens

One of the S cuboids was scanned by an optical scanner (Ceramill map400, Amman Girrbach, Germany), and 28 identical copies of the scanned cuboid were designed on the pre-sintered zirconia blank (Ceramill Zolid fx, Amman Girrbach, Germany) on the computer screen using its special software (Ceramill Mind design software). Then, the order was given to the 5-axis milling machine (Ceramill Coolstream, Amman Girrbach, Germany) to dry mill the 28 cuboids with 20% volume enlargement. Sintering of the cuboids was performed according to the manufacturer's recommendations using the sintering furnace (Programat P500, Ivoclar Vivadent, Liechtenstein). Then the Fx cuboids were sprayed with their special glaze (Ceramill glaze Amman Girrbach, Germany) and fired according to the manufacturer's recommendations. The Fx specimens were randomly divided into 2 equal main groups (n=14); group G (glazed): specimens were left glazed, group P (polished): specimens were ground with 40 µm diamond grinding stones then polished with the special diamond polishing kit (Amann Girrbach diamond polishing bits) recommended by the manufacturer.

Specimens' submersion and storage:

All specimens of each ceramic group S & Fx (n=14) were randomly subdivided into two subgroups (n=7) according to the immersion solution used: Black Tea (T) (Lipton Tea; Unilever), and Cola (C) (Coca-Cola Company, Cairo, Egypt). Preparation of Tea was performed regarding the maker's guidelines (15 g in 300 mL of boiled, distilled water). Before submersion, baseline readings for color and surface roughness were registered for all specimens. Every specimen was submersed independently in a closed separate tube filled with 5 ml of submersion drink (Tea or Cola) and stored in an incubator at 37 °C for 28 days. Every 48 hours, specimens were removed from their tubes, cleaned using filtered water then re-immersed in newly prepared Tea or Cola to prevent bacteria or yeast contamination.[32]

Color change measurements:

The staining susceptibility is characterized as variation in shading, that is estimated through contrasting outcomes and starting inputs.[17] A Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany) was used for color estimation of all specimens, at the beginning and after 28 days of submersion (Figure 2). The aperture size was set to 4 mm and the specimens were lined up with the device. A white background was used, and assessment was made using the CIE L*a*b* shading space comparative with CIE standard illuminant D65. The color changes (ΔE) of the specimens were assessed utilizing the following equation:

$$\Delta E_{CIELAB} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})\ ½$$

Where L* is the lightness (0-100), a* is the change in color on the red/green axis and b* is the color on the yellow/blue axis.[33]

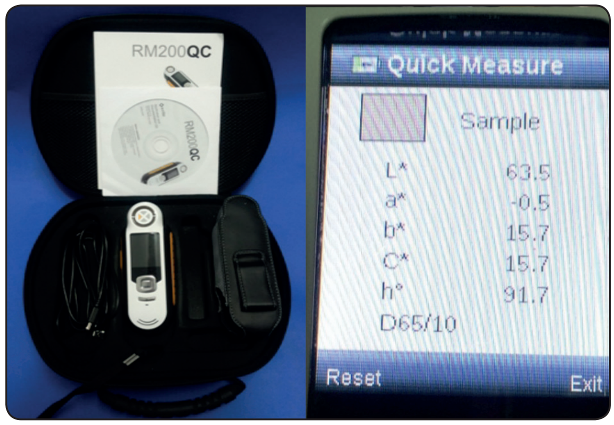

Fig. (2): Reflective spectrophotometer

Surface roughness methodology and assessment

Surface roughness (Ra) measurement was achieved using USB digital surface profile gauge, (Elcometer 224/2, Elcometer Instruments, Great Britain), and computer software of roughness tester supplier (Elcomaster 2, Elcometer Instruments) was utilized for data recording. The mean estimation of three readings yielded the mean estimation of the roughness of every specimen, the consequent range of roughness esteems (Ra) termed in µm were registered and tabulated.

Statistical evaluation and data translation:

Data were fed to the computer and evaluated utilizing IBM SPSS software (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp). Quantitative data were described using mean, standard deviation for parametric data after testing normality using Shapiro–Wilk test. Significance of the acquired outcomes was judged at the (0.05) level. Student *t*-test was used to analyze

2 independent groups and three-Way ANOVA test for detection of combined effect of more than 2 independent variables on continuous parametric outcome.

RESULTS

The mean and standard deviations of ΔE and surface roughness of ceramic specimens immersed in black Tea and Cola beverages are presented in table 1. The resulted data of the current study revealed that, there was a statistical significant difference between the impact of Tea and Cola on the color stability and surface roughness of the two types of ceramics. Tea showed higher effect on color constancy of both types of surface finishing (glazed and polished) in both groups of ceramics (S & Fx) than did Cola. Tea showed noticeable color changes on Fx groups as ΔE values were greater than 3.3 which was considered clinically unacceptable based on previous studies. [34,35]

Regarding the surface changes, Cola showed higher surface roughness on both glazed and polished groups in both types of ceramic than did Tea.

Regarding the methods used for ceramic surface finishing either glazing or polishing, the present results revealed that, there was no significant difference between glazed and polished ceramics when immersed in Tea or Cola in relation to color change and surface roughness as p >0.05 (Table 2). Also, it was noticed that Tea and Cola showed higher effect on the color of polished Suprinity and Zolid fx ceramic specimens than glazed ones. On the other hand, Tea and Cola beverages showed the higher effect on surface roughness of glazed Suprinity ceramic specimens than polished ones. While, both beverages showed the higher effect on surface roughness of polished Zolid fx ceramic specimens than glazed ones, however these effects were not significant.

Applying the 3-way ANOVA test on the results of this study revealed that the combined R squared value is 82.4% of the color change can be predicted by change in material type with beverages, also applying the 3-way ANOVA test on the results of surface roughness revealed that the combined R squared value is 92.1% can be predicted by change in material type with beverages.

TABLE (1): Mean Delta E and surface roughness between beverages with Suprinity and Zolid fx materials

Variables	**Suprinity**					
	Glazed		Test of significance	**Polished**		Test of significance
	Tea	***Cola***		***Tea***	***Cola***	
Delta E	2.90±0.40	2.30±0.30	t=2.80 p=0.016*	3.0±0.30	2.41±0.20	t=4.32 p=0.001*
Surface roughness Ra in μm	0.19±0.04	0.251±0.05	t=2.52 p=0.02*	0.17±0.03	0.24±0.06	t=2.76 p=0.017*
Variables	**Zolid fx**					
	Glazed		Test of significance	**Polished**		Test of significance
	Tea	***Cola***		***Tea***	***Cola***	
Delta E	4.0±0.35	2.50±0.40	t=7.5 p=0.001*	4.33±0.12	2.60±0.50	t=8.9 p=0.001*
Surface roughness Ra in μm	0.42±0.03	0.51±0.04	t=4.76 p=0.005*	0.46±0.01	0.54±0.05	t=4.15 p=0.001*

Student t-test *statistically significant if p<0.05

TABLE (2): Mean Delta E and surface roughness between surface finish with Suprinity and Zolid fx materials

Variables	Suprinity					
	Tea		Test of significance	Cola		Test of significance
	Glazed	*Polished*		*Glazed*	*Polished*	
Delta E	2.90±0.40	3.0±0.30	t=0.53 p=0.60	2.30±0.30	2.41±0.20	t=0.81 p=0.44
Surface roughness Ra in μm	0.19±0.04	0.17±0.03	t=1.06 p=0.31	0.251±0.05	0.24±0.06	t=0.373 p=0.715
Variables	**Zolid fx**					
	Tea		Test of significance	Cola		Test of significance
	Glazed	*Polished*		*Glazed*	*Polished*	
Delta E	4.0±0.35	4.33±0.12	t=1.36 p=0.63	2.50±0.40	2.60±0.50	t=0.413 p=0.68
Surface roughness Ra in μm	0.42±0.03	0.46±0.01	t=1.34 p=0.61	0.51±0.04	0.54±0.05	t=1.23 p=0.23

Student t-test *statistically significant if p<0.05

DISCUSSION

The null hypothesis of this *in-Vitro* study was rejected, as the used staining beverages made changes in color and surface roughness of the used ceramic materials.

A few variables influence the restorations in the mouth and make them susceptible to changes in color and surface characteristics, for example, variations in temperature, humidity, type of nourishment and smoking habits.[36] Mechanical and physical properties are not only the main factors required for success of restorative materials but also their esthetic appearance.

Ceramic restoration fabrication technology is considered the quickest developing zone of dental material innovative work and development regarding its capability of restoring natural appearance, biocompatibility, chemical inertness, and more protection against wear.[37] The ceramic materials used in this study were Suprinity which is a zirconia reinforced lithium silicate and Zolid fx which is a high translucent zirconia, both are introduced in the dental market and no sufficient investigations were made on them regarding their color stability and surface roughness.

Glazed and polished surface finishing were used in this study to simulate the clinical condition occurred during intra oral adjustment of ceramic restorations. Different polishing kits were used for each type of ceramic as recommended by the manufacturers.

In the present study, the used beverages (Tea and Cola) were chosen since they are the most preferred and commonly consumed beverages in our country. The immersion time in the staining beverages was chosen to be 28 days as it was estimated to be equal to 2.5 years of clinical ageing. [36,38] The staining beverages were replaced with fresh ones every 48 hours to prevent bacteria or yeast contamination.[32]

For many years, tooth color was determined using tooth shade guide as a conventional method for shade selection. Although this method is inaccurate and subjective, but simple to utilize. Lately, scientific methods were presented to overcome insufficiencies with the visual guide. A spectrophotometer is a device detecting shading variations in which readings can be converted into quantitative data. The benefits of this device involve accuracy, ability to analyze the principal components of a series of spectra, and the ability to convert data to various color measuring systems.[20]

The results of this study showed that, the selected immersion drinks elevated the staining capacity and surface roughness of the 2 main ceramic groups. The beverage capability of changing the color of restorative materials relies upon the sort of the material itself as expressed by other researchers. [39,40] In the study performed by Hipólito et al., (2013)[41] they found that the pH of immersion solutions affected the color of tested restorative materials and although, Cola drink has lower pH (2.4) than black Tea (4.9) which affected the ceramic surface roughness, the low amount of yellow colorant in its structure made color change not perceptible to the human eye. Moreover, composition of Cola contains mainly carbonic and phosphoric acids [42] causing ionic disintegration and release of basic lithium and aluminum particles of silica in ceramic structure, which may be toxic, [43] and resulting in deficiency of alkaline ions.[44] Therefore, surface damage occurs producing more entrance of stains and thusly, more staining of ceramic which was coordinate with the results of this study despite the use of different types of ceramics.

On the other hand, discoloration occurred by black Tea could be due to the adsorption of polar colorant agents onto the outer surface of ceramics, which may clarify the staining of the ceramic specimens observed after immersion in Tea.[45] In this study, black Tea showed higher effect on color stability of glazed and polished ceramics than Cola. These results agreed with those of Tanizawa et al., (2007)[46] who explained that Tea includes 2 primary pigment groups, theaflavins and thearubigins that were created by the fermentation process through the oxidative polymerizations. These stains comprise of natural mixtures like the polyphenols and other inorganic mixtures, when they are exposed to air for a period, they are settled and become hard to be eliminated. The development of resistant stain is mainly an oxidation response, the arrangement of silicates covering the underlying organic materials is considered the second point in balancing out or reinforcing the colorants. These explanations were coincident with the results of this study as Tea caused a significant color change in both glazed and polished zirconia ceramic and these changes were clinically noticeable (ΔE 4.0±0.35 & 4.33±0.12). While color changes in ZLS with Tea were not clinically noticeable (ΔE 2.90±0.40 & 3.0±0.30) which may be related to the special homogeneous fine-grained structure resulted from crystallization of the ZLS having grain size of 0.5-0.7 μm [47,48] compared to that of zirconia being more than 0.8 μm as reported by the manufacturer.

In the current study, drenching of ceramics in Tea and Cola resulted in increased surface irregularities in both types of ceramics and in both types of surface finish especially with Cola which may be attributed to its lower pH. However, the surface roughness caused by Tea was low and insignificant.

Regarding the results of both color and surface roughness of both types of ceramics and tested beverages, there were no significant difference between glazed and polished surface finish within the same type of ceramic. This may be related to using the special polishing kit recommended by each ceramic manufacturer which was coordinate with the results of Dawood (2016).[30]

The polished Suprinity groups revealed the lowest surface irregularity values among tested groups, this may be attributed to the coherence between the matrix and the filler particles of the material which may result from heat generation during the polishing process. This is coinciding with the results of Kamala and Annapurni (2006) [49] and Firouz et al (2019)[42] although they used different finishing kits and different incubation temperatures. However, the results disagreed with those of Motro et al.,(2012) [50] which may be due to their use of different types of ceramic.

Considering the results of surface roughness of both surface finish of ceramics and tested beverages, there were statistically significant difference between ZLS and Zirconia within the same beverage. This may be attributed to the difference in surface roughness base line measurements of both materials (0.18 ± 0.03, 0.16 ± 0.06 μm for ZLS and 0.41 ± 0.07, 0.45 ± 0.14 μm for zirconia) due to the difference in their grain size and composition.

CONCLUSIONS

Based on the findings of the current study, the accompanying outcomes were obtained:

1. Tea increased the color parameters (ΔE) of both types of ceramics (ZLS and zirconia) significantly than did Cola regardless the surface finish (glazed or polished), and this effect was clinically noticeable with zirconia ceramic.
2. Cola affected the surface roughness of both types of ceramic significantly than did Tea regardless the surface finish.

Limitations of Study

Fundamental limits of the current investigation are that the examination is done *in-Vitro*, and only two distinct drinks were utilized in the current study. Furthermore, Atomic Force or Scanning Electron Microscopy testing of specimens may be recommended to support measurements of surface roughness with profilometer.

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