EFFECT OF SURFACE FINISHING AND DIFFERENT IMMERSION MEDIA ON THE COLOR STABILITY AND SURFACE ROUGHNESS OF VITA LUMEX VENEERING ZIRCONIA (An In-vitro study)

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ABSTRACT:

Aim: The current study sought to evaluate the effect of surface finishing and staining solutions and surface roughness of Vita lumex veneering zirconia. **Methodology:**42 square specimens of 10 mm width, length and 2 mm height (1 mm for zirconia substructure & 1 mm for veneering materials) were sectioned. All the specimens were ground with 40 µm diamond grinding stones to simulate intra oral occlusal adjustment, then randomly divided into 2 equal groups according to surface finish either polishing or glazing. Before immersion, baseline readings for color and surface roughness were registered for all specimens. Each group was randomly subdivided into three subgroups according to the immersion solution used either: coffee, citric acid or artificial saliva. Surface roughness measurements were achieved using a non-contact profilometer and a color estimation of all specimens was done by reflective spectrophotometer. **Results:** Regarding glazed surfaces, there were insignificant differences in roughness in all immersion solutions before (P=0.84), and after (P=45). Regarding polished surfaces, there were insignificant differences in roughness in all immersion solutions before (P=0.79), and after (P=39). While regarding the color changes for both surface treatments (ΔE2000), artificial saliva was significantly the lowest, then citric acid, while coffee demonstrated significantly the highest color changes. **Conclusions:** Coffee had the greatest influence on the color of polished and glazed used ceramics, but it was clinically acceptable. However, there was no significant increase in surface roughness for both polished and glazed types of used ceramics.

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

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INTRODUCTION:

Metal-free restorations have gained popularity, particularly in rehabilitation cases because of superior esthetic results. These materials have properties that validate their use, such as high compression and abrasion resistance, high chemical stability, high tensile strength, biocompatibility, attractive esthetics, translucency, opalescence, opacity, fluorescence, and a coefficient of thermal expansion similar to natural teeth. [1–3]

The restoration's esthetic success can be summarised in two terms: initial color matc hing and stability over time. Eventually, restorative materials should have outstanding coloration stability to preserve up their color from modifications going on because of plaque aggregation, stains from ordinary liquids, surface irregularities, and chemical degradation.[4]

Increased surface roughness in ceramics may reduce strength and impact the clinical outcome of ceramic restorations. Surface texture can alter color perception, as rougher surfaces reflect less light. Rough restoration surfaces are also correlated with caries or periodontal problems.[5]

It was claimed that not only diet and immersion time but also surface texture affects color stability. A study conducted on surface roughness and color measurements of glazed or polished restorative materials after coffee immersion, managed to reach that the mean surface roughness raised across all sample groups, as did the mean color change, but both remained within clinically acceptable ranges.[6,7]

Vita Lumex AC is a leucite-reinforced glass-ceramic veneering system with the VITA material formula where the leucite content of the glass allowed for shade accuracy and vivid, reliable results along with optimum bond to all conventional, all-ceramic framework materials (zirconia, lithium silicate and feldspar ceramics), for veneering titanium, also leucite contributes to high material strength for the construction of restorations without a framework (e.g., veneers)

Up to the present, little consideration has been given to the vulnerability of dental porcelain to discoloration caused by certain beverages.

The study's null hypothesis stated that no change in the color and surface roughness of Vita Lumex veneering material will be noted.

METHODOLOGY:

Sample Preparation:

A ceramillZolid HT+ disc was added into the CAM software with its specific shrinkage factor. A cuboid block of 12.3mm*12.3mm*16mm was designed in Blender 4.1 software, exported in STL format then imported to CAM software to be nested into the virtual disc and supporting sprues were placed prior to milling. Dry milling using ImesIcoreCoritec 250i (5 axis) milling machine in order to get eight cuboid blocks. Then the cuboid blocks were mounted on holder using cyanoacrylate glue, and by using isomet precision cutting machine**,** the blocks were sliced into 42 plates of 1.25 mm thickness each. The specimens were then placed in tray over sintering beads, to be sintered following the manufacturer recommended sintering cycle, in a TABEO-1/M/ZIRKON-100 furnace.

Layering of Vita Lumex was done by the help of mould, aiming to get 0.7 mm dentine layer and 0.3 mm enamel layer. After combining with modeling liquid, a 0.2mm thick wash bake of power wash material was applied to the zirconia substrate. Followed by a layer of dentine of 0.5 mm thickness **"Figure 1"**.After firing the specimens were inspected for any defects to add correcting layer then enamel layer was applied in several small quantities. Adjustments were done using diamond burs with diamond heads. All firing was done in Ivoclar Programat EP 3010according to manufacturer instructions.

All samples were subjected to grinding by single operator using football red coded diamond stone **(40 µm)** in high-speed handpiece under water coolant to simulate intraoral adjustment.

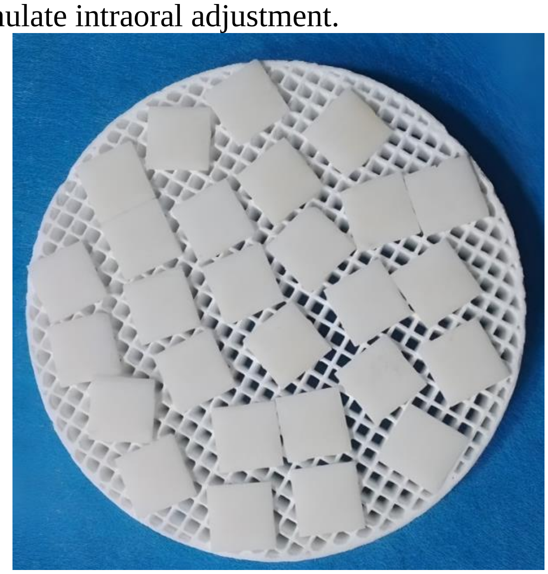


Figure 1: *Specimens after dentine firing*

A total of 42 specimens were numbered from 1 to 42**,** then randomization of the specimens was performed through dividing them into two groups **(n=21)** according to surface treatment through computer generated random tables by (random.org).

Surface Treatment:

Glaze firing (Auto glaze) was executed following manufacturer instructions while for **polishing,** a three steps diamond-impregnated polishing system in low-speed hand-piece under water ejected through air-water tip from time to time was utilized, this was done under **(10.000 RPM)**. It offered a smooth surface without the need for further glazing and can be utilized with a range of ceramic materials.[8]

Baseline reading:

Prior to staining, all specimens' baseline color and surface roughness were measured. Measurements were taken three times for each specimen.

Specimens' immersion and storage:

Each group (n=21) was randomly subdivided into three subgroups (n=7) according to the immersion solution: Artificial saliva, Coffee (Seelaz instant coffee classic, Egypt) or Citric acid. Coffee was prepared according to the manufacturer's recommendations. 50 ml of boiling water per one scoop of coffee (about 10 g/50 ml). Preparation of Citric acid was done by adding 20g of citric acid powder to 100 ml of distilled water to get 2% citric acid.

The pH was measured with a pH meter, measured 3 times to ensure accuracy of results. The results were as follows:citric acid was 1.1, coffee was 5.1, while artificial saliva was 6.9.

Figure 2: Tightly sealed container for storage in immersion solutions

Each specimen was immersed in a closed container filled with 5 ml of immersion solution "Figure 2" and stored in an incubator at 37 ˚C for 14 days, with the exception of citric acid for 8 hours. To avoid bacterial or yeast contamination, specimens were taken from their containers every48 hours, washed with filtered water, and re-immersed in a freshly prepared solution.[9–11]

Color change measurements:

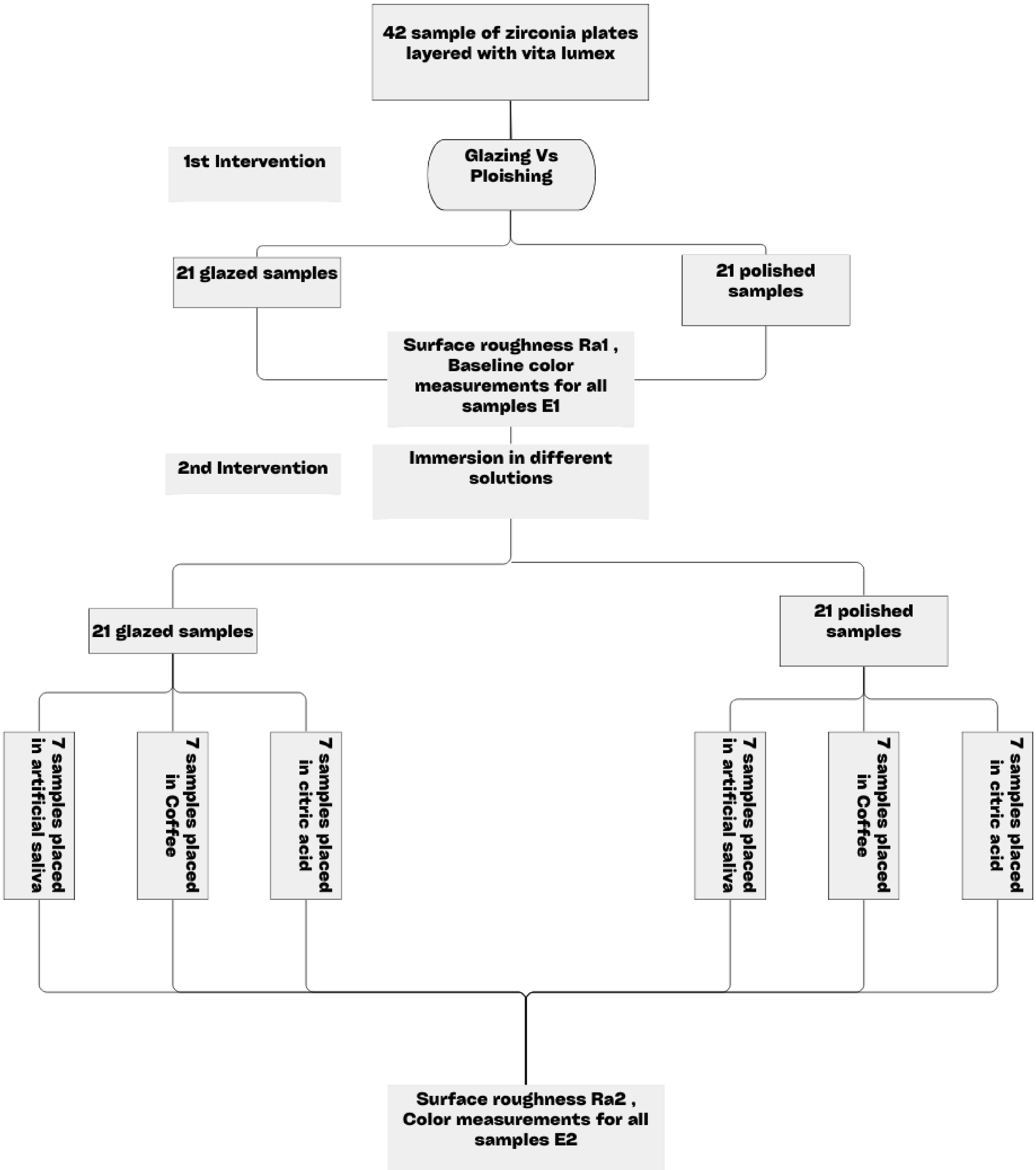
The staining susceptibility is defined as a shading varying that is evaluated by comparing the results to the initial input. At both the start and end of the 14-day was estimated using a spectrophotometer (Cary 5000 UV-Vis-NIR Spectrophotometer "Agilent (USA)"). All values are measured under Illuminant D65 and standard observer 10^{o}.The color changes (ΔE) of the specimens were evaluated using the following equation: $\Delta E = (\Delta L*2 + \Delta a*2 + \Delta b*2)$ 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.

immersion period, the color of all specimens

Surface roughness measurement:

A 3D non-contact optical profilometer (U500x Digital Microscope, Guangdong, China) with a resolution of 3 Mega Pixels was used to quantify surface roughness (Ra), which was set vertically 2.5 cm away from the samples. The angle between the lens axis and the illumination sources is roughly 90 degrees. The roughness of each specimen was estimated using three readings. The resulting roughness range (Ra) in µm was recorded and summarized.

Statistical evaluation and data translation:



Statistical analysis was carried out using SPSS 20®, Graph Pad Prism®, and Microsoft Excel 2016. All data were examined for normality using the Shapiro-Wilk and Kolmogorov Normality tests and reported as means and standard deviation (SD) values. Shapiro Wilk and Kolmogorov were used for normality exploration. The independent t test was used to compare glazed and polished groups regarding before and after immersion. The Wilcoxson signed rank used to compare glazed and polished groups regarding difference between before and after immersion. Comparison between before and after were performed by using Paired t test. Comparison between different immersion solutions was performed by using One Way ANOVA test followed by Tukey's Post hoc test for multiple comparisons.

RESULTS:

Comparison between different immersion solution:

"Table 1"and **"Figure 4"** present data on color changes (ΔE1976 and ΔE2000) for glazed and polished ceramic surfaces after immersion in artificial saliva, coffee, and citric acid. The analysis used a One-Way ANOVA test to compare the effects of different solutions on color change which revealed a significant difference between different solutions as:

In Glazed surfaces regarding ΔE1976: the color changes in artificial saliva (1.267 ±0.14) were significantly the lowest, then Citric acid (3.161 ± 0.15), while Coffee (4.036 ± 0.14) was significantly the highest. Regarding ΔE2000: the color changes in artificial saliva (0.943 ± 0.11) was significantly the lowest, then Citric acid (2.410 ± 0.101), while Coffee (2.953 ±0.07) demonstrated significantly the highest color changes.

In Polished surfaces regarding ΔE1976: the color changes in artificial saliva (1.291 ± 0.11)were significantly the lowest, then Citric acid (3.301 ± 0.17), while Coffee (4.354 ± 0.18) demonstrated significantly the highest color changes. Regarding ΔE2000: the color changes in artificial saliva (0.967 ± 0.08) was significantly the lowest, then Citric acid (2.553 ± 0.107), while Coffee (3.253 ± 0.09) demonstrated significantly the highest color changes.

Table 1 : Mean and standard deviation of color changes (ΔE1976, ΔE2000)after immersion in different solution regarding glazed and polished groups, comparison between different solutions using One Way ANOVA test:

		Artificial saliva		**Coffee**		**Citric acid**		**P value**
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	
Glazed	**DE1976**	1.267	0.147	4.036	0.141	3.161	0.152	0.0001*
	DE2000	0.943	0.110	2.953	0.078	2.410	0.101	0.0001*
Polished	**DE1976**	1.291	0.114	4.354	0.184	3.301	0.170	0.0001*
	DE2000	0.967	0.085	3.253	0.099	2.553	0.107	0.0001*

**Significant difference as P<0.05.*

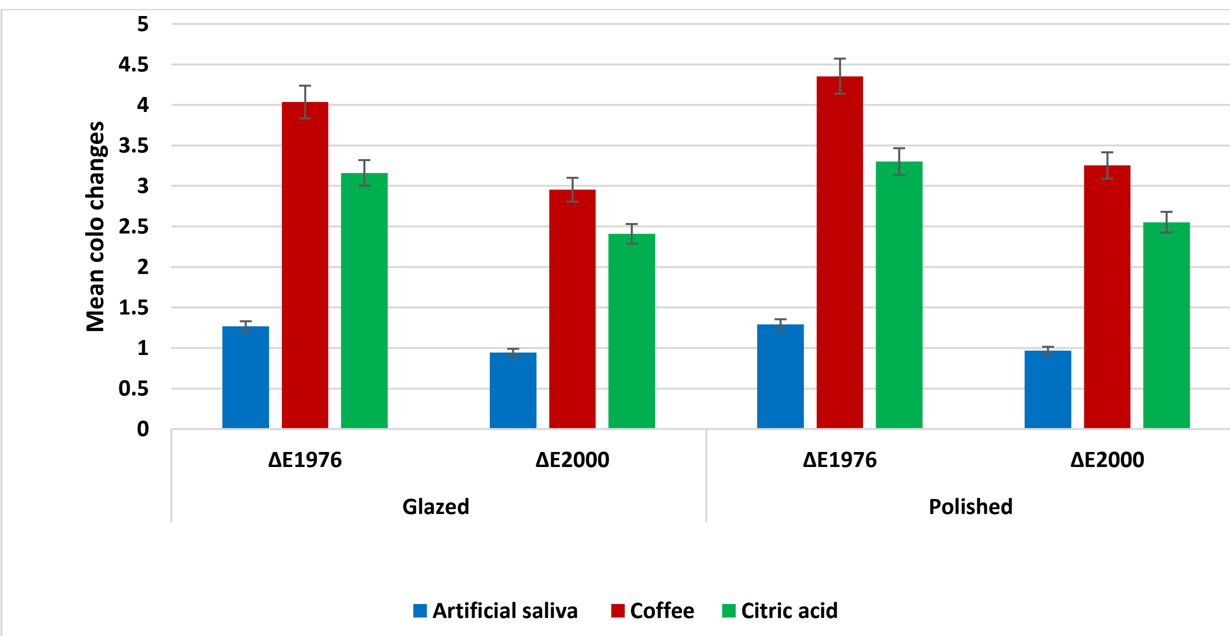


Figure 4 : Bar chart representing comparison between different solutions in both glazed and polished surfaces regarding color changes.

Comparison between glazed and polished surfaces (effect of surface treatment):

"Table 2" and **"Figure 5"** present data comparing the surface roughness of glazed and polished surfaces before and after immersion in different solutions: artificial saliva, coffee, and citric acid using independent t test which revealed that:

1. Artificial Saliva: For both glazed and polished surfaces, there was a slight decrease in surface roughness after immersion. There was insignificant difference between glazed and polished surfaces before and after immersion in artificial saliva ($p > 0.05$).
2. Coffee: Glazed surfaces showed a slight increase in roughness, while polished surfaces showed a slight decrease, there was insignificant difference between glazed and polished surfaces before and after immersion in coffee ($p > 0.05$).
3. Citric Acid: Glazed surfaces showed a minimal increase in roughness, while polished surfaces showed a slight decrease. There was insignificant difference between glazed and polished surfaces before and after immersion in citric acid ($p > 0.05$).

Table 2: Mean and standard deviation of surface roughness before and after immersion in different solutions, comparison between glazed and polished surfaces using independent t test:

		Group				Comparison				
		Glazed		Polished		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
		Mean	Standard Deviation	Mean	Standard Deviation			Lower	Upper	
Artificial saliva	Before	0.264	0.082	0.270	0.016	-0.006	0.032	-0.075	0.063	0.849
	After	0.240	0.061	0.268	0.019	-0.028	0.024	-0.080	0.025	0.273
	Difference	-0.023	0.107	-0.002	0.028	-0.021	0.042	-0.113	0.070	0.450
Coffee	Before	0.250	0.022	0.266	0.029	-0.016	0.014	-0.046	0.014	0.265
	After	0.266	0.030	0.262	0.021	0.003	0.014	-0.027	0.033	0.816
	Difference	0.016	0.024	-0.003	0.037	0.019	0.017	-0.017	0.055	0.130
Citric Acid	Before	0.264	0.032	0.262	0.014	0.002	0.013	-0.027	0.031	0.891
	After	0.268	0.036	0.253	0.021	0.015	0.016	-0.020	0.050	0.364
	Difference	0.004	0.056	-0.010	0.022	0.013	0.023	-0.036	0.063	0.710

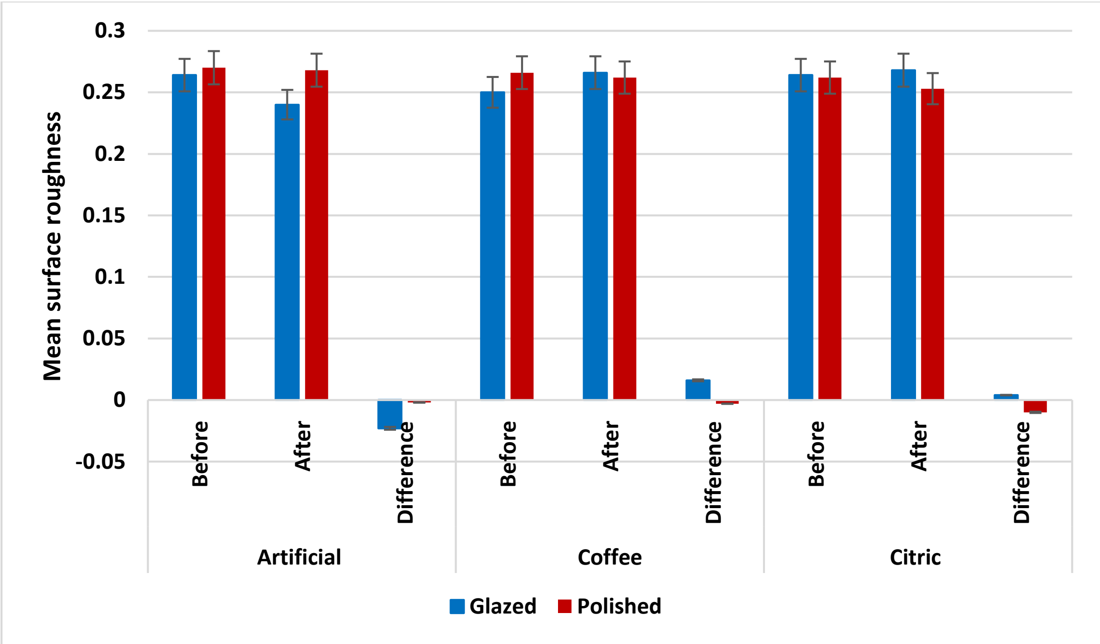


Figure 5 : Bar chart representing comparison between glazed and polished surfaces among different solutions regarding surface roughness.

The roughness of the examined samples' surfaces was photographed and then interpreted as peaks and valleys using a USB Digital microscope.**"Figures 6-13"**

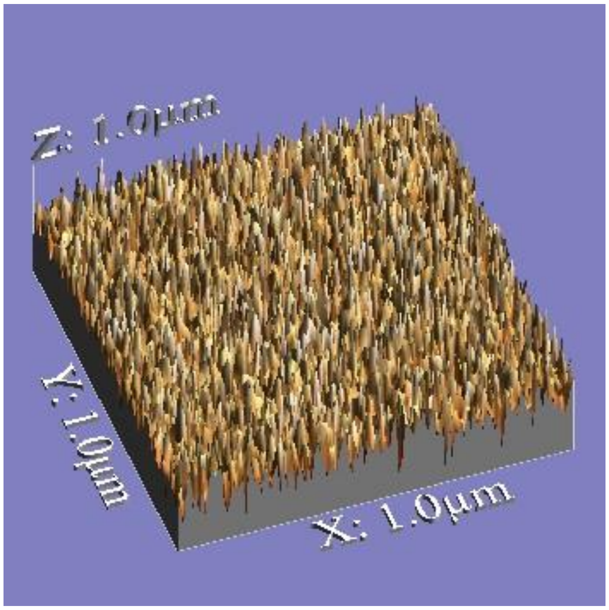


Figure 6 :Detailed image of a "Glazed" Vita Lumexsample's topography before it was immersed.

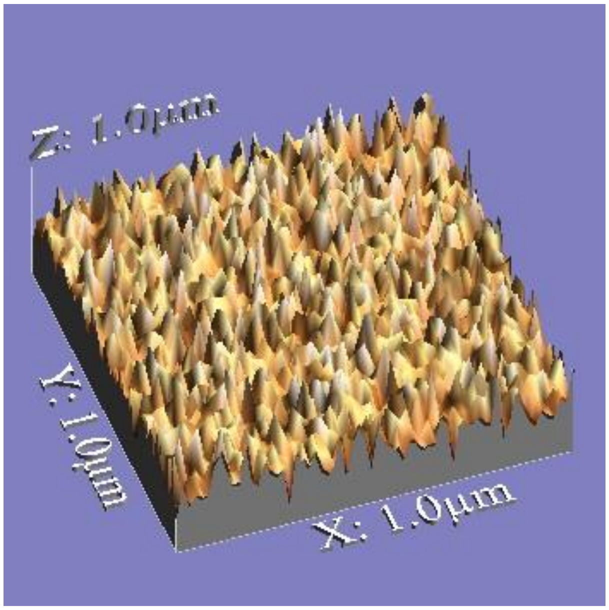


Figure 7 : Detailed image of a "Glazed" Vita Lumex sample's topographyafter it was immersed in coffee.

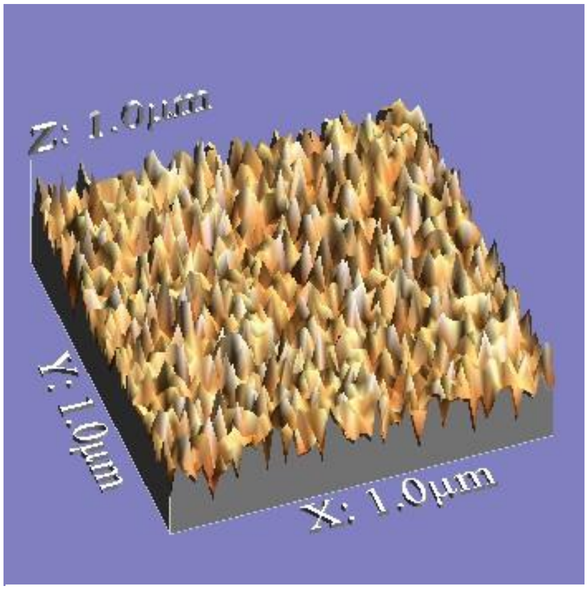


Figure 8 : Detailed image of a "Glazed" Vita Lumex sample's topographyafter it was immersed in citric acid.

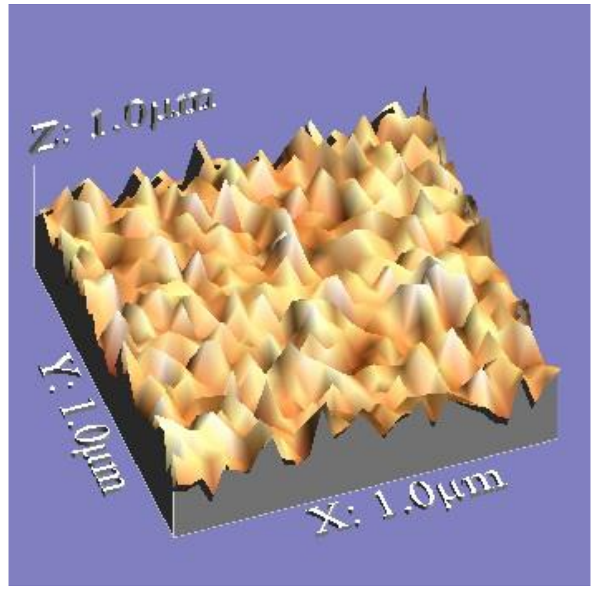


Figure 9 : Detailed image of a "Glazed" Vita Lumex sample's topographyafter it was immersed in artificial saliva.

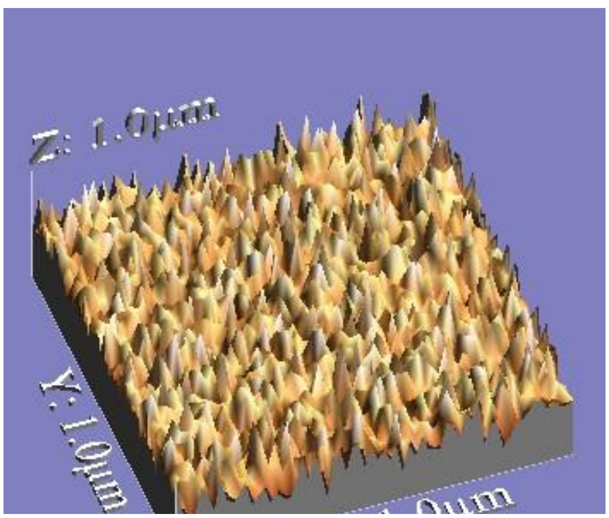


Figure 11: Detailed image of a "Polished" Vita Lumex sample's topography before it was immersed.

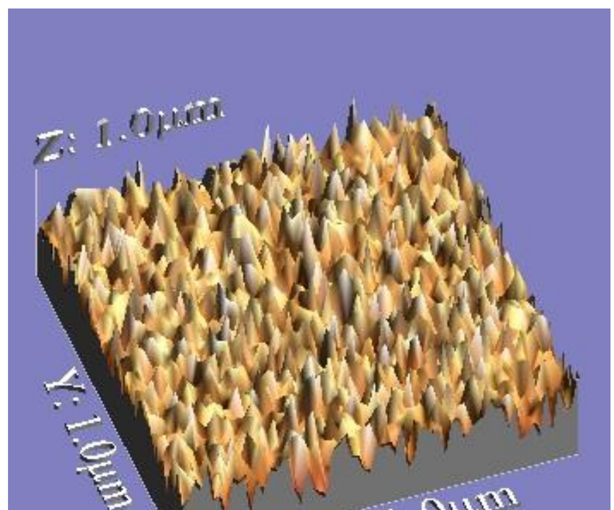


Figure 10 : Detailed image of a "Polished" Vita Lumex sample's topographyafter it was immersed in coffee.

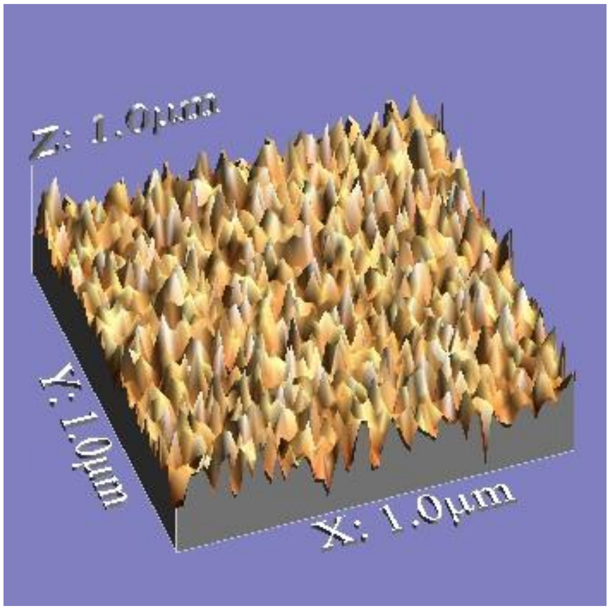


Figure 12 :Detailed image of a "Polished" Vita Lumex sample's topographyafter it was immersed in citric acid.

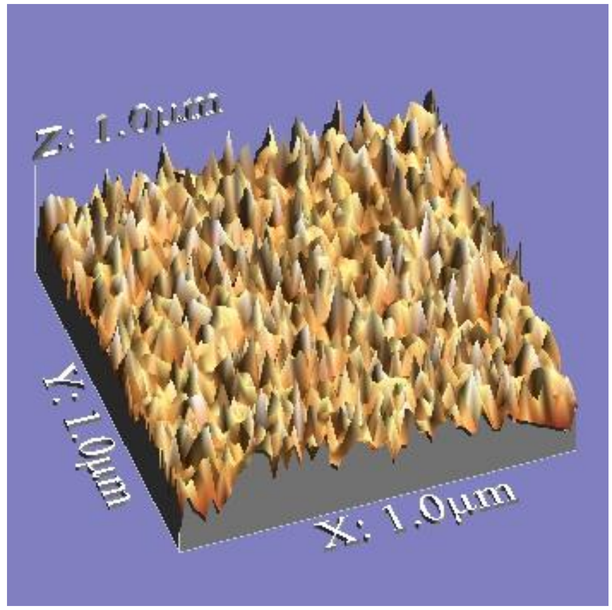


Figure 13 :Detailed image of a "Polished" Vita Lumex sample's topographyafter it was immersed in artificial saliva.

DISCUSSION:

This study focused on Vita Lumex AC, a recently introduced leucite-reinforced glass ceramic in the dental market. No previous research had been conducted on its color stability or surface roughness.

It surpasses other materials by having a vibrant play of color and light through special opal materials that have been developed to achieve a particularly vibrant opalescence. Also, its versatility which simplifies your day-to-day work, thanks to a wide variety of indications due to its reliable bond to the framework thanks to the coordinated coefficients of thermal expansion (CTE) with zirconia, glass-ceramic and titanium substructures.

The success of dental restorations depends on both their mechanical and physical properties, as well as their aesthetic appeal.[12]Color changes in a restorative material over time might reduce the lifespan and quality of restorations.[4,13]

Also surface roughness plays a great role in success of restoration as **according to Quirynen et al. (1995),** While surface-free energy may influence bacterial adhesion and retention, surface roughness appears to be the dominant factor. Moreover**, according to Jagger et al. (1994**), Rough surfaces can lead to abrasion of neighboring teeth and tooth discoloration. To ensure patient comfort, optimal esthetics, oral hygiene, and clinical success, surface roughness should be minimized.

Occlusal correction may be necessary when applying ceramic restorations to remove occlusal interference. However, this method can result in a rough ceramic surface. Chairside polishing with a ceramic polishing kit after occlusal correction is a simpler and more efficient way to reduce surface roughness.[14]

Consumption of hot and cold acidic beverages along with food, smoking habits and continuous fluctuation in humidity lead to some degree of color changes in restorations in the oral cavity. [15]Also, in the oral environment, restorative materials are also subjected to different pHs, load stress, besides the effect of tooth brushing.[16]

Coffee, which is considered since the most popular and widely consumed in our country, contains acidic components with a pH of 5.1 and is a hot caffeinated beverage that causes discoloration of all ceramic restorations, different acids can de-calcify the tooth structure, and they can induce ceramic damage due to their chelation effect. [17–19] To reduce the differences in salivary protein concentration between individuals and the uncertainties associated with testing outside the mouth, artificial saliva was used as a substitute for human saliva.[20]

Many researchers have praised the 3D non-contact profilometer method used in this study for measuring the Ra parameter, as it provides high-resolution imaging of the traced surface and is more reliable and efficient for quantitative surface topographic analysis.[21,22]

The Ra parameter continues to be a valuable general indicator of surface topography, providing a meaningful and comparable number that allows for the comparison of Ra values across various materials and with the results of other studies and standards.[14]

Although Colorimeters are frequently selected due to their inexpensive cost and ease of use also due to their consistent and rapid sensing nature, but they are often less accurate than spectrophotometers because of their inability to match the standard observer functions. [23] So, this study used a spectrophotometric equipment, which allowed for a quantitative color assessment. Additionally, it enables the analysis of the primary components of a sequence of spectra and the transformation of data to various color measurement systems.[24]

The CIE Lab technique, which is effective for measuring subtle color differences, was used to record color variations. The CIE Lab system is widely used in dentistry because L*, a*, and b* are evenly distributed in a perceptual color space.[25]

Color can be affected by the thickness and smoothness of the specimen surface. This study used specimens with a thickness of 2mm (1mm for zirconia and 1mm for Vita Lumex), which aligns with clinical standards.[26,27] Color and surface roughness measurements required careful selection of sample dimensions. To prevent edge loss, the light beam emitted by the spectrophotometer must be narrower than the sample's surface area. [28] For those reasons, samples were prepared 10*10 mm.

The current investigation found that both the glazed and polished groups had statistical color changes, however the color change values could be clinically acceptable for both the glazed and mechanical polishing procedures.

All tested ceramics in both groups after immersion in coffee showed high (ΔE) values than those in citric acid and artificial saliva groups. This can be justified by the fact that coffee contains substantial levels of staining chemicals, such as gallic acid, that enhancestaining.[29]

In this study and in many previous ones, Coffee has consistently demonstrated a higher staining capacity compared to other beverages, potentially due to the less polar nature of its yellow pigments. The polarity of colorants can influence their degree of penetration into materials; less polar colorants are more readily absorbed, while more polar ones tend to be adsorbed only superficially.[30]

Increased absorption was observed in materials immersed in solutions with pH ranging from 4 to 6. Because coffee's pH is greater than 5.1, it may have increased sorption, resulting in a more noticeable color change.[31]

These results agree with the results from previous study done by Colombo et al., Alharbi et al., Awad et al., Ataya et al., and Acar et al. which showed greater ΔE values with coffee. [4,32–35]

Researches by **Ghahramanloo et al., Aydın et al., and Saba et al.** suggested that common beverages including red wine, tea, and coffee might cause discolouration in composite resins and dental porcelains.[36–38]

The results of this study showed both groups showed increased stain retention after exposure to the selected drinks but to varying extents, in both groups while surface roughness insignificantly changed in both groups, and this agrees with what Mahrous et al. concluded.[39]

Though other studies as the one conducted by Sham et al. didn't agree with this study as it was found that glazed porcelain and other types of treatment methods were resistant to staining with coffee.[40]

If the object's surface is smooth, light is reflected in a narrow cone centered at the angle of reflectance. A gradually roughened surface would reflect separate specular beam segments at slightly varied angles.[41]This explains why the glazed group experienced less color change (lower ΔE values) compared to the polished group.

The glazed and polished surfaces exhibited similar levels of roughness. This might be attributed to the use of a specialized polishing kit that reduces surface defects, minimizes cracks, and enhances the restoration's fracture resistance. Polishing may also induce residual compressive strength, hardening the ceramic surface.[42]

This agrees with **Dawood et al., El-Sharkawy et al., and Wright et al.,** who demonstrated that chair side polishing performs just as well as glazing[43–46]. Only a few research investigations have proven the opposite conclusion, which is that chairside polishing is not as effective as glazing.[47–49]

Although there was no significant difference in Ra values, coffee and citric acid increased surface roughness, particularly in the glazed group. This could be due to the low pH of citric acid and the elevated temperature of instant coffee, which can negatively impact the mechanical and physical properties of ceramics. Additionally, the acidic pH of these solutions may dissolve silica, leading to the loss of alkaline ions, surface corrosion, and further deterioration of the glaze, resulting in increased roughness.[50,51]

This phenomenon may also be due to the H_3O^+ and OH^- ions terminating the silica network and the H_2O molecules breaking the Si-O-Si bonds, leading to the selective leakage of alkaline ions. These mechanisms appear to work together. Studies have shown that elements such as Si, Al, Na, K, and Zr are lost from ceramic materials.[52]

This study hypothesized that there will be no change in the color and surface roughness of Vita Lumex veneering material. The research hypothesis was partially rejected as it is not corroborated by the results, since significant differences were found in ΔE while in significant difference in Ra values among the groups.

LIMITATIONS OF THE STUDY

The study was conducted in a laboratory setting (in-vitro) and had a limited investigation time. The immersion period of two years simulated only a portion of the lifespan of a prosthetic restoration, and the clinical simulation was restricted.

To complement the profilometer measurements of surface roughness, Atomic Force Microscopy or Scanning Electron Microscopy testing of the specimens might be recommended. Additionally, clinical studies should support the findings of this investigation. Further clinical and in-vitro research is needed to evaluate Vita Lumex's susceptibility to surface roughness from other beverages and nutrients. Moreover, the cumulative effects of other common aging factors like tooth brushing were not examined. Future research should also address the impact of additional contributing factors such as smoking.

CONCLUSION:

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

1. Coffee has the most negative effect on the color stability of Vita Lumex in comparison to citric acid or artificial saliva, regardless of surface finish either glazed or polished.
2. Regarding surface roughness, there were no significant differences between them regardless of the surface finish.

RECOMMENDATIONS:

1. Further studies with a larger number of samples are recommended.
2. Future studies including different methods of oral environment simulation are proposed.
3. Clinical investigations into the color stability and surface roughness of Vita Lumex are recommended.

CONFLICT OF INTEREST:

The authors declare a lack of conflict of interest

FUNDING:

This research was not funded by any public, commercial, or non-profit organization.

ETHICS:

The Research Ethics Committee (REC) of the Faculty of Dentistry, Cairo University, Egypt, approved the study proposal on June 28, 2022.**Approval number: (17622)**

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