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# Assessment of Color Stainability of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) Ceramic Materials After Hot and Cold Coffee Immersion at Different Time Intervals

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**Background:** This spectrophotometric study assessed the color stability of CAD/CAM restorative materials with different exposed surfaces following staining by hot Arabic Qahwa and cold coffee.

**Material/Methods:** Ninety-six specimens were fabricated from 3 different CAD/CAM ceramic materials: Vita Suprinity (Vita-S), Vita Enamic (Vita-E), and Vitablocs Mark II (Vitablocs-MII). We divided 32 specimens for each group into glazed or polished surfaces, with 16 specimens in each group, then subdivided them according to staining materials: Arabic Qahwa and Frappuccino Cold Coffee. Color of specimens was measured during immersion in staining materials (BEFORE) as baseline with (Vita classic) and (L, a, b), for average color changes ( $\Delta E_{00}$ ), then remeasured after 2, 4, and 12 weeks, and described as 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> measurements for VITAPAN Classic shade and T1, T2, and T3 for  $\Delta E_{00}$  values using the CIE L\*a\*b\* equation. We performed ANOVA and then post hoc testing.

**Results:** We found significant differences in  $\Delta E_{00}$  values during immersing in hot Arabic Qahwa and cold coffee for tested materials in glazed or polished specimens. Polished specimens of Vita-S and Vita-E had the highest color changing and staining compared to glazed surfaces. Vitablocs-MII had the best color stability through immersion periods. Moreover, there were changes in relation to VITAPAN Classic shade guide for both Vita-S and Vita-E specimens during different immersion periods.

**Conclusions:** Coffee caused staining and contamination of ceramic material. Values of  $\Delta E_{00}$  for tested ceramic materials were significantly different but were within the clinically acceptable range. Polished specimens showed higher staining; therefore, we highly recommend re-glazing of ceramic restorations to maintain color stability.

**Keywords:** **Color • Staining and Labeling • VITA Suprinity**

**Full-text PDF:** <https://www.medscimonit.com/abstract/index/idArt/932745>

 4910

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 3

 52



## Background

There is growing demand for highly esthetic restoration with better patient satisfaction and treatment success. Significant improvements in dental restorative materials and technology, such as computer-aided design and computer-aided manufacturing (CAD/CAM), have produced esthetic, affordable, efficient, and predictable restorations [1]. The importance of CAD/CAM workflow is that it simplifies and integrates dental prostheses fabrication. Today CAD/CAM systems are increasingly used in dentistry. This technology allows a completely digital workflow, from impression to final framework, and the materials used showed excellent mechanical properties [2] and good precision [3]. The restorative materials are pre-designed to be as a block, and the restoration will be milled out of it. The ceramic blocks are made as pre-sintered ceramic blocks. After milling, the restoration is fully centered at standardized parameters of pressure and temperature to achieve the desired mechanical and biological properties [4].

Earlier, the clinical performance of CAD/CAM ceramic restorative materials were unsatisfactory since they had short survival in the oral cavity. In 1991, Vita Mark II (Vita MII) was introduced to the market for better restoration mechanical properties. The blocks of VITA MII ceramic have fine constructed particles, and a different machining system to improve mechanical properties and strength [1]. These blocks were monochromatic or available in multi-shade layers that permit a shade gradient as well as improved translucency [1,5,6]. Other brands of polymer-infiltrated ceramics and resin nano-ceramics, based on their contents, have improved material properties. For instance, it contained more resin, so they are soft and cause less damage to the opposing teeth and had low wear resistance because of the presence of nano- or macro-particles. In addition, they allow high surface smoothing with finishing and polishing procedures [6]. The materials with higher ceramic content exhibited greater wear resistance, enhanced esthetic results, better biocompatibility, and high discoloration resistance [7,8].

The CAD/CAM technology was used to develop high-loading capacity hybrid ceramics, merging ceramic and glass polymers [9]. Vita Enamic consists of 86% ceramic and 14% polymer by volume. Vita Suprinity is a zirconia-reinforced lithium silicate ceramic comprising 8-12% zirconium oxide, 56-64% silicone dioxide, and 15-21% lithium oxide. These materials are favored for their good mechanical properties [9,10].

Coffee can discolor materials and can be used to assess a materials' tendency for discoloration [11]. Dental ceramics, including CAD/CAM milled ceramics, are considered to have higher discoloration resistance. They show an excellent color match and high color stability during clinical use [12,13]. Visual color difference thresholds can be used as a quality control tool

and guideline for selecting esthetic materials [14]. However, some restorative and prosthetic materials in the oral cavity are exposed to changes in humidity and temperature, as well as being exposed to beverages, food, and smoking, which can cause extrinsic discoloration of these materials [15].

Arabic coffee (Qahwa Arabia) is a brew made of boiled coffee beans. Its color is light to dark brown, the taste can be plain or spicy, and it is served in a finjan, which is a small, handle-less coffee cup. It can be consumed at any time of the day. For most families, gathering for Arabic coffee drinking has social and cultural importance [16]. Coffee is claimed to have several health benefits [11]. A recent study published in the *Annals of Internal Medicine* found that people who drink a cup of coffee a day were 12% less likely to die from cancer, stroke, diabetes, heart disease, kidney disease, and respiratory diseases [17]. Coffee also has other health benefits, such as being calorie-free and containing antioxidants (eg, vitamin E) [18]. However, there are still concerns that come with frequent drinking coffee. One of those concerns has to do with oral health; just one cup of coffee a day increases the risk of cavities. Additionally, coffee can contribute to halitosis or bad breath because of its strong smell, it increases oral bacteria in the mouth, and it causes different types of extrinsic tooth discoloration [19]. Seydaliyeva et al and Sarikaya et al recorded an increase in the mean color changes of CAD/CAM restorative materials after coffee staining and immersions [20,21].

The CIE  $L^* a^* b^*$  color system is used for the determination of color differences values [22-24]. The CIE-  $L^* a^* b^*$  values are known as the "chromaticity coordinates": ( $L^*$ ) value refers to "lightness"; the higher the  $L$  value, the greater the lightness. ( $a^*$ ) reveals red color on positive values and green color on negative values ( $-a^*=green$ ;  $+a^*=red$ ); ( $b^*$ ) shows yellow color on positive values and blue color on negative values ( $-b^*=blue$ ;  $+b^*=yellow$ ) [25,26]. The mean color differences values ( $\Delta E_{00}$ ) were calculated with this equation:

$$\Delta E_{00} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}.$$

Most patients are usually seeking aesthetic restorations like white teeth, and at the same time they are daily consuming a high quantity of the staining materials in the form of different types of coffee. The purpose of this in vitro study was to assess and compare the color stability of 3 CAD/CAM restorative materials (Vita Suprinity, Vita Enamic, and Vitablocs Mark II) with different exposed surfaces (glazed or polished) following exposure to staining with 2 different types of coffee drinks, and to record these changes on the basis of the VITAPAN Classical shade guide. The null hypotheses were: 1) There is no significant color change for every individual group after immersion in different types of coffee drinks compared to the original color evaluated with the VITAPAN Classical shade guide; 2) There is

no significant difference in the overall average color changes ( $\Delta E_{00}$ ) between different CAD/CAM restorative materials after staining with different types of coffee drinks; and 3) There is no significant effect of surface smoothing with glazing or polishing in color changes with coffee exposure.

## Material and Methods

### Study Design

In this in vitro study, 96 specimens (shade B2) were constructed from 3 types of machinable CAD/CAM ceramic materials, then they were used to measure and evaluate the effect of 2 types of coffee and mean color changes of glazed or polished CAD/CAM ceramic materials at different time intervals. Furthermore, the change in color in relation to the VITAPAN Classical shade guide was also evaluated. Color measurements were done using a spectrophotometer (VITA Easyshade® V, VITA, Germany). **Table 1** describes the supplied materials and devices used in this in vitro research. A diagram of the study design is shown in **Figure 1**. The sample sizes were calculated as 3 groups of 32 specimens per testing group, determined according to previously published studies [2,15]. The sample size was calculated with G\* 85 Power software (version 3.1; University of Dusseldorf, Germany), with an effect size (d) of 1.4,  $\alpha$  of 0.05, and  $1-\beta$  (power) of 0.85. The effect size was calculated from the color changes of CAD/CAM specimens after beverage immersion at different time intervals.

### Specimens Manufacturing

A total of 96 specimens were manufactured from B2 Vita shade of 3 CAD/CAM restorative materials (32 specimens from each material): Vita Suprinity, Vita Enamic, and Vitablocs Mark II (Vita Zahnfabrik, H. Rauter, Bad Säckingen, Germany). The specimens were fabricated using a CAD/CAM machine (Amann Girrbach GmbH, Dürrenweg, Pforzheim, Germany). The blocks were installed on a milling machine to produce specimens of identical size and shape (16 mm in width and  $2.0 \pm 0.1$  mm thickness) for each ceramic material. Then, the specimens were sintered and glazed in accordance with the manufacturer's recommendation.

### Specimens Surface Treatments and Weight Measurements

The specimens of each group were then divided into 2 subgroups of 16 specimens each. The surfaces of one of the subgroups specimens was kept as glazed from the research laboratory and the other subgroup specimens were further polished with the Porcelain Adjustment Kit (SHOFU Dental ASIA-Pacific Pte. Ltd, Singapore) polishing kit. The proper arrangement of this kit is using the Dura-White Stones HP each CN1, FL3, and

RE1 for adjusting and finishing, then Ceramisté Points HP each of KN7, PC2, and WH6 in standard, ultra, or ultra II grits for intraoral polishing of all ceramic prosthesis. The recommended average speed for Dura-White Stones is from 5000 to 20 000 rpm while the speed for Ceramisté Points is 10 000 to 12 000 rpm, using equal numbers of grindings in one direction with light, controlled pressure [27]. Then, all specimens were measured using a VEVOR laboratory analytical balance (Schuler Scientific SLB-124, Milan, ITALY), and a Mettler Toledo Excellence XS 11106015 Model XS64 analytical balance, 61 g capacity, 0.1 mg. readability, and the measured weight was considered as the specimen's weight before coffee staining and aging.

### Specimens Color Change Measurements with Spectrophotometer

The 4 subgroups from each CAD/CAM ceramic restorative material group were transferred to colorimetric evaluation according to the CIE L\*a\*b\* system. It was performed by a blind, trained operator immediately when it came from the laboratory as glazed or after surface treatments as polished, and this was considered as T0. Ahead of each measurement, the specimens were lightly washed with distilled water and air dried. Colors of the specimens were measured with a spectrophotometer (Vita Easyshade® Compact, Vita Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany) version V against a black background to mimic the absence of light in the mouth against a gray background. All specimens were chromatically assessed twice, and the average values were calculated by the above-mentioned equation; then, each color parameter for each specimen of the same shade was averaged as measured by previous studies [22-24]. In addition, the Vita Easy Shade Spectrophotometer Version V was used to record the color of the specimens according to the VITAPAN Classical shade guide before (baseline).

### Specimens Staining with Coffee and surface contamination

Following the baseline color assessments, the 16 samples of each individual subgroup were further divided, one half (8 samples) were stained in Arabic Qahwa, (Baja Food Industrial Co., Jeddah, Saudi Arabia) and the other half were stained in cold Frappuccino Coffee Drink (Arla Foods AMBA dk/8260 Viby J. Denmark) during the aging period. Instant Arabic hot Qahwa came in a nitrogen-flushed packet for single use. The staining solution prepared from each packet (30 g) was mixed with 0.5 L boiled water at 100°C, then kept boiling for 15 s. Starbucks Frappuccino cold coffee drinks are stored in a refrigerator and offered in sealed containers ready to use by shaking well before drinking. New coffee solutions were changed every 24 h. Following the aging process, all the specimens were dipped in distilled water 10 times, wiped with tissue paper, and left to completely air dry. During the immersion period, the color measurements of all samples were recorded after 2 (T1), 4 (T2),

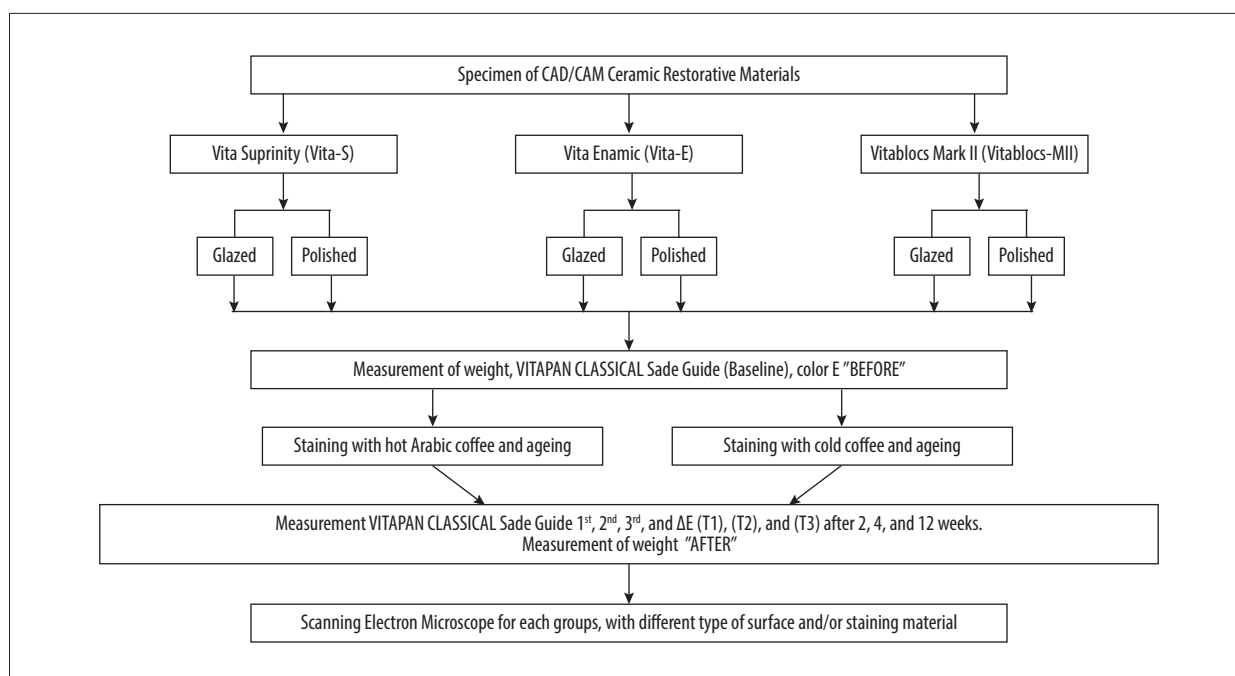
**Table 1.** Materials and devices used in the study [8-10].

Material/device type	Brand name	Composition	Manufacturers	Lot or model #	Shades
CAD/CAM Zirconia-reinforced lithium disilicate glass ceramic	Vita Suprinity <b>VITA-S</b>	Silicon dioxide (56-64%), lithium oxide (15-21%), zirconium oxide (8-12%), La <sub>2</sub> O <sub>3</sub> (0.1%) and pigments	Vita Zahnfabrik H. Rauter, Bad Säckingen, Germany	53990	B2
CAD/CAM Hybrid glass ceramic blocks	Vita Enamic <b>Vita-E</b>	Polymer-infiltrated feldspathic ceramic network material with 86wt% ceramic, UDMA, TEGDMA 14% Methacrylate polymer by weight	Vita Zahnfabrik H. Rauter, Bad Säckingen, Germany	51960	B2
CAD/CAM Feldspathic ceramic blocks	Vitablocs Mark II <b>Vitablocs-MII</b>	Fine-particle feldspar glass ceramic mill block 30%, constituted of silica SiO <sub>2</sub> (55-78%), alumina Al <sub>2</sub> O <sub>3</sub> (<10%), modifying alkaline oxides such sodium oxide Na <sub>2</sub> O, potassium oxide K <sub>2</sub> O and more rarely lithium dioxide Li <sub>2</sub> O	Vita Zahnfabrik H. Rauter, Bad Säckingen, Germany	42550	B2
Laboratory Analytical Balance	VEVOR Analytical Balance 100 g×0.1 mg, Pharmacy (100 g×0.1 mg)	Mettler Toledo Excellence XS 1110601 Model XS64 Analytical Balance, 61 g Capacity, 0.1 mg Readability. High Precision Electronic Analytical Balance, High Accuracy Balance with 80 mm Pallet, Digital Scientific Lab Scale, for Laboratory	(Schuler Scientific SLB-124, Italy	6670-01-600-1345-XS64	NA
Porcelain Adjustment Kit-HP	PN 0301B	For Finishing and Polishing Porcelain Restorations Assortment	SHOFU Dental ASIA-Pacific Pte. Ltd. Singapore	801612	NA
Instant Arabic Qahwa	Baja	Arabic coffee, Cardamom, Cloves, Nondaily Coffee Creamer, Saffron, used as Hot Coffee	Baja Food Industrial Co., Saudi Arabia	628105 795290 Product-Date 16/Jan/20120, Exp 16/10/2020	Yellowish
Frappuccino Coffee Drink	Starbucks	Semi-skimmed-milk, Starbucks Arabica-coffee (water, coffee extract), sugar, natural coffee flavoring, acidity regulator (potassium carbonates), ↑ caffeine content 40mg/100 ml	Arla Foods AMBA dk/8260 Viby J. Denmark	5711953024345 Production-Date 16/10/2019 Expired on 16/5/2020	Brownish
Spectrophotometer	Vita Easyshade® V	Machine used to assess wavelength transferred from an object at a moment in time, with no being influenced by subjective interventions of color	Vita Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany	10180	NA
Scanning electron microscope	JEOL® JSM-6610 LV Scanning electron microscope	Samples were gold sputter coated with Quorum® Q-150R, then loaded into sample stage using 20kv and magnification×250	Akishima, Tokyo, Japan		

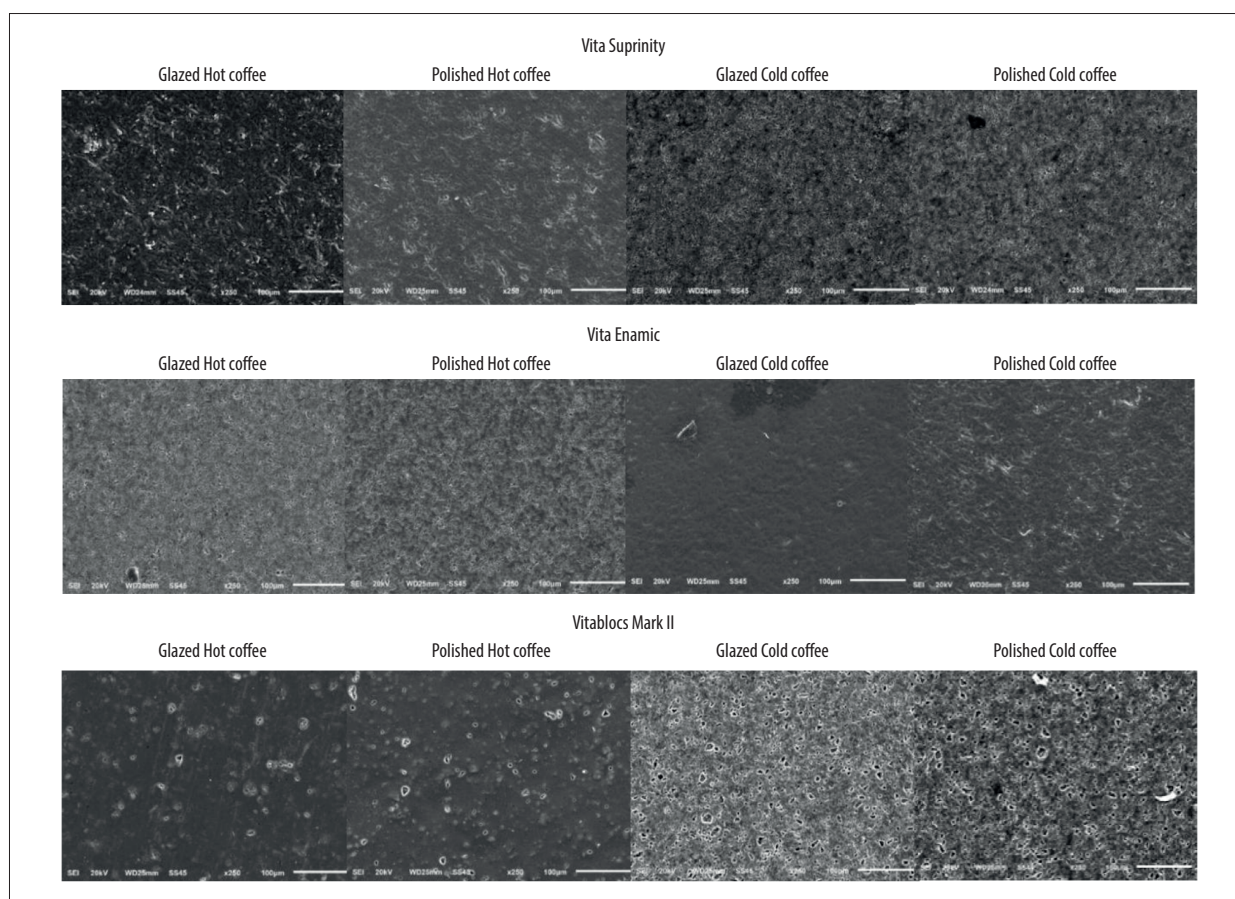
and 12 (T3) weeks. In addition, the shade of specimens was measured using the VITAPAN Classical shade guide (Vita classical Guide and Vita Bleached guide, Vita Zahnfabrik, Germany) (1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup>) after 2, 4, and 12 weeks. Moreover, the color change ( $\Delta E_{00}$ ) values were calculated by the above equation.

### Scanning Electron Microscope Capturing

A single specimen from each type of tested material, glazed or polished, and from Arabic Qahwa and Frappuccino Coffee Drink were selected for scanning electron microscopy (SEM)



**Figure 1.** A diagram showing the design of the study and sequences of research steps.



**Figure 2.** Representative SEM image of tested CAD/CAM materials “Vita Suprinity, Vita Enamic, and Vitablocs Mark II” at ×250 magnification after staining and aging.

**Table 2.** Mean and SD of the  $\Delta E_{00}$  for ceramic materials stained by Arabic coffee.

Mean color change	Type of ceramic (mean±SD)	Vita Suprinity	Vita Enamic	Vitablocs Mark II	P value “ANOVA”
Glazed Hot Coffee					
ΔE00 (T1)	Vita Suprinity (1.89 & 0.98)	-----	0.002*A,C	0.007*A,B	0.001*
	Vita Enamic (3.04 & 0.08)	0.002*B,C	-----	1.000	
	Vitablocs Mark II (2.87 & 0.07)	0.007*B,C	1.000	-----	
ΔE00 (T2)	Vita Suprinity (1.08 & 0.46)	----	0.000*A,C	0.010*A,B	0.000*
	Vita Enamic (1.74 & 0,09)	0.000*B,C	-----	0.496	
	Vitablocs Mark II (1.54 & 0.12)	0.010*B,C	0.496	-----	
ΔE00 (T3)	Vita Suprinity (0.86 & 0.24)	---	0.005*A,C	0.000*A,B	0.000*
	Vita Enamic (1.16 & 0.12)	0.005*B,C	-----	0.015*A,B	
	Vitablocs Mark II (1.41 & 0.09)	0.000*B,C	0.015*A,C	-----	
Polished Hot Coffee					
ΔE00 (T1)	Vita Suprinity (2.42 & 0.35)	-----	0.004*A,C	0.035*	0.004*
	Vita Enamic (2.90 & 0.13)	0.004*B,C	-----	1.000	
	Vitablocs Mark II (2.79 & 0.26)	0.035*B,C	1.000	-----	
ΔE00 (T2)	Vita Suprinity (1.74 & 0.24)	----	1.000	0.000*A,B	0.001*
	Vita Enamic (1.39 & 0,14)	0.001*B,C	-----	0.009*A,B	
	Vitablocs Mark II (1.46 & 0.08)	0.001*B,C	1.000	-----	
ΔE00 (T3)	Vita Suprinity (1.04 & 0.15)	---	1.000	1.000	0.714
	Vita Enamic (1.02 & 0.20)	1.000	-----	1.000	
	Vitablocs Mark II (1.15 & 0.54)	1.000	1.000	-----	

Different superscript letters indicate statistically significant differences inside the respective subgroup ( $P < 0.05$ ) based on ANOVA tests followed by Bonferroni tests.

to assess consistency of color changes. The samples were gold sputter coated (**Figure 2**) with Quorum® Q-150R (East Sussex, BN8 6BN United Kingdom). Then, the samples were loaded into the specimen's stage of the JEOL® JSM-6610 LV (Akishima, Tokyo, Japan) scanning electron microscope using 20 kv and 500 $\times$ magnification for scanning and photography. A diagram of the study design and steps of the study is shown in **Figure 1**.

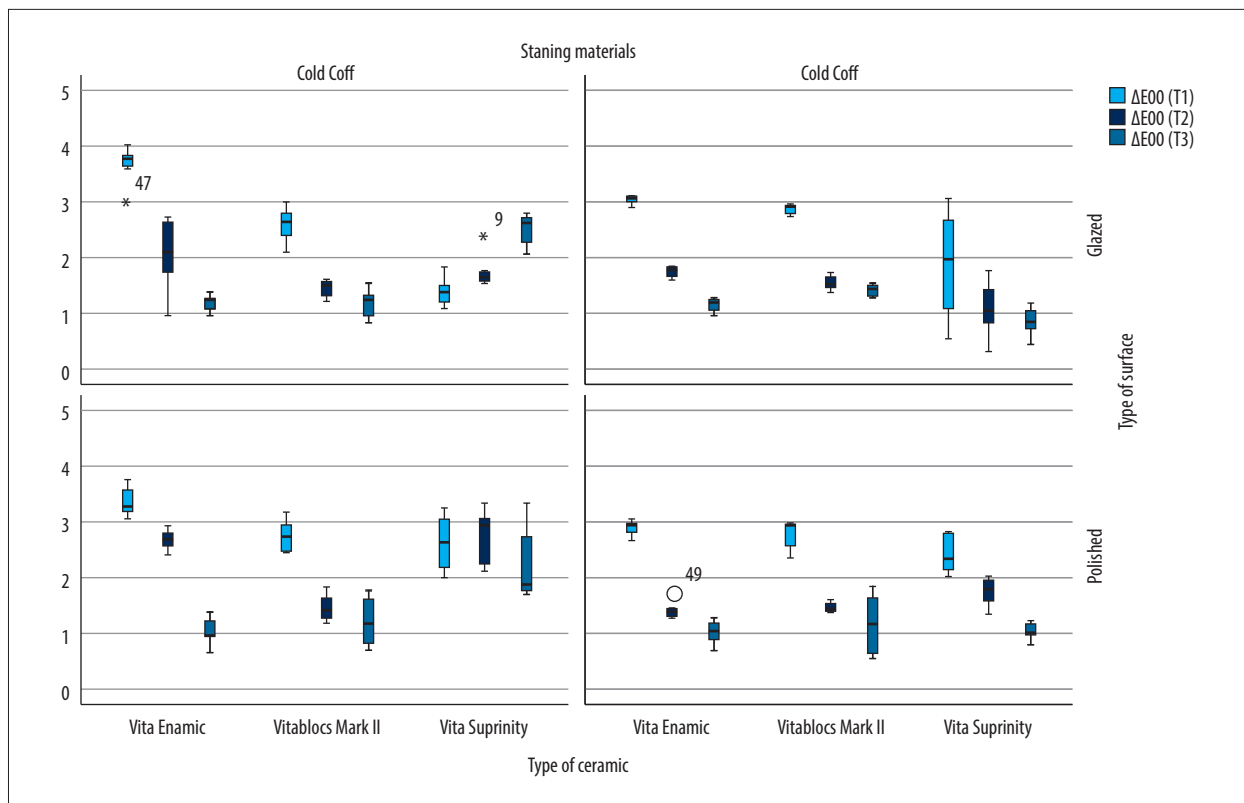
### Statistical Analysis

Mean differences in color change ( $\Delta E_{00}$ ) by the staining protocols were registered with Microsoft Excel 13 software, then data were calculated and analyzed using Statistical software Package for Social Science (SPSS) version 22.0 (SPSS, Inc., Chicago IL, USA). Descriptive statistics that involved mean and standard deviation (SD) values were determined for each CIE L\*a\*b\* variable and the 4 subgroups of the VITAPAN Classical

shade guide. The mean weight changes were calculated as the differences between pre- and -post values of weight. One-way analysis of variance (ANOVA) and multiple comparison Bonferroni post hoc test were performed to determine whether there were any significant differences in the  $\Delta E_{00}$  between and within the subgroups at  $p > 0.05$ . Then, color change values were compared to these thresholds to determine the clinically acceptable color change of each group.

### Results

In relation to the mean values of the VITAPAN CLASSIC shade guide for Vita-S and Vita-E specimens at baseline shade (B2), at the first reading, both glazed and polished, either immersed in Arabic or cold coffee drink, the color of material had changed to C3 and C1. At the second reading and third readings, all



**Figure 3.** Mean and SD values of color changes of different type of ceramic at different time intervals in relation to surface type and staining materials.

the VITAPAN CLASSIC shade guide colors were changed to either A1, A2, B2, or a combination of each 2 colors. In the other hand, the Vitablocs-MII specimens remained as B2 throughout the 3 testing periods (Table 2).

The mean color changes  $\Delta E_{00}$  values differences for the evaluated different ceramic materials with different surface smoothing and immersed in Arabic coffee were the highest at the T1, followed by values of  $\Delta E_{00}$  at T2 and T3, respectively (Figure 3, Table 3). These results show reduction of the coffee contamination over time. There was a significant difference between and within the groups of ceramic stained by Arabic and with  $P$  value less than 0.050, except the  $\Delta E_{00}$  (T3) of the polished Arabic coffee, which had a  $P$  value 0.714 (Table 3).

The mean color changes  $\Delta E_{00}$  values differences for Vita-E and Vitablocs-MII with different surface smoothing and immersed in the cold coffee drink were the highest at T1, followed by T2, and T3 (Figure 3, Table 4). These results show reduction of the coffee contamination over time. The mean color changes  $\Delta E_{00}$  values differences for Vita-S with different surface smoothing and immersed in the cold coffee drink were the highest at T3, followed by T2 and T1 (Figure 3, Table 4). These results show increased coffee contamination with cold coffee drink over time. There was a significant difference between and within

the groups of ceramic stained by or cold coffee with  $P$  value less than 0.050 (Table 4).

The mean weight changes for all type of CAD/CAM ceramic materials in form of glazed or polished before and after staining with aging were between 0.110 and 0.619 mg. Furthermore, there were no significant differences between the groups and within the subgroups with  $P$  value ranging from 0.124 to 0.967, which were higher than 0.05 (Table 5). In addition, ANOVA showed no significant differences between and within all subgroups.

The SEM images showed scratch lines which were deeper in the glazed or polished cold coffee specimens of the Vita-S group in compared to the hot coffee specimens. Furthermore, Vita-E showed smoother surface texture with uniform dispersed small particles, whereas Vitablocs-MII specimens revealed uniform larger cluster filler particles protruding in some surfaces (Figure 2).

## Discussion

In the current study investigates the color changes and spectrophotometric analysis, the  $\Delta E_{00}$  and color stainability of CAD/

**Table 3.** Mean and SD of the  $\Delta E_{00}$  for ceramic martials stained by cold coffee drink.

Mean color change	Type of ceramic (mean±SD)	Vita Suprinity	Vita Enamic	Vitablocs Mark II	P value “ANOVA”
Glazed Cold Coffee					
ΔE00 (T1)	Vita Suprinity (1.39 & 0.23)	-----	0.000 <sup>*a,c</sup>	<b>0.000<sup>*a,b</sup></b>	0.000 <sup>*</sup>
	Vita Enamic (3.69 & 0.30)	0.000 <sup>*b,c</sup>	-----	<b>0.000<sup>*a,b</sup></b>	
	Vitablocs Mark II (2.59 & 0.29)	0.000 <sup>*b,c</sup>	0.000 <sup>*a,c</sup>	-----	
ΔE00 (T2)	Vita Suprinity (1.72 & 0.27)	----	0.306	0.539	0.019 <sup>*</sup>
	Vita Enamic (2.07 & 0,62)	0.306	-----	0.16 <sup>*a,b</sup>	
	Vitablocs Mark II (1.45 & 0.15)	0.539	0.016 <sup>*a,c</sup>	-----	
ΔE00 (T3)	Vita Suprinity (2.50 & 0.28)	---	0.000 <sup>*a,c</sup>	0.000 <sup>*a,b</sup>	0.000 <sup>*</sup>
	Vita Enamic (1.18 & 0.14)	0.000 <sup>*b,c</sup>	-----	1.000	
	Vitablocs Mark II (1.16 & 0.24)	0.000 <sup>*b,c</sup>	1.000	-----	
Polished Cold Coffee					
ΔE00 (T1)	Vita Suprinity (2.63 & 0.49)	-----	0.002 <sup>*a,c</sup>	1.000	0.001 <sup>*</sup>
	Vita Enamic (3.36 & 0.27)	0.002 <sup>*b,c</sup>	-----	0.008 <sup>*a,b</sup>	
	Vitablocs Mark II (2.75 & 0.28)	1.000	0.008 <sup>*a,c</sup>	-----	
ΔE00 (T2)	Vita Suprinity (2.74 & 0.48)	----	1.000	0.000 <sup>*a,b</sup>	0.000 <sup>*</sup>
	Vita Enamic (2.67 & 0,17)	1.000	-----	0.000 <sup>*a,b</sup>	
	Vitablocs Mark II (1.46 & 0.23)	0.000 <sup>*b,c</sup>	0.000 <sup>*a,c</sup>	-----	
ΔE00 (T3)	Vita Suprinity (2.23 & 0.69)	---	0.000 <sup>*a,c</sup>	0.001 <sup>*a,b</sup>	0.000 <sup>*</sup>
	Vita Enamic (1.04 & 0.24)	0.000 <sup>*b,c</sup>	-----	1.000	
	Vitablocs Mark II (1.21 & 0.41)	0.001 <sup>*b,c</sup>	1.000	-----	

Different superscript letters indicate statistically significant difference inside the respective subgroup ( $P<0.05$ ) based on ANOVA tests followed by Bonferroni tests.

CAM restorative materials as zirconia-reinforced lithium silicate glass ceramic (Vita-S), hybrid glass ceramic blocks (Vita-E), and feldspathic ceramic blocks (Vitablocs-MII) with different exposed surfaces (glazed or polished) following immersion in hot or cold coffee. The first null hypothesis was partially rejected, because of there were changes in the mean color of Vita-S and Vita-E. The Vitablocs-MII specimens remains as the same color during the 3 different time intervals which has been extended into 12 weeks.

The value of  $\Delta E_{00}$  is clinically important and challenging at different levels of color measurements. It has been shown that the borderline  $\Delta E_{00}$  which is perceptible to all people in a color test is 2.5 [14,28]. So, identifying the value of  $\Delta E_{00}$  that is perceptible or clinically acceptable is challenging, and different levels have been suggested [21,28-30]. Based on the previous studies, the  $\Delta E_{00}$  values from 1 to 3.3 units considered as clinically

acceptable, while  $\Delta E_{00}$  values greater than 3.3 are considered to be clinically unacceptable [22,31-38]. Nevertheless, an in-vivo studies has presented the perceptible and clinically acceptable thresholds  $\Delta E_{00}$  to be between 2.8 and 4.2 units [14,22,39].

Therefore,  $\Delta E_{00}$  perceptible and clinically acceptable thresholds should be borne in mind when assessing color change spectrophotometrically. There were a significant and non-significant difference in the average color changes ( $\Delta E_{00}$ ) between CAD/CAM restorative materials, surface type (glazed or polished), and coffee type (hot or cold), so the second null hypothesis were partially rejected and partially accepted. The overall  $\Delta E_{00}$  values for the tested CAD/CAM restorative materials among specimens immersed in glazed hot coffee were between 0.86-3.04 for Vita-E and Vita-S, while the  $\Delta E_{00}$  values for the polished specimens stained with hot coffee were between 1.02-2.9 for Vita-E, at the 3 different examined periods.

**Table 4.** Mean and SD of the weight changes values parameter in each tested subgroup.

Mean color change	Type of ceramic (mean±SD)	Vita Suprinity	Vita Enamic	Vitablocs Mark II	P value "ANOVA"
Glazed Hot Coffee	Vita Suprinity (0.119 & 1.30)	-----	1.000	.349	0.133
	Vita Enamic (0.178 & 1.04)	1.000	-----	.186	
	Vitablocs Mark II (0.619 & 10.44)	.349	.186	-----	
Glazed Cold Coffee	Vita Suprinity (0.192 & 1.50)	-----	1.000	1.000	0.967
	Vita Enamic (0.110 & 1.99)	1.000	-----	1.000	
	Vitablocs Mark II (0.183 & 1.66)	1.000	1.000	-----	
Polished Hot Coffee	Vita Suprinity (0.421 & 5.51)	-----	0.295	0.186	0.124
	Vita Enamic (0.263 & 0.34)	0.295	-----	1.000	
	Vitablocs Mark II (0.292 & 5.70)	0.186	1.000	-----	
Polished Cold Coffee	Vita Suprinity (0.186 & 1.10)	-----	1.000	1.000	0.859
	Vita Enamic (0.223 & 5.85)	1.000	-----	1.000	
	Vitablocs Mark II (0.144 & 10.69)	1.000	1.000	-----	

**Table 5.** Comparison in color changes between basic colors of VITABAN Classical shade guide and the tested specimens after staining with coffee at different time intervals.

Glazed Arabic Coffee Vita Suprinity				Glazed Cold Coffee Vita Suprinity			
Baseline	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	Baseline	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>
B2	C3	B2 & A2	A1	B2	C1	A1, B2	B2
100%	100%	75% B2 & 25% A2	100%	100%	100%	62% A1 & 38% B2	100
Glazed Arabic Coffee Vita Enamic				Glazed Cold Coffee Vita Enamic			
B2	C3	B2	A3 & A2	B2	C1	A1 & B2	A2
100%	100%	100%	62% A3 & 38% A2	100%	100%	50% B2 & 50% A1	100%
Glazed Arabic Coffee Vitablocs Mark II				Glazed Cold Coffee Vitablocs Mark II			
B2	B2	B2	B2	B2	B2	B2	B2
100%	100%	100%	100%	100%	100%	100%	100%
Polished Arabic Coffee Vita Suprinity				Polished Cold Coffee VITA Suprinity			
Baseline	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	Baseline	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>
B2	C3	B2	A1	B2	C1	A1	A1
100%	100%	100%	100%	100%	100%	100%	100%
Polished Arabic Coffee Vita Enamic				Polished Cold Coffee Vita Enamic			
B2	C3	B2	A2	B2 & A1	C1	A1	A1
100%	100%	100%	100%	50% B2 & 50% A1	100%	100%	100%
Polished Arabic Coffee Vitablocs Mark II				Polished Cold Coffee Vitablocs Mark II			
B2	B2	B2	B2	B2	B2	B2	B2
100%	100%	100%	100%	100%	100%	100%	100%

In other hand, overall  $\Delta E_{00}$  values for the glazed specimens immersed in cold coffee were between 1.16-3.69 for Vita-E and Vitablocs-MII, while it was between 1.04-3.36 for Vita-E for polished cold coffee at the 3 different examined periods. So, all the recorded  $\Delta E_{00}$  values for the tested CAD/CAM restorative materials in both surfaces and coffee types were within the clinically acceptable range. For  $\Delta E_{00}$  values recorded at the end of 2 weeks, our findings were similar to values of previous results conducted with glazed specimens immersed in hot coffee by Özyılmaz et al, and Abu-Obidah et al, for the 3 tested types [35,40]; Aydın et al, for Vita-S and Vita-E [41]; and Colombo et al, as well as Quek et al, for Zirconia and Vita-E, respectively [15,42]. Among, the polished samples immersed in cold coffee in this study, the  $\Delta E_{00}$  values recorded were coincided with values documented by Abu-Obidah et al, for the 3 tested types [40]; Sarıkaya et al, for Vita-E, and Al Moaleem et al, for Vitablocs-MII and zirconia [21,34]. In other hand for glazed cold drink, the  $\Delta E_{00}$  values in the current study were in parallel with results of Quek et al, [42], those stained their Vita-E samples with cold red wine and Coca Cola, and similar with Sarıkaya et al, and Sagsoz et al, [21,30], those immersed their polished Vita-E CAD/CAM restorative material specimens in cold drinks. Contritely, the overall obtained  $\Delta E_{00}$  values were lesser than scores gained by Saba et al, and Jian et al, those documented a  $\Delta E_{00}$  values were above the clinically accepted range  $\geq 3.7$  [32, 43].

Glazing is the most popular surface finishing steps for ceramic prostheses. Many studies concluded that glaze layer was superior to other polishing systems in relations to surface characteristics and staining resistance [14,34,44]. Furthermore, several studies [20-21,25,29-31,42-46], had specified that glazed ceramic prostheses have shown a reduced amount of discoloration than mechanically polished prostheses. In the current study, the  $\Delta E_{00}$  values for the glazed specimens after 2 weeks immersion in an instant- hot- Arabic Qahwa (T1) were 1.98; 3.04; 2.87 for Vita-S, Vita-E, and Vitabloc-MII, respectively. While the  $\Delta E_{00}$  values for the polished specimens after the same immersion period in hot- Arabic Qahwa (T1) were 2.42, 2.90, 2.79 for Vita-S, Vita-E, and Vitabloc-MII, respectively. All these color differences were within the clinical acceptable range which demonstrates that the polishing procedures and protocols used in this study were effective in achieving very smooth surface that got experience acceptable color change compared to glazed samples. This agreed with some previous studies assured that some porcelain polishing kits and protocols may be comparable to glazing [30,40,47]. The polishing kit which has specifically preferred assortment of white stones and porcelain polishers for chairside correction and glaze-like polishing of porcelain restorations prior or after cementation. Also, the set is indispensable in the dental research laboratory for very fine corrections of porcelain restorations and successive high-gloss polishing. In addition, kit helps eliminate the

tedious re-firing process, saves time by avoiding the restoration being sent to the laboratory for re-glazing, which may affect the ceramic color and prevents the inconvenience of a recall appointment for the patient. Finally, it is essential in the dental research laboratory for very fine improvements of CAD/CAM prosthesis and creates a successive high-gloss polishing.

It is important to point out that this study was evaluated the daily used beverage in our live and it is known to have the potential to stain prosthetic and restorative restorations. In relation to the Frappuccino coffee cold drink, the  $\Delta E_{00}$  values were the highest at the T1 (3.69 and 3.36) for glazed and polished Vita-E, and 3.36 Vitablocs-MII, respectively, followed by T2, while the lowest values were at T3 (1.04 and 1.21) for polished specimens of Vita-E and Vitablocs-MII with significant differences between CAD/CAM restorative materials at 4 weeks' time intervals with p value  $>0.001$ . Aydın et al, measured the  $\Delta E_{00}$  among Vita-E and Vita-S after 4-weeks immersion in different beverage staining drinks [41]. They recorded  $\Delta E_{00}$  values in relation to glazed Vita-E ceramics were 2.31 for coffee, 6.46 for wine, and 0.051 for Coca Cola drinks, but for glazed Vita-S, the values were 2.27 for coffee, 6.05 for wine, and 0.69 for Coca Cola. Those values are much higher than our  $\Delta E_{00}$  values especially for wine drinks, but it agreed in the values of glazed samples stained by coffee in both examined CAD/CAM restorative materials, with significant differences for glazed coffee group [41]. Arocha et al, recorded  $\Delta E_{00}$  for coffee after 4 weeks immersion for hybrid ceramic (Lava Ultimate) in form of glazed (control group) 1.79, for immersed in coffee 14.21, which somewhat at higher values than our findings [47]. This was already illustrated and agreed that the progressive staining of the ceramic materials was visually observed by the end of the 14-day period after coffee immersions [20,48]. These results will advise that we should, as much as we can, instruct the patients not to eat or drink any discoloration materials in the first 2 weeks after placing any aesthetic ceramic restoration.

Significant differences and the lowest  $\Delta E_{00}$  values after 12 weeks for all examined CAD/CAM restorative materials, with  $\Delta E_{00}$  ranged from 0.86 to 1.41 for glazed Vita-S and Vitablocs-MII, but it was 1.02 to 1.15 for polished specimens of Vita-E and Vitablocs-MII after immersion in hot Arabic Qahwa. Those values were lesser in comparing to values recorded by Alghazali et al, for both glazed feldspathic or zircon specimens or 4.23 and 4.34 for polished feldspathic and zircon specimens immersed in Arabic Qahwa [23]. Also, current study values were in matching with values of Alharbi et al, whose demonstrated that staining caused by glazed or polished Vita-E blocks results after red wine immersion in compared to hot coffee after 120-day staining [49]. Specimens of Vita-S recorded  $\Delta E_{00}$  values 2.81 and 4.08 for glazed or polished after immersion in coffee and other beverages [49]. Jain et al, after 90 days of staining, they reported a  $\Delta E_{00}$  values of 7.13, 5.80, and 4.73 for

hot coffee, cold Coca Cola, and cold orange juice, respectively. Those values are much higher than values recorded in the present study, this could be explained by that ceramic samples used by Jain et al, were manually prepared and condensed over a layer of metal alloy, while our specimens were fabricated by milling machine and were metal free [43]. The values of polished samples were much lesser and ranging from 1.04 to 1.15 for Vita-S and Vita-E with no significant at the 3 months' time interval with  $P$  value 0.714 [41].

To correlate the results of this spectrophotometric in vitro laboratory study with the in-vivo clinical situation, we created on the following scenario: If 1-day storage would equal to 1-month consume of staining solutions, the 2-week storage used during in vitro immersion would correspond to 1 year and 2 months in an in-vivo clinical setting [20]. In other way specimens were immersed in different staining solutions for 1 month should be equivalent to about 2.5 years of oral cavity survive [50]. This mean the 3 months interval for this in vitro immersion period is equal to 10 years of the survival rate of the CAD/CAM restorative materials in oral cavity. Other researchers suggested that immersion in coffee for one week was equivalent to 7 months of coffee drinking with the assumption that the coffee persisted in the mouth throughout drinking [24]. Thus, 4 weeks immersion of specimens in staining materials for calculation of the consequent staining outcome might be an exaggeration of the truth.

Regarding to VITAPAN CLASSIC shade guide (B1), the Vita-S and Vita-E were changed into C3 and C1, (darker color) after 2-weeks staining, while after 4 weeks and 12 weeks the color returned back to the lighter colors "A1, A2, B2 or a combination of each 2 colors". Parallel findings were recorded by Derafshi et al, those demonstrated significant differences and changing into darker color after 24 hours, but into lighter color of zirconia and e.max samples after 72 h and 7 days of immersions in chlorhexidine mouth wash [46]. Al Moaleem et al observed changes in the VITAPAN CLASSIC shade guide of different glazed or polished feldspathic metal ceramic samples as VMK MSSTER (90%), followed by 70% for VMK 95, and less than half (40%) for VMK VM13 type after 1-week immersion in khat extract [33], but in the present study no changes were recorded for glazed or polished Vitablocs-MII feldspathic CAD/CAM ceramic materials immersed in hot or cold coffee. This will suggest and assure that feldspathic ceramic is still the least in color change and color stability as it has no glass filler which will always keep the surface smooth enough even after polishing protocols. Therefore, we suggest utilizing feldspathic ceramic wherever possible for our aesthetic treatments.

There are various factors causing color changes in restorations, as plaque accumulation, pigmentation effect of staining and immersion materials, dehydration, water absorption,

surface roughness, and chemical degradation [30]. Even though the Vita-E CAD/CAM restorative material consists primarily of 66% by weight hydrophobic urethane dimethacrylate (UDMA) and 33% by weight hydrophilic triethylene glycol dimethacrylate (TEGDMA), and water uptake by Bis GMA-based resins increased from 3 to 6% as the proportion of TEGDMA was increased from 0 to 1%, respectively. Accordingly, the high weight% of TEGDMA in Vita-E blocks may have resulted in greater water sorption which may have permitted the penetration of any hydrophilic colorant into the resin matrix [32]. In addition, to that the ceramic materials are hydrophilic, but no significant different among the tested CAD/CAM restorative materials were recorded in the weight of the samples after 12 weeks of aging and immersion in hot or cold coffee. This was coincided with those said that there was no significant correlation or differences between  $\Delta E_{00}$  for Vita-E, Vitablocs-MII, and conventional restorative resin blocks and water sorption or solubility after immersion for a period of time [49]. Zidan et al, stated that sorption in distilled water or artificial saliva for groups containing zirconia showed sorption values lower than the control group at 90 and 180 days without significant differences in comparison to the control group [50]. Since the pH of hot or cold coffees are recognized to equivalent to 5.4, this might cause higher sorption values were knowledgeable in materials wrapped up in solutions with pH extending between 4 and 6 [14].

The clinical relevance for studying of prosthetic materials are to guide, help, and support the dental clinicians or practitioners and dental technicians. Also, to estimate the color stability of commonly used dental restorative materials and the effect of glazing and polishing in removal or elimination of discolorations and extrinsic discolorations [20]. The present report evaluated discoloration under ideal conditions. However, many variables could have an influence on the results of the present report. In fact, some variables such as brushing [51], or wear [52] could have a significant effect in surface characteristics of dental materials. These factors could also influence color conditions. Therefore, this can consider as a limitation, and an additional report are needed in order to confirm the results of the present report. Further *in-vitro* and *in-vivo* studies are necessary to evaluate the susceptibility of other CAD/CAM restorative materials staining by other beverages and nutrients.

## Conclusions

This in vitro spectrophotometric color change study reached the following conclusions.

- All the recorded average/mean color changes ( $\Delta E_{00}$ ) values for the tested CAD/CAM restorative materials with different surfaces were in the range of clinical acceptability.

- In general, the mean values for the  $\Delta E_{00}$  color differences and the standard deviation of the evaluated CAD/CAM restorative materials in the form of glazed or polished surfaces with hot coffee staining material were the highest at T1, followed by  $\Delta E_{00}$  values at T2 and T3, for the 3 types of ceramics restorative materials.
- $\Delta E_{00}$  for glazed or polished surfaces for the cold coffee were the highest at T1, followed by T2 and T3, but the opposite was found for the CAD/CAM restorative material of "Vita Suprinity" specimens, which had values of T1 <T2, and T2 <T3 in the glazed and polished surfaces.
- There was a significant difference between the CAD/CAM ceramic restorative materials types and subgroups of glazed or polished specimens stained by hot or cold coffee at all time intervals, except in the polished hot coffee specimens.
- No significant differences were found regarding mean weight between the groups or within the subgroups in the tested materials.
- Significant color changes were recorded in Vita Suprinity and Vita Enamic CAD/CAM restorative materials in relation to VITAPAN CLASSIC shade guide color during all time intervals, while no color changes were noticed for Vitablocs Mark II restorative materials during all staining times.

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## Conflicts of interest

None.

## Declaration of Figures Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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