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Influence of Surface Type with Coffee Immersion on Surface Topography and Optical and Mechanical Properties of Selected Ceramic Materials

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Background: The aim of this study was to assess and compare the effect of surface type (glazed or polished) with coffee immersion and aging on surface topography (Ra), optical properties (TP, OP), and mechanical properties (fracture forces and modes) of zirconia-reinforced lithium silicate (Vita Suprinity), hybrid polymer-infiltrated-feldspathic ceramic network material (Vita Enamic), and leucite-containing feldspathic glass (Vitablocs® Mark II) made by computer-aided design and computer-aided manufactured (CAD/CAM) ceramic materials.

Material/Methods: Fifty-four specimens were assembled out of the above 3 CAD/CAMs ceramic materials. Each group was divided into glazed or polished surfaces, having 9 specimens of every type and stained in coffee for 15 days. Ra and color of specimens in the form of TP and OP were recorded before and after immersion in staining material. Fracture forces and modes were analyzed after the 90-day aging. Data were analyzed using ANOVA, then post hoc analysis and Bonferroni tests.

Results: Our study found significant differences in Ra, TP, and Op before and after coffee immersion between glazed and polished specimens, with higher values in the polished surfaces among the 3 ceramic materials. The highest values of fracture resistance were noted in Vita Suprinity, and Vita Enamic had the lowest values, without significant differences among groups.

Conclusions: Most of the TP and OP values were in acceptable clinical range, and Vita Suprinity had superior TP than the other groups. Reparable fracture types were observed in Vita Suprinity, whereas semi-reparable and non-reparable were predominant in other groups.

Keywords: **CD 3 Color Developer • Ce-TZP-Al2O3**

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Background

Achieving excellent aesthetic colored ceramic restoration has become mandatory. Nonetheless, maintaining long-term color stability and biocompatibility of these prostheses is essential in the oral environment. Some studies reported that CAD/CAM prosthetic material discoloration is related to diet, immersion time, and type of ceramic surfaces, while others found that color stainability of CAD/CAMs materials are affected by the surface texture [1,2]. CAD/CAM systems have grown in popularity over the years; alumina, zirconia, disilicate-based ceramics, and lithium silicate, among others, can be milled rapidly and conveniently utilizing these systems [3,4]. Also available as CAD/CAM blocks, hybrid ceramics are composed of a leucite-based ceramic network strengthened by zirconia and interconnected with an acrylate polymer network. They have been demonstrated to possess superior resistance to damage, decreased elastic modulus, and better stiffness and hardness compared to other indirect restorative ceramic materials [5,6]. Despite that, their translucency is lower than feldspathic ceramics, resin composites, and glass ceramics [7].

The optical properties of ceramics may be altered by both inherent and exogenous elements, like surface layer and porcelain microstructure [8,9]. Color, translucency, and opalescence affect the overall cosmetic outcome of CAD/CAM restorations [10]. Translucency parameter (TP) is the percentage of light that is transmitted through a ceramic [11,12]. The TP stands for the ΔE value of a ceramic on the same background [13]. Opalescence is an optical property in which visible light disperses shorter wavelengths, which gives an object a bluish appearance in the reflected color and an orange/brown appearance in the transmitted color [13]. Opalescence parameter (OP) determines the opalescence of dental materials, which is the difference in yellow and blue color coordinate (CIEΔb^*) and red and green color coordinate (CIEΔa^*) in reflected and transmitted colors [14,15]. This quality can be measured by the reflected and transmitted light against a black and white background [16,17]. Ceramic TP and OP can change due to ceramic thickness, grain size, material surface, and crystalline structure [18,19].

Depending on the ceramic microstructure, treatments like glazing and polishing can be used to alter the optical qualities of dental materials like ceramics [20]. Glazing prior to cementation is crucial for preventing the restoration from discoloration and preserving the color stainability [6,13]. Glazed ceramic surfaces reduce roughness and abrasiveness by closing surface pores and increasing ceramic strength [21]. Clinically, adjusting the glazed ceramic surface is typically done to correct occlusion [22]. The resulting rough ceramic surfaces are more vulnerable to staining [23]. Others stated that polishing protocols can create a ceramic surface as smooth as glazed ones [24,25]. Moreover, a study suggested the use of polishing technique for CAD/CAM materials as an alternative to glazing [24]. The CAD/CAMs system does not require multiple firings, and the blocks allow fast milling and improved fracture resistance and many more advantages [9].

CIE $L^*a^*b^*$ color system helps determine color difference values [26,27]. The CIE-$L^*a^*b^*$ values are called "chromaticity coordinates": (L^*) value is referred to as "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), whereas (b^*) shows yellow color on positive values and blue color on negative values ($-b^*$=blue; $+b^*$=yellow) [28-30].

Coffee one of the most commonly consumed beverages globally and in Saudi Arabia. It causes the maximum discoloration of porcelain veneers [31,32]. Some coffee contains additives such as cardamom, ginger, and saffron. Furthermore, it was proposed that it can act as a staining component in aesthetic restorations. Given its peculiar additional ingredients, it is also regarded as a staining drink [26-29].

During the last years, laboratory studies have measured and assessed the stainability of different CAD/CAMs restorative materials after immersion in different media and beverage solutions to evaluate TP alone or combined with OP without any difference in the surface texture [33-36]. Thus, the present study aimed to assess and compare the effects of surface type (glazed or polished) and coffee immersion with aging on the surface topography (Ra), optical properties (TP, OP), and mechanical properties (fracture forces and fractures mode) of zirconia-reinforced lithium silicate (Vita Suprinity), hybrid polymer-infiltrated-feldspathic ceramic network material (Vita Enamic), and leucite-containing feldspathic glass (Vitablocs® Mark II) CAD/CAMs restorative materials. The null hypothesis was no difference would be observed in Ra, TP, and OP values for glazed, polished specimens before and after 15-day coffee immersions by 50: 50 color perceptibility (PT) and color acceptability (AT) thresholds. Additionally, no difference was found in compressive strength force value and types of fracture before and after coffee immersion. We used 3-month aging of glazed or polished CAD/CAMs materials.

Material and Methods

Study design

In the current study, 3 widely utilized and commercially available CAD/CAMs ceramic restorative materials were chosen and we evaluated the effect of coffee staining for 15 days on optical properties and 3-month aging on their mechanical properties after prolonged aging. Sample size was calculated by using G*Power software. (Version 3.1.9.7.) There were 3 groups

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in the study. Assuming a moderate effect size between the groups for fracture resistance (0.25), at 5% level of significance and 85% power, the required sample size was 18 subjects per group. Therefore, the total sample size required was 18×3=54 subjects [2,14].

Specimen Manufacturing and Grouping

The CAD/CAMs materials were Vita Suprinity, Vita Enamic, and Vitablocs® Mark II materials (Vita Zahnfabrik, H. Rauter Bad Säckingen, Germany). Fifty-four (19 in each group) specimens of machinable CAD/CAMs porcelain blocks were cut into square slices of 1.5 mm ±0.2 thickness and dimension of 12×14 mm using a CAD/CAMs machine (Amann Girrbach, GmbH, Durrenweg 40 75177 Pforzheim, Deutchland). Next, all specimens underwent finishing and polishing by 300- to 800-grit silicon carbide papers to achieve uniform thickness. Afterwards, all specimens were sintered in a furnace (Programat P310; Ivoclar Vivadent AG, H. Rauter Bad Säckingen, Germany) for 2 h at 1550°C, in accordance with manufacturer's instructions. Specimens from every group were subdivided into 2 equal subgroups of 9 each on the basis of surface types (glazed or polished).

Specimen Surface Treatments and Cleaning

One subgroup was saved as glazed from the laboratory, and further measurements were conducted without any surface modifications to the working/immersed surface. The other subgroup (18 each) was polished through an OptraFine polishing set (Ivoclar, Vivadent, H. Rauter Bad Säckingen, Germany) following manufacturer instructions underneath persistent load (2±0.25 kg) with an identical number of grinders in a one-way direction [37]. Polishing steps are first, finishing=F (light blue), and second polishing=P (dark blue). The employed handpiece could polish at a maximum speed of 15,000 RPM while using OptraFine HP Polishing Paste and a high-gloss polishing brush (HP) that rotated at speeds between 5,000 and 7,000 RPM (maximum 10,000 RPM) [28,29]. Sample surfaces were polished and changed to replicate the clinical adjusting of ceramic restorations [29]. The samples underwent a 10-minute ultrasonic cleaning procedure using distilled water and isopropanol to remove any remaining oil. Next, they were dried using compressed air for 20 seconds before being submerged [29]. The specimens are handled by only one operator (Al MM.) in accordance with instructions provided in booklet for all CAD/CAM all ceramic types.

Surface Topography Test

Specimen description & tomography were completed with a 3D noncontact surface metrology using interferometry (Bruker Contour GTK, Bruker Nano Surfaces Division, Tucson, AZ, USA). Through an upright scan interferometer with a 5 Michelson amplification lens, a field of interpretation of 1.5 1.5 mm, a Gaussian regression filter, a scan speed of 1, and a thresholding of 4, specimens were computed or measured. Microscope was equipped with the Vision 64 (Bruker) software suite, which manages tool placements, assesses the statistics, and generates graphical results. Assessments were reserved across the specimens at two-time measurements, at baseline, post coffee immersions, and 3-month aging. Each specimen was scanned 5 times (at the center and each side) and then averaged to calculate the surface roughness (Ra) values in µm, calculated in accordance with ISO 11562 recommendations for standardization [38-40]. 2 specimens of all 3 groups in glazed and polished tested ceramic CAD/CAMs materials were scanned for Ra test (**Figure 1**).

Color Parameters Measurements

Using a spectrophotometer of 6mm diameter tip, the color parameters of each specimen were measured in accordance with the International Commission on Illumination (CIE) L*a*b* color scale relative to the CIE standard illuminant, that corresponded to "average" daylight. (VITA Easyshade 3 Advance, Vita Zahnfabrik, Bad Säckingen, Germany) [27-30]. Before each measurement for each specimen, the spectrophotometer was calibrated using a spectrophotometer following manufacturer's instructions. Five measurements were taken from various places on BnW background for each item, and average values were calculated. On W and B backgrounds, spectrophotometry was used to determine the specimens' color characteristics, including L1, a1, and b1 values. To guarantee that specimens stayed in the same location while assessing optical readings, a square window opening measuring 22cm was utilized & fastened to BnW back grounds. By utilizing following formula to determine the specimen color difference in BnW and color backgrounds, TP measurements were obtained. [33-36]:

$$TP=[(L_B-L_W)^2+(a_B-a_W)^2+(b_B-b_W)^2 2]^{1/2}.$$

A material that is entirely opaque has a TP value of 0. A high TP suggests that the material has high actual translucency. To determine a specimen's opalescence, OP was calculated, that is modification in yellow-blue (CIE Δb^*) and red–green (CIE Δa^*) color coordinates among reflected and transmitted colors by using this equation [33-36]:

$$OP=[(a^*B-a^*W)^2+(b^*B-b^*W)^2]^{1/2},$$

where subscripts B and W refer to color coordinates over BnW backgrounds.

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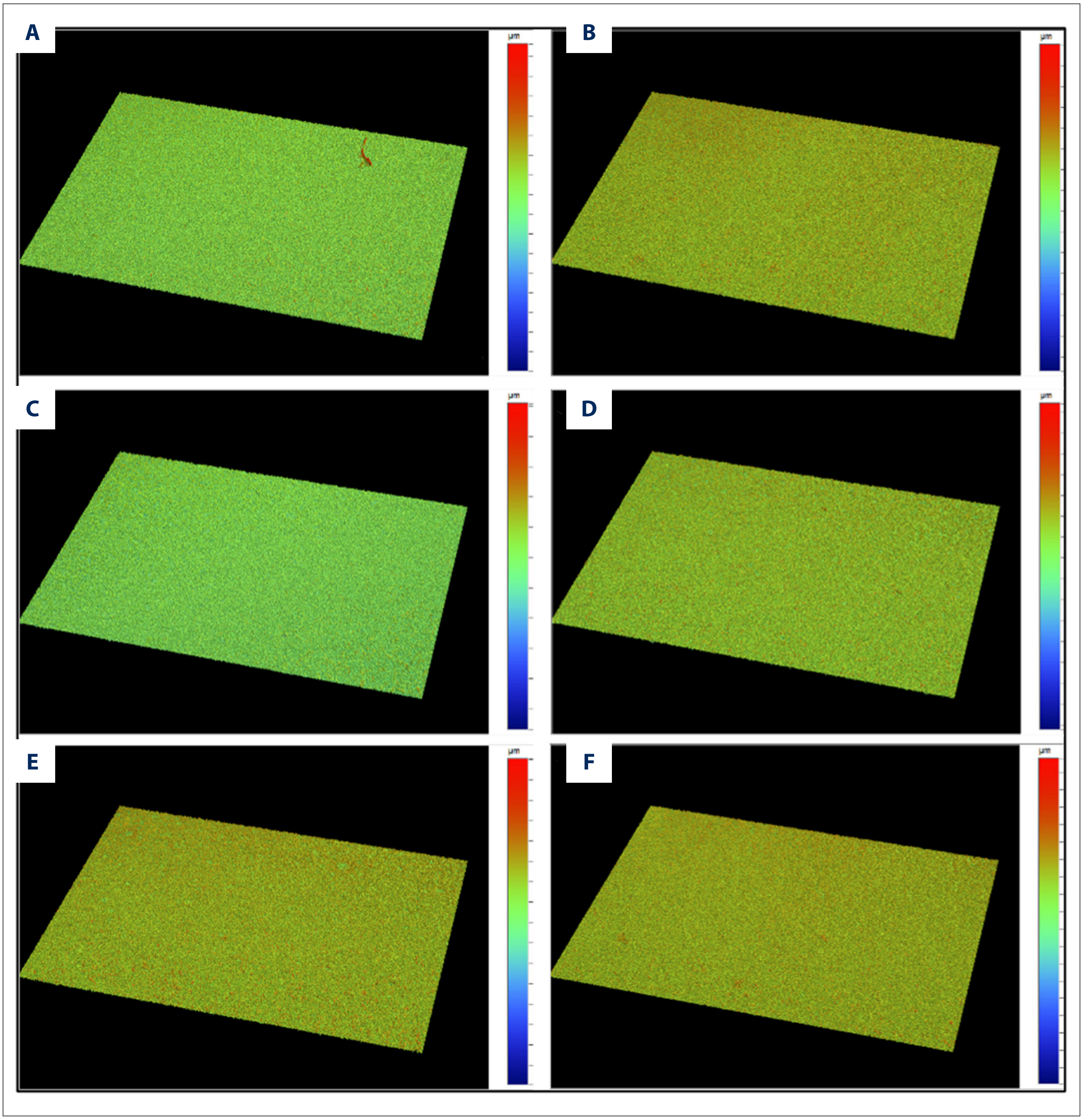

Figure 1. Representative white light interferometer microscope images of Vita Suprinity (**A, B**), Vita Enamic (**C, D**), and Vitablocs® Mark II (**E, F**) CAD/CAM materials with glazed and polished surfaces under ×50 magnification.

Specimens' Immersion in Coffee

All samples were submerged in coffee solution (pH 5.1; Dunkin' Donuts Original Blend Ground Coffee, Medium Roast, Shahia Food Limited Company, Saudi Arabia) that was prepared in accordance with the manufacturer's instructions. Fifteen consecutive days were used as the immersion duration to simulate a year of coffee consumption [27-29,36]. Specimens were kept stirring in it during the immersion cycles and housed at 37°C in an incubator. The coffee was made fresh and replenished every day. Twice daily, the coffee was changed. Each day's samples were gently dried after being rinsed under running distilled water to get rid of any lingering coffee odor [27-29,38-40].

Specimen Color Measurements and Aging

Following coffee staining and aging, the color parameters of the specimens were once again assessed, and these results were taken into account. L2, a2, and b2 were evaluated once more using the same operator, location, and backdrop. The average values for ∆L, ∆a, and ∆b employed calculated the second and first value differences. These numbers were entered to measure color parameters.

Specimens' Compressive Force Test

Compressive fracture resistance value of specimens was calculated with a computer-controlled universal testing machine (Zwick Z010/TN2A, Ulm, Germany) at a cross-head speed of 0.5 mm per minute using a 4-mm diameter rod as per ISO 6872, in air at room temperature. After inserting a 0.5-mm thermoplastic resin tape between force loading the tip and the strained CAD/CAMs specimen surfaces to disperse the fracture forces and confirm a broadly even connection, a hemispherical stainless-steel tip with a 3-mm radius was pointed at the center of each specimen. Computer software was linked to working apparatus applied fracture forces along the longitudinal axis at the center of each specimen until breaking. Maximum force load of each specimen was entered in MPs automatically [35,36]. The above values were determined for all samples at King Saud University, Biomaterial Laboratory, College of Dentistry, Riyadh, Saudi Arabia.

Specimens' Failure Type Reorganization

Types of fractures was classified in relation to the shape, number of pieces after fractures, and its ratio from original shape of samples as follows: Reparable where samples were broken in 2 parts or 50-50 of the original shape, semi-reparable where specimens were broken into 3 to 4 fractures wherein every piece measured 20% to 35% of original size of sample, and non-reparable where each fracture piece was less than 20% of the original size of the specimen [35-36,41-42].

Statistical Analysis

Statistical analysis was done using SPSS version 23. Descriptive statistics were shown as mean and standard deviations (SD) for all variables. One-way ANOVA was done for comparing the means of transparency, opalescence, and surface roughness for glazed and polished surfaces of different types of ceramics before and after coffee immersion with aging. Then, post hoc and Bonferroni tests were used. The same was done with the compressive surface strength of all types of ceramic after prolonged aging. Finally, two-way ANOVA was carried out for evaluating interaction of surface treatment and types of ceramic within TP, OP, and surface roughness.

Results

Tables 1 and 2 present coffee immersion effects for 15 days and aging for both glazed/polished ceramic types of transparency. **Table 1** presents the ANOVA results for the mean surface roughness (Ra) of glazed and polished ceramic types before and after coffee immersion with aging. The mean SR was significantly different among the 3 glazed ceramic groups before and after the immersion (0.351, 0.337, 0.397, and 0.383, 0.348, 0.426 before and after, respectively, at $P<0.0001$). The same result was found in the 3 polished ceramic groups before and after coffee immersion. Significant surface roughness changes occurred in Vita Suprinity ceramic, whether it was glazed or polished (**Table 2**). Conversely, no significant surface roughness changes occurred among the Vita Enamic and Vita Mark II ceramic groups, although the Vita Mark II's significant surface roughness changed before and after immersion.

In relation to the TP, **Tables 3 and 4** show that the glazed Vita Suprinity ceramic had more significant transparency than the other 2 ceramic groups (Vita Enamic and Vita Mark II) before and after coffee immersion with aging ($P<0.01$). No significant difference in transparency existed between Vita Enamic and Vita Mark II before and after coffee immersion with aging. However, with polished surfaces, significant differences in transparency occurred among the 3 ceramic groups before coffee immersion with aging. By contrast, Vita Suprinity significantly more transparent than the other 2 ceramic types. The transparency changes were significant in Vita Enamic and Vita Mark II ceramic groups, whereas no significant transparency changes were present in Vita Suprinity ceramic.

Before its coffee immersion for OP groups, no significant opalescence difference existed between the glazed ceramic groups (**Table 5**). After immersion, a significant opalescence difference existed between the glazed Vita Enamic and the other 2 glazed ceramic groups ($P<0.003$). No significant difference existed between them. For the polished Vita Suprinity ceramic, the opalescence was the same as with Vita Enamic before coffee immersion. However, after immersion in coffee with aging, a significant opalescence difference existed between them ($P<0.007$). The opalescence polished Vita Mark II ceramic was significantly different from the other 2 ceramics before immersion. After immersion in coffee, the opalescence was the same as polished Vita Suprinity and significantly different from polished Vita Enamic. In **Table 6**, the *t* test for all the types of ceramic opalescence before and after coffee immersion with aging was used. The Vita Suprinity ceramic had a significant opalescence difference before and after coffee immersion ($P<0.001$, 0.003, respectively). Moreover, the Vita Enamic ceramic had significant opalescence changes ($P<0.030$), and no significant opalescence changes were observed in Vita Mark II.

Table 7 presents the interaction of transparency, opalescence, and surface roughness among different surface types with different ceramic groups. For transparency, no significant difference was noted in the surface type and the types of ceramic.

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Table 1. ANOVA for mean and standard deviation of surface roughness of different surface types of all ceramic groups before and after coffee immersion with aging.

Surface type	Ceramic type	Surface roughness Before/mean (SD)	Surface roughness After/mean (SD)	Surface roughness Changes/mean (SD)
Glazed	Vita Suprinity	0.351 (0.006)^{A}	0.383 (0.015)^{a}	0.032 (0.013)^{A}
	Vita Enamic	0.337 (0.014)B	0.348 (0.126)^{b}	0.011 (0.003)^{B}
	Vita Mark II	0.397 (0.007)^{C}	0.412 (0.009)^{c}	0.016 (0.006)^{C}
	P-value	0.000*	0.000*	0.000*
Polished	Vita Suprinity	0.375 (0.016)^{A}	0.386 (0.015)a	0.015 (0.006)
	Vita Enamic	0.348 (0.006)B	0.359 (0.009)^{b}	0.009 (0.005)
	Vita Mark II	0.416 (0.006)C	0.426 (0.006)^{c}	0.006 (0.006)
	P-value	0.000*	0.000*	0.951

Means with a different superscript capital letter are statistically significant at p≤0.05. Means with a different superscript small letter are statistically significant at p≤0.05. * Significant difference at P-value ≤0.05.

Table 2. *t* test for all the type of ceramic surface roughness before and after coffee immersion with aging.

Ceramic type (glazed and polished)	Parameter	P-values
Vita Suprinity (glazed and polished)	Surface roughness before	0.001*
	Surface roughness after	0.685
	Surface roughness changes	0.000*
Vita Enamic (glazed and polished)	Surface roughness before	0.055
	Surface roughness after	0.051
	Surface roughness changes	0.831
Vita Mark II (glazed and polished)	Surface roughness before	0.000*
	Surface roughness after	0.001*
	Surface roughness changes	0.094

* Significant difference at P-value ≤0.05.

The only significant difference was found in the interaction between the ceramic and surface types (*P*<0.015). By contrast, a significant opalescence effect was found among the surface type and the interaction between ceramic and surface types (*P*<0.018, 0.010, respectively). No significant opalescence was found among ceramic group types. In the surface roughness, a significant effect was found among the kind of ceramic, surface type, and the interaction between ceramic and surface types. **Table 8** shows the effect of aging for 90 days on both glazed/polished ceramic types of compressive force strength. A significant difference in mean compressive force strength (*P*<0.000) was found between the glazed and polished ceramic groups.

Figure 2 shows the percentage of fracture types (reparable, semi-reparable, and non-reparable fractures) between the glazed and polished different ceramic groups. In the glazed surface ceramic groups, the reparable fracture type was found to be the highest percentage in Vita Suprinity (77.8%). In Vita Enamic and Vita Mark II ceramic groups, the semi-reparable was the highest (77.8%, 66.7%, respectively, at *P*<0.001). In the polished surface ceramic groups, the highest fracture type was the non-reparable fractures with Vita Mark II ceramic (100%). For the Vita Suprinity and Vita Enamic, it was the same as the glazed ceramics (*P*<0.000). **Figure 3** shows the percentage of different glazed and polished ceramic groups among different fracture types. The non-reparable fracture types had a significantly higher percentage than other types of fractures in Vita Mark II (66.7%, *P*<0.009), but no significant fracture type percentage difference was found among other 2 ceramic groups (*P*<1.00, 0, 22, respectively).

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Table 3. ANOVA for mean and standard deviation of transparency of different surface types of all ceramic groups before and after coffee immersion with aging.

Surface type	Ceramic type	Transparency Before/mean (SD)	Transparency After/mean (SD)	Transparency Changes/mean (SD)
Glazed	Vita Suprinity	24.18 (3.056)[A]	19.94 (4.466)[a]	-4.24 (2.689)
	Vita Enamic	16.30 (3.186)[B]	13.92 (2.226)[b]	-2.38 (1.727)
	Vita Mark II	15.68 (2.128)[B]	11.39 (3.284)[b]	-4.29 (2.225)
	P-value	0.000*	0.000*	0.144
Polished	Vita Suprinity	24.80 (3.057)[A]	20.24 (2.522)[a]	-4.56 (2.279)
	Vita Enamic	20.00 (3.905)[B]	15.48 (3.988)[b]	-4.52 (2.113)
	Vita Mark II	14.80 (3.258)[C]	12.70 (3.129)[b]	-2.09 (1.713)
	P-value	0.000*	0.000*	0.025*

Means with a different superscript capital letter are statistically significant at p≤0.05. Means with a different superscript small letter are statistically significant at p≤0.05. * Significant difference at P-value ≤0.05

Table 4. *t* test for all the types of ceramic transparency before and after coffee immersion with aging.

Ceramic type (glazed and polished)	Parameter	P-values
Vita Suprinity (glazed and polished)	Transparency before	0.677
	Transparency after	0.865
	Transparency changes	0.792
Vita Enamic (glazed and polished)	Transparency before	0.043*
	Transparency after	0.322
	Transparency changes	0.032*
Vita Mark II (glazed and polished)	Transparency before	0.507
	Transparency after	0.397
	Transparency changes	0.032*

* Significant difference at P-value ≤0.05.

Discussion

The current study assessed and compared effects of surface type (glazed or polished) along with coffee staining with aging on the surface topography (Ra), optical properties (TP, OP), and mechanical properties of Vita Suprinity, Vita Enamic, and Vitablocs® Mark II CAD/CAMs ceramic materials. Our null hypothesis showed no differences in the Ra, TP, and OP values with respect to glazed as well as polished specimens before and after the 15-day coffee immersion. The result for the Ra showed a significant difference in the glazed surface type but no significant difference with polished ones of the tested CAD/CAMs materials. Moreover, the overall TP and OP changes recorded a non-significant difference among the glazed surfaces, whereas a significant difference was recorded among these tested CAD/CAM materials relative to polished surfaces. This finding implies a partial acceptance of this hypothesis. The overall results of this study differed from values documented by Al Moaleem et al [43] for those materials in glazed or polished surfaces and slightly lesser than those values obtained in different studies by Adawi et al, Aldosari et al, Vasiliu et al, and Abdalkadeer et al [28,29,34,44] for both types of the exposed and stained surfaces in relation to the Ra values; this phenomenon could be explained by the duration of the immersion materials as well as the stained media or beverage. Nevertheless, the values achieved in this laboratory study in relation to the optical properties were in agreement with many different studies [30,33,36] for optical property values in the form of TP and OP of the tested materials.

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Table 5. ANOVA for mean and standard deviation of opalescence of different surface types of all ceramic groups before and after coffee immersion with aging.

Surface type	Ceramic type	Opalescence Before/mean (SD)	Opalescence After/mean (SD)	Opalescence Changes/mean (SD)
Glazed	Vita Suprinity	12.13 (1.188)	10.79 (0.503)^{a}	-1.33 (0.985)
	Vita Enamic	13.70 (2.949)	12.96 (2.149)^{b}	-.73 (3.424)
	Vita Mark II	13.01 (1.894)	10.93 (0.713)^{a}	-2.07 (1.867)
	P-value	0.313	0.003*	0.485
Polished	Vita Suprinity	16.48 (3.126)^{A}	12.89 (3.125)^{a}	-3.58 (2.804)^{A}
	Vita Enamic	15.43 (3.726)^{A}	10.52 (1.233)^{b}	-4.91 (3.976)^{B}
	Vita Mark II	12.01 (0.473)^{B}	11.17 (0.667)^{a}	-.84 (0.533)^{A}
	P-value	0.007	0.048	0.017*

Means with a different superscript capital letter are statistically significant at p≤0.05. Means with a different superscript small letter are statistically significant at p≤0.05. * Significant difference at P-value ≤0.05.

Table 6. *t* test for all types of ceramic opalescence before and after coffee immersion with aging.

Ceramic type (glazed and polished)	Parameter	P-values
Vita Suprinity (glazed and polished)	Opalescence before	0.001*
	Opalescence after	0.003*
	Opalescence changes	0.037*
Vita Enamic (glazed and polished)	Opalescence before	0.291
	Opalescence after	0.009*
	Opalescence changes	0.030*
Vita Mark II (glazed and polished)	Opalescence before	0.147
	Opalescence after	0.478
	Opalescence changes	0.075

* Significant difference at P-value ≤0.05.

Several methods were used to assess the roughness of different dental materials, but Ra values are the most commonly used in dentistry. For our study, Ra was assessed with an optical noncontact profilometer, based on the principle of two-beam optical interferometry without any instrument being physically in contact with the surface undergoing analysis [45,46]. An Ra value of 0.2 μm was regarded as the clinical threshold that prevented plaque retention and microorganism adherence to dental restorative surfaces [47]. At baseline, Ra values were within the threshold values for all of them, but the 3 tested materials were observed to have increased Ra compared to baseline. They were much less than those reported by other researchers such as Vasiliu et al [30] and in parallel with findings verified by other published research [39,40]. In relation to the values between glazed and polished surfaces, this study recorded significant differences among the glazed specimens of the tested materials, where the values were insignificant between glazed and polished zirconia samples only. Those results agree with findings of Al Moaleem et al for zirconia samples [43]. Dogdu and Ceylan recoded a higher value for both glazed 1.15 and polished zirconia 0.81 μm; similar results were also registered by Alp and Subaşı for both glazed and polished CAD/CAM specimens [48,49].

It is essential for the long-term clinical and survival effectiveness of CAD/CAMs materials to maintain their color stability while chewing. Coffee and other beverage staining materials with aging may result in slight optical color change measurements. These effects were slightly higher in polished surfaces than with glazed ones [33-36,44]. Ceramic materials with

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Table 7. ANOVA interaction of TP, OP, and Ra among different surface types with different ceramic materials.

Source	Type III sum of squares	df	Mean square	F	Sig.
TP changes					
Ceramic (Suprinity, Enamic, Mark II)	14.655	2	7.327	1.584	0.216
ST (glazed, polished)	.103	1	0.103	0.022	0.882
Ceramic*ST	42.688	2	21.344	4.614	0.015*
Error	222.060	48	4.626		
OP changes					
Ceramic (Suprinity, Enamic, Mark II)	18.060	2	9.030	1.350	0.269
ST (glazed, polished)	40.439	1	40.439	6.046	0.018*
Ceramic*ST	67.538	2	33.769	5.049	0.010*
Error	321.066	48	6.689		
Surface roughness changes					
Ceramic (Suprinity, Enamic, Mark II)	.001	2	0.001	9.962	0.000*
ST (glazed, polished)	.001	1	0.001	18.826	0.000*
Ceramic*ST	.001	2	0.001	10.850	0.000*
Error	.003	48	5.386E-5		

* Significant difference at P-value ≤0.05.

Table 8. ANOVA for mean (SD) compressive forces strength of different surface types of all ceramic groups.

Surface type	Ceramic type	Compressive forces (MPs)/mean (SD)
Glazed	Vita Suprinity	114.45 (0.775)^{A}
	Vita Enamic	75.88 (0.682)^{B}
	Vita Mark II	41.21 (0.321)^{C}
	P-value	0.000*
Polished	Vita Suprinity	9.6926 (0.911)^{A}
	Vita Enamic	5.5711 (0.654)^{B}
	Vita Mark II	3.2674 (0.197)^{C}
	P-value	0.000*

Means with a different superscript capital letter are statistically significant at p≤0.05. * Significant difference at P-value ≤0.05.

their thickness were used in this laboratory study because those materials are the most frequently used among practitioners [28,29,50], and optical properties of materials are usually dependent on and effected by the components and stained materials as well as the immersion times [27-29,36]. It has been reported that TP of human teeth ranged from 15 to 19 at a thickness of 1 mm and for the restorative materials, it increased up to 25 [51]. For our study, TP ranged from 12 to 16 at a thickness of 1.5 mm. Similar TP values were recorded on the same CAD/CAMs materials in glazed or polished form post immersion in similar beverage for the same period of time [30,33,35,36]. This thickness was used since the majority of the ceramics required a reduction of 1.5 mm in the tooth structure for restorations to be successful [51,52].

OP values with respect to glazed specimens either before or after thermocycling reach a maximum value of 14 units, which is within the same value before coffee immersion [34]. A higher value of OP was noted for polished Vita Triluxe, ranging from 22.1 to 16.2, and were higher than glazed surface values and

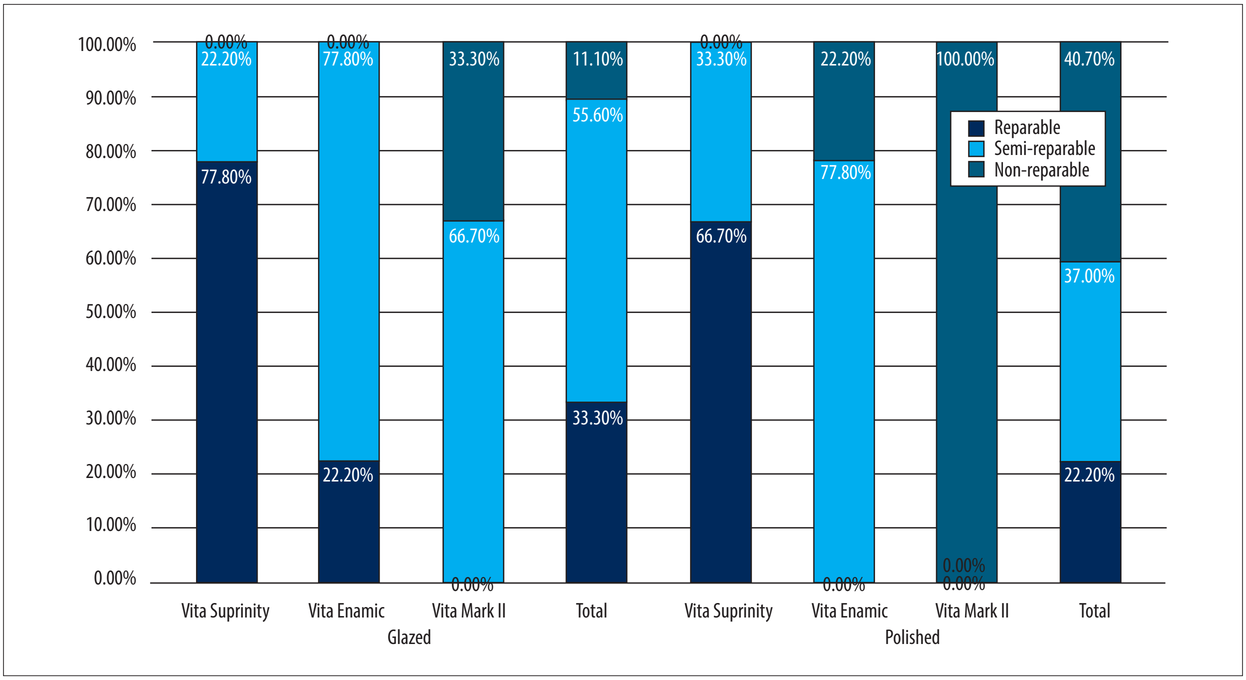

Figure 2. Percentage of fracture types between the glazed and polished different ceramic groups.

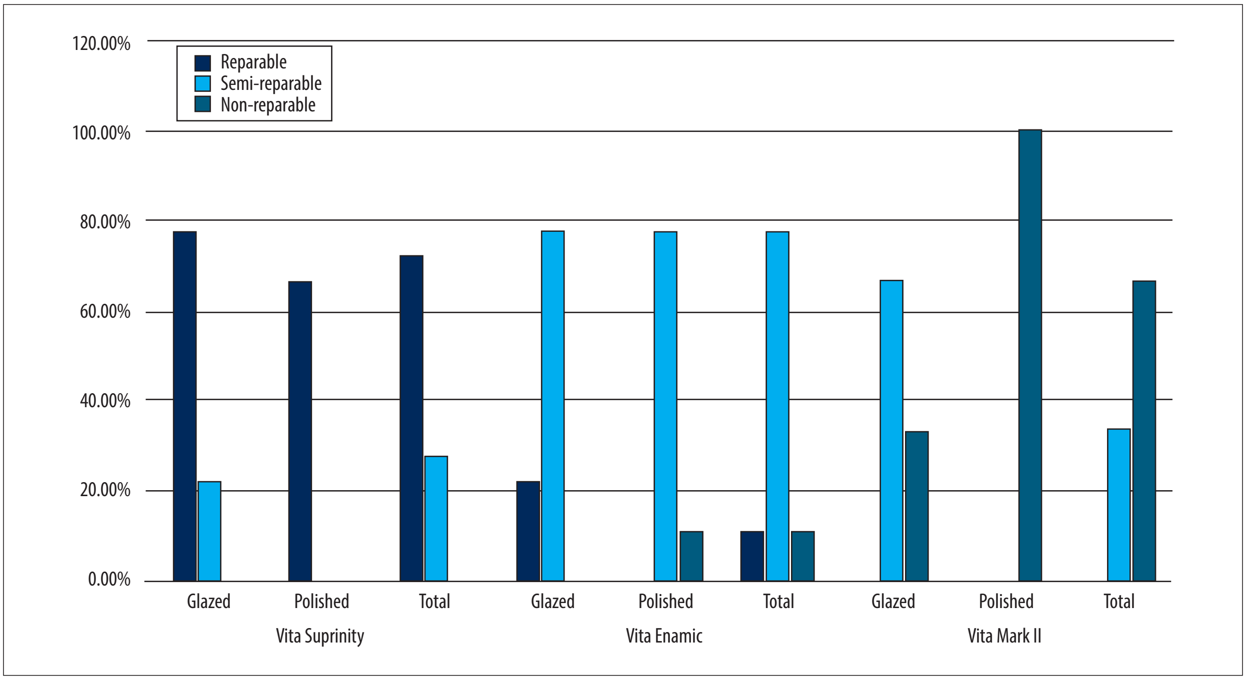

Figure 3. Percentage of different glazed and polished ceramics among different fracture types.

decline overall [35]. Koseoglu et al [33] presented marginal findings, where OP values for zirconia reached 18. Zirconia material TP values obtained by Wahba reported 9.6 as the highest value documented amongst all test groups. The OP established for human teeth is up to 22 [39]. Our findings proved that the OP BW parameter was in a range of 3-13 and 13-15 before and after thermocycling, respectively [51,52].

TP and OP were calculated and assessed by using the VITA Easyshade Compact spectrophotometer, which was used earlier for similar research and was deemed reliable owing to its internal light source illuminant. Therefore, environmental light does not influence the color results [27-30]. Immersion or staining time and laboratory storage for materials during in vitro testing is an important factor to assess the material

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behaviors. We developed the following scenario to compare our in vitro results to those in clinical settings. If 30 days of immersion beverage consumption equaled 1 day of storage, the 15-day packing used throughout the present in vitro immersion was equivalent to 14 months of in vivo clinical setting [36,41]. Secondly, CAD/CAM's restorative material survival rate in an oral environment is equal to more than 10 years for samples aging at intervals of 3 months during laboratory soaking [35,36,42]. Additionally, surface pretreatment with different polishing agents, as reported by Scribante et al, have been demonstrated to have significant effects on dental surface, so they could be considered also for optical properties of CAD-CAM restorative materials [53].

Mechanical properties are in the form of compressive strength forces and type of fracture after coffee immersion. Then, 3-month aging for glazed or polished CAD/CAMs materials used showed significant differences with different values among the tested materials. Therefore, this hypothesis was rejected. Alakkad et al [54] evaluated and compared the biaxial flexural strength (FS) for 3 CAD-CAMs glass-ceramic materials. They found the lowest FS was 89.34±25.30 MPa for Celtra Duo, whereas it was higher for IPS e.max CAD and IPS Empress CAD. Vafaee et al [55] measured the FS for LAVA Ultimate, CAD/CAM composites, hybrid ceramics, and lithium disilicate glass-ceramic materials and found that IPS e.max CAD had the highest FS, followed by LAVA Ultimate, whereas the lowest FS was observed in Vita Enamic and IPS EmpressCAD. Al Ahmari et al [42] documented values of IPS e.maxCAD miswak sticks having highest mean values of compressive fracture at 829.21±101.79, Vitablocs Mark II had lowest values 312.65±19.33, and 340.63±55.93 for Vita Suprinity cleaned with mouthrinse and dentifrice. Significant differences were seen in the IPS e.max CAD group [42]. Alahmari recorded a biaxial fracture force in N of 830-843 for IPS e.maxCAD and 632-656 for the multilayer Ceramil Zolid PS zirconia group [36]. Alqahtani found that highest mean values and SD of CFFs (MPa) were seen in Vita Suprinity, and then Vita Enamic and Vita Mark II, with values of 103.59, 60.69, and 36.91, respectively [41]. Our study observed a similar pattern for all test materials, with mean and SD denoted in Newtons: VS>, VE, >VM II. ANOVA showed significant differences amongst all tested groups for the CFF values (MPa and Newtons). Al Moaleem et al reported that glazed and polished zirconia had significantly higher compressive fracture forces than glazed and polished Vita Triluxe [35]. Reparable fractures were observed in IPS e.max CAD, whereas semi-reparable fractures were found in other groups [36]. They also found that IPS e.max CAD was associated with Type 1 fractures, whereas Types 2 and 3 fractures were chiefly recognized with Vita Suprinity and Vitablocs Mark II groups. Nearly 100% IPS e.max CAD were present in the miswak derivatives but absent in Vita Suprinity and Vitablocs Mark II groups. Type 2 fracture was mainly seen in 70% to 80% of all groups of Vita Suprinity and in 60% to 80% of all groups of Vitablocs Mark II. Type 3 fracture type was seen in 20% to 30% of all groups of Vita Suprinity, and in 20% to 40% of 3 types of failures were presented [35,42]; 25% of VMII and VS had semi-reparable fractures. VE had 56.3% non-reparable and 43.8% semi-reparable fractures [41]. Al-Ahmarei recorded reparable fracture in IPS CAD and the 3 types with zirconia group semi and non-reparable fractures [36]. Generally, materials with higher compressive fracture forces were recorded with reparable fracture type and resulted in a fracture into 2 halves and vice versa.

The current laboratory study contains some limitations. In spite of the robust technique that was implemented in this study, we were not able to accurately recreate the conditions that are present in vivo. In the oral cavity, the glazed or polished surface can be stained with coffee and aging. Such factors causing the staining may occur simultaneously in real situations. In this study, the 2 conditions were applied separately. Thus, different color parameters and Ra values of tested materials may be predicted. Moreover, irregularities in diet and coffee drinking and staining among subjects could mean that our study was overly simple. Lastly, the saliva and tongue in the oral cavity occasionally play a part in washing processes, thus lowering contact duration of coffee elements and the prosthesis surface. Further studies may aid extensive research into next-generation prosthetic materials having longer staining, which will enhance color stability. These variables should be tested in future clinical and laboratory studies. Other variables that could have an influence on the optical results should be hypothesized. Also, the present report evaluated fracture forces. Future studies should test CAD/CAM materials evaluating other variables such as Vickers microhardness [56], and flexural strength (force levels) of fiber-reinforced composites and orthodontic stainless-steel wires with a 3-point bending test [57].

Conclusions

Based on this laboratory findings, we can conclude that:

- Ra was slightly higher after aging and immersion for tested ceramics.
- Glazed Vita Suprinity showed more significant TP than the other 2 ceramic groups (Vita Enamic and Vita Mark II) before and after coffee immersion with aging. For polished surface, a significant TP occurred between 3 ceramic groups before coffee immersion with aging.
- Before its coffee immersion for OP, no significant opalescence difference existed among glazed ceramic groups; whereas after immersion, a significant OP difference existed among glazed Vita Enamic and other 2 glazed ceramic groups. For polished Vita Suprinity, OP was the same as Vita Enamic before coffee immersion.

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- Compressive forces were similar to clinically accepted values with respect to Vita Suprinity, whereas it was half the values for Vita Enamic and Mark II. Reparable fractures were found most with glazed Vita Suprinity, but all samples of Vita Mark II showed a non-reparable fracture.

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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