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COLOR STABILITY OF THREE ESTHETIC MONOLITHIC BLOCK MATERIALS AFTER IMMERSION IN COMMONLY CONSUMED BEVERAGES

Nehal Lotfy Abouraya* *and* Hadil Ahmed Sabry**

ABSTRACT

Background: The resistance of CAD/CAM monolithic esthetic materials to staining by commonly consumed beverages is of prime importance for the success and longevity of such restorations.

Aim: The aim of the current study was to evaluate the color change of three commercially available esthetic monolithic block materials: Vita Suprinity (zirconia enriched lithium silicate glass ceramic), Lava Ultimate (Nanoceramic resin composite) and Vita Enamic (hybrid ceramic/PICN) after immersion in commonly consumed beverages namely: coffee and cola compared to distilled water as control.

Methodology: A total of 45 specimens were cut from CAD/CAM blocks where each slice was 2 mm thick. Three subgroups of each material group (n= 5) were tested according to the immersion solutions. Specimens were stored in 20 ml of each solution for 2 weeks at 37 °C before being tested. A spectrophotometer was employed to detect color change (ΔE) before and after immersion.

Results: Coffee produced the highest color change (ΔE) in Vita Enamic while cola had the same influence on Lava Ultimate. Vita Suprinity showed the least color change compared to the other two materials on immersion in both beverages. Distilled water resulted in the highest ΔE value in Lava Ultimate. Vita Enamic and Vita Suprinity were significantly affected by immersion in coffee and cola, where immersion of Vita Enamic in coffee revealed higher ΔE compared to cola while the opposite is exhibited by Vita Suprinity showing higher ΔE in cola. Vita Suprinity showed highest color change upon immersion in distilled water with all (ΔE) values within acceptable range for color change

Conclusion: Coffee can be considered a potential staining beverage. Also, cola can adversely affect color in resin-containing materials but less than coffee. Vita Suprinity can be considered the most color stable of the tested blocks. Vita Enamic may constitute a compromise regarding its color stability while Lava Ultimate exhibited inferior color stability on immersion in coffee, cola and distilled water.

KEYWORDS: Color stability, CAD/CAM monolithic esthetic blocks, Coffee, Cola

* Lecturer of Dental Materials, Biomaterials Department, Faculty of Dentistry, Cairo University, Egypt.
** Associate Professor of Biomaterials, Biomaterials Department, October 6 University, Egypt

INTRODUCTION

Recently, the esthetic appearance of restorative materials constitutes a major/high demand by the patients, thus dictating innovation of solutions that fulfill several requirements such as proper mechanical properties, accuracy, reduced manufacturing time and limited clinical visits besides esthetics.[1,2] Computer-aided design/computer-aided manufacturing (CAD/CAM) monolithic block materials opened up a new horizon in dental treatment to meet the expectations of the clinicians and patients allowing time-efficient fabrication of precise tooth-colored highly reliable restorations.[1-10]

Generally, CAD/CAM materials used to produce monolithic restorations can be categorized as ceramic/glass ceramic, indirect resin-based composite, and hybrid ceramic. Ceramic/glass ceramic include zirconia, lithium disilicate ceramics, zirconia reinforced lithium silicate ceramics, leucite reinforced ceramics and feldspathic ceramics.[3,5,7,11-13] Since 2000, CAD/CAM composite resin blocks were developed[4] possessing a microstructure of reinforcing inorganic fillers dispersed in a polymeric matrix.[7,11-15] Additionally, they were industrially polymerized under high temperature and pressure to achieve optimum properties and a high degree of conversion.[4,12,16] Despite the superior mechanical and esthetic properties possessed by ceramic/glass ceramic [1] they suffered from low fracture toughness, brittleness and difficulty in machining.[1,3,12] CAD/CAM processed composite resins offered an alternative to ceramics[4,8,15] based on their easy fabrication, easier and less visible intra-oral repairability of minor functional defects.[4,8,12] Nevertheless, resinous blocks lack optimum wear resistance and sustained mechanical properties in the wet oral environment.[12,17,18] Hybrid ceramics were introduced to avoid the shortcomings and combine the advantages of both material categories; ceramics and resinous composite.[19] These materials are characterized by a dual network structure of ceramic and polymer, in which the dominant porous sintered feldspathic ceramic network is reinforced by a completely interpenetrated methacrylate polymer network, thus termed polymer infiltrated ceramic network (PICN).[3,6,10,12,20,21] The manufacturer claims that it has lower brittleness and fracture toughness than ceramics and higher than resin composites. They can be easily repaired on the chairside, possess excellent mechanical properties and optimal integrity. Moreover, they possess physical properties very close to those of natural teeth leading to less abrasion of the antagonist natural teeth in comparison to all ceramic materials and undergo less wear than composites. In addition, they possess higher damage tolerance than CAD/CAM ceramics implying better machinability.[6,10,17,22] Among the commercially available materials that belong to the mentioned material categories are Vita Suprinity; zirconia enriched lithium silicate reinforced glass ceramic, Lava Ultimate; resin nanoceramic CAD/CAM restorative material and Vita Enamic; hybrid ceramic or PICN material.

The resistance of these CAD/CAM monolithic esthetic materials to staining over time is decisive for the success and longevity of such restorations, especially in harsh oral environment conditions.[1,3,4,23,24] Commonly consumed beverages such as coffee and cola often contain colorants or impose acidic pH that may adversely affect esthetic restorations causing discoloration.[4,23,25]

Discoloration could be caused by either extrinsic or intrinsic factors. Extrinsic factors include surface roughness, smoking and exposure to stain-producing beverages and colored solutions. while intrinsic factors include mainly physicochemical reactions in the deeper portion of the restorative material.

Discoloration of restorations can result in an unacceptable color change that can be detected by the dental professional and even the patient.[3,19,26]

The color change can be accurately evaluated using the CIE *L*a*b** system, which proved its efficiency in determining minute color changes, in addition to its sensitivity and reproducibility.[3,23,27,28] The CIE Lab system is developed by the Commission of Internationale de l'Eclairage (CIE), where, L* represents lightness and takes a value between 0 (black) and 100 (white). a* represents the saturation on the red-green axis, and b* represents the saturation on the yellow-blue axis. The color difference is calculated as ΔE using these three parameters. Clinically, the acceptable color change or clinically acceptable threshold (AT) was reported to be ≤ 3.3.[7,8, 10,28-32]

It is obvious that the color stability of esthetic restorations is a property of prime importance to guarantee its success in addition to other material properties. Therefore, this in-vitro study aimed to evaluate the color change of three commercially available esthetic monolithic block materials: Vita Suprinity, Lava Ultimate and Vita Enamic after immersion in commonly to consumed beverages namely: coffee, cola compared to distilled water as control. The null hypothesis was that there would be no difference in the color between the tested materials after immersion in the different beverages.

MATERIAL AND METHODS

Specimen preparation

A total of 45 specimens (n= 15 specimens/ group) with dimensions of 14 x12 x 2 mm were cut from CAD/CAM blocks with a water-cooled diamond disk at low speed (150 rpm) in a precision saw machine (Isomet 1000, Buehler, Illinois, USA). Specimens were finished and polished by the same operator using silicon carbide paper in the following sequence: 120-, 240-, 400-, 600-, 800-, and 1,200-grit. Finally, the thickness was checked using a digital caliper (Powerfix Profi1, OWIM Haiger, Germany). During the polishing process, the thickness of the samples was repeatedly evaluated until the final thickness of 2 mm was achieved. [3,16,23,33-35]

Specimens grouping according to immersion beverages

Three subgroups of each material group (n= 5) were tested according to the immersion solutions: coffee (Nescafé classic- Egypt), cola (Pepsi-Cola by Pepsi Bugshan Investment S.A.E., Egypt) and distilled water (Core, Diagnostic Distilled Water, LOT360404) as control. The coffee was prepared by dissolving 20 gm of powder in 1000 ml of boiling distilled water. The solution was stirred every 30 min for 10 s until they cooled down to room temperature, and then filtered.[36,37] Five specimens were stored in

TABLE (1): Materials used in the study

Material	Shade	Chemical Composition (% by weight)	Manufacturer
Vita Suprinity	A2/HT	Lithium silicate reinforced ceramic enriched with ZrO_2 (8% - 12%), SiO_2 (56% - 64%), Li_2O (15% - 21%), K_2O (1% - 4%), P_2O_5 (3% to 8%), Al_2O_3 (1% - 4%) and CeO_2 (0% - 4%)	Vita Zahnfabrik, Bad Säckingen, Germany
Lava Ultimate	A2/HT	80% of nanoceramics (zirconia and silica nanoparticles) components that are embedded in a highly cross-linked polymeric matrix 20%	3M Espe, Seefeld, Germany
Vita Enamic	2M2/HT	Hybrid ceramic with a dual network structure (glass ceramic in a resin interpenetrating matrix). The main feldspathic ceramic network 86% is reinforced with a polymer (UDMA, TEGDMA) 14%	Vita Zahnfabrik, Bad Säckingen, Germany

20 ml of each solution for 2 weeks at 37 °C before being tested. The solutions were stirred once a day to avoid sedimentation of particles and renewed every three days.[5,13,16,35-38]

Color change measurement

Before color measurements, all the ceramic specimens were ultrasonically cleaned in distilled water for 10 minutes and dried under compressed air. The same operator took three measurements without removing the specimen, and the results were averaged. Before all measurements, the spectrophotometer (*Model RM200QC, X-Rite, device S/N: 2010001158 tolerance Type: CIE LAB D65, Neu-Isenburg, Germany*) was calibrated to the manufacturer's recommended standard white point. The specimens were perfectly aligned within the instrument and the aperture size was adjusted at 4 mm. A white background was chosen, and measurements were taken in relation to the CIE standard illuminant D65 according to the CIE L*a*b* color space.[1,4,8,23,25]

Measurements were done for each group before and after immersion in each solution to produce ΔL*, Δa * and Δb* that represent the differences in the respective coordinates. The color changes (ΔE) of the specimens were evaluated using the following formula:

$$\Delta E^{*}_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where: L* = lightness (0-100), a* = (change the color of the axis red/green) and b* = (color variation axis yellow/blue).[3,6,10,13,14,16,26,28,31,39]

Statistical analysis

SPSS 16 ® (Statistical Package for Scientific Studies), Graph pad prism & windows excel were employed to perform statistical analysis. Data exploration for normality was performed using the Shapiro-Wilk test and Kolmogorov-Smirnov test where insignificance was detected as a p-value > 0.05 indicating that the concluded data originated from a normal distribution (parametric data). Comparison between different immersion solutions regarding each material and comparison between different materials regarding each solution was performed by using the One-Way ANOVA test followed by Tukey`s Post Hoc test for multiple comparisons which revealed a significant difference as p-value <0.05.

RESULTS

Color change ΔE results are presented in table (2) and figure (1). Regarding the effect of the different beverages used, results revealed that coffee and cola immersion produced the least color change in Vita Suprinity (0.43±0.2, 1.16±0.3 respectively, P<0.0001). Moreover, coffee immersion resulted in a significantly lower color change in Lava Ultimate (4.13±1.82) compared to Vita Enamic, while cola immersion produced the least color change in the Vita Suprinity group.

The highest color change for beverages was recorded in coffee immersion for the Vita Enamic group (5.35±2.10) and the cola immersion for the Lava Ultimate group (4.11±1.2). Meanwhile, distilled water resulted in the highest color change in the Lava Ultimate group (4.64±2.1) compared to the other two materials. P<0.0001)

Regarding the different esthetic monolithic block materials used in the current study, results revealed that Vita Suprinity and Vita Enamic had significantly different color change (Δ E) values on immersion in either coffee or cola. The Vita Enamic was greatly affected by the coffee that showed the statistically highest color change (Δ E=5.35 ±2.10, p-value <.0001) compared to immersion cola (1.93±0.65). Meanwhile, in the Vita Suprinity group, the highest color change was recorded after cola immersion (1.16±0.3) rather than coffee immersion (0.43±0.2) (p-value <.0001). However, for the Lava Ultimate group no significant difference was recorded between cola and coffee immersion (p=0.79).

TABLE (2): Mean values and standard deviation for the color change results (ΔE) for each material and different subgroups

		Vita Suprinity		Lava Ultimate		Vita Enamic		p-value (Comparison of the three materials in each beverage)
		M	SD	M	SD	M	SD	
Coffee	ΔE	0.43^{Cc}	0.2	4.13^{Ab}	1.82	5.35^{Aa}	2.10	<0.0001*
Cola	ΔE	1.16^{Bc}	0.3	4.11^{Aa}	1.21	1.93^{Bb}	0.65	<0.0001*
Distilled water	ΔE	1.95^{Ab}	0.4	4.64^{Aa}	2.11	1.45^{Bb}	0.68	<0.0001*
p-value (Comparison of each material in the three beverages)		<.0001*		0.79 ns		<.0001*		

Within the same column, significant difference is denoted by different uppercase letters and a p-value of 0.05.

Within the same row, significant difference is denoted by different lowercase letters and a p-value of 0.05.

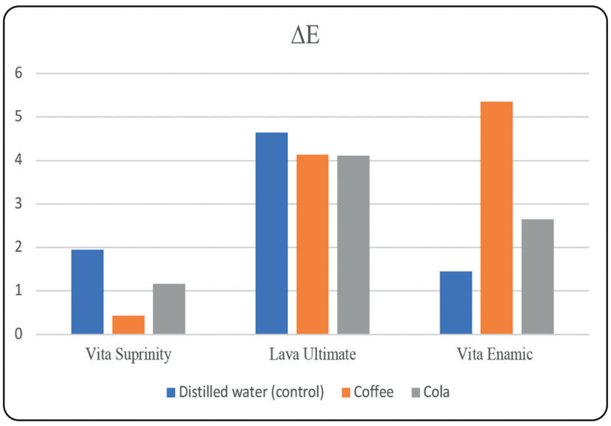

Fig. (1): Color changes ΔE of Vita Suprinity, Lava Ultimate and Vita Enamic after immersion in coffee, cola, and distilled water (control)

DISCUSSION

Resistance of esthetic restorative materials to staining in an oral environment where colored beverages are frequently consumed is an essential property to assure proper service and success of such restorations. Beverages such as coffee and cola are frequently consumed on daily basis and come in contact with dental restorations present in the oral environment which may hamper their color stability.[19] This dictated evaluation of color change of materials used to construct esthetic restorations.

In the current study, specimens prepared from three CAD/CAM esthetic monolithic materials were immersed in coffee, cola, and distilled water as a control for two weeks. This period is equivalent to 14 months of in vivo consumption of these beverages as postulated in previous studies that 24 hours of staining in-vitro corresponds to approximately one month in vivo.[2,4,15,16,19,23,31,37,38] All specimens were polished by the same operator for standardization. Several methods can be used to measure the color change, whereas a spectrophotometer is considered a reliable, reproducible, and accurate color measuring device so it was used in this study.[7,9,19,32] Color change of specimens was measured against a white background as it compensates for chromatic shortage resulting from potential absorption effects on any of the color parameters.[39,40]

Results of this study showed that coffee immersion produced the highest color change in Vita Enamic followed by Lava Ultimate where both values were greater than the acceptable threshold (AT) ≤3.3 for color change[3,7,19,26,29,32,41] while Vita

Suprinity recorded the least color change. This highly significant discoloration of Vita Enamic by coffee is in agreement with several studies and was mainly explained by the compositional and structural configuration of the material.[1,3,4,8,10,13,16,21,37] Vita Enamic is composed of 86wt% ceramic and 14wt% polymer.[10,19,37] The polymer/organic part consisted of 66 wt % hydrophobic urethane dimethacrylate (UDMA), and 33 wt % hydrophilic triethylene glycol dimethacrylate (TEGDMA).[37] This relatively high TEGDMA content in Vita Enamic accentuates water uptake and pigment absorption due to its hydrophilicity.[10] Although UDMA is more hydrophobic and therefore more color stable, the formed cross-linked networks entrap unreacted monomers which act as plasticizers forming an open structure thus facilitating additional water sorption accompanied by pigmentation.[1,3,14,19,21,28,29] Coffee contains yellow stains/colorants and brown macromolecular compounds of low polarity thus capable of penetrating deeper into the polymer network and possesses pH ranging from 4-6.[3,10,31,37] The dominant ceramic network has leucite as the major phase and zirconia as a minor crystalline phase.[11] The mild acidity of the solution could lead to degradation of the ceramic by loss of alkaline ions and dissolution of silica, especially on the surface[2,24] which may result in roughness adding to discoloration.[10,42] In addition, Della Bona et al. 2014 observed a few microcracks in the network boundaries of Vita Enamic[11] that deflect at the polymer ceramic interface which may have resulted from the cutting of the blocks.[22] These cracks may become filled with colorant pigments despite the hydrophobicity of ceramic. In addition, a study revealed that the weak polymer matrix could be easily separated from the ceramic network of hybrid ceramics resulting in surface roughness that can accumulate stains adversely affecting optical properties.[10] However, several studies revealed that discoloration of hybrid ceramic (Vita Enamic) by coffee is less than Lava Ultimate and could lie within the AT which disagrees with our findings.[19,43]

Results also revealed that cola produced less discoloration in Vita Enamic than coffee which was below the AT.[19,37] The same was detected for distilled water immersion (control).[37] This could be attributed to the more polar dye of cola compared to the less polar yellow colorant of the coffee, thus hindering penetration of caramel dye present in cola into the polymer part of Vita Enamic. It has been postulated that cola discoloration of Vita Enamic was extrinsic in nature as more polar dyes tend to be adsorbed on the surface only and therefore, it could be easily removed by rinsing and wiping.[19] Some studies postulated that the resinous content of Vita Enamic had more tendency for discoloration and staining in a mildly acidic medium compared to a higher one which further accounted for the higher discoloration effect of coffee compared to cola.[31,37] Moreover, Marco Colombo et al. confirmed the high resistance of zirconia-reinforced ceramics to discoloration by acidic drinks.[4]

Nanoceramic resin composite CAD/CAM block material, Lava Ultimate, was polymerized industrially at high temperatures and pressures to ensure optimal properties and present higher surface energy than other materials. It was ranked second following Vita Enamic regarding discoloration by coffee which was also more than the AT (4.13 ±1.82) in agreement with Jorquera et al.[43] Lava Ultimate consists of nanoceramic components embedded in a highly cross-linked polymer matrix. Previously, it was found that the high polymer content implied high water sorption where more than 90% occurred in the first week.[14,44,45] Thus, water uptake may have facilitated discoloration due to immersion in coffee by low polarity yellow dye molecules attracted to the polymer network, especially at the OH- groups leading to intrinsic and extrinsic discoloration through adsorption of colorants on the surface and the subsurface.[13,14,42] Moreover, previous studies reported that the hydroxyl groups within Bis-GMA increase viscosity and are responsible for color change.[7,25,43] At the same time, the addition of hydrophilic TEGDMA to the polymeric matrix leads to increased water absorption allowing the ingress of colorants into the resin matrix. However, the presence of UDMA in high percent could have reduced the sorption and the accompanying color change which may explain its lower value compared to Vita Enamic.[7,13,23,37] This finding is in disagreement with Stamenkovic et al. who found no difference in color change between nanoceramic resin and hybrid ceramic after immersion in coffee and Liebermann et al. who found that the color change of Lava Ultimate was greater than Vita Enamic. In addition, Eldwakhly et al. stated that coffee discoloration of Lava Ultimate was within the AT. [13,14,37]

Moreover, our results showed that Lava Ultimate possessed color change beyond the AT after immersion in cola and distilled water, which was also in disagreement with Eldwakhly et al. who explained their finding by the lower tendency for discoloration of resins in a highly acidic medium.[37] On the contrary, Shetty et al. stated that coffee exhibited higher pH than coca cola thus less staining compared to cola. They explained that cola beverages had low pH that could adversely affect the surface integrity leading to softening of the matrix and loss of structural ions such as calcium, aluminum, and silicone from the glass filler phase. In addition, the composite resin restorative materials may exhibit higher water sorption in acidic media thus facilitating the staining of the composite resins.[42] Sara et al. emphasized that color change could be also attributed to the roughness of the specimens caused by the low pH (2.62) of cola solution leading to adsorption of the caramel color present in cola on the resin surface.[19] When the composite resin is exposed to a low pH environment, the inorganic fillers tend to fall out from the resin material and the matrix components decompose.[21,46] Generally, water contributes to the color change of composite materials in several ways. Water sorption induced by hydrophilic resinous components as mentioned before could lead to discrepancies in the refractive index of the different components within the organic matrix.[13,19] Moreover, the absorbed water could hydrolyze the interfacial silane coupling agent leading to filler debonding or causing swelling of the resin matrix. The introduced radial tensile stresses at the filler interfaces, strained the Si-O-Si bonds. Thus the fillers become more susceptible to stress corrosion attack and eventually complete or partial filler debonding consequently producing cracks at the resin–filler interface where colorants may penetrate the cracks and cause color changes.[16,21,46,47]

The zirconia nanofiller component accentuated the problem as they cannot be effectively silanized due to their high crystallinity.[16,48] In addition, zirconia was shown to exhibit progressive phase transformation in contact with water known as low-temperature degradation (LTD). Transforming from the tetragonal to monolithic phase (T-M transformation), induced roughness of the surface, particle displacement and water penetration into the matrix thus adding to water sorption and hence the color change of the material.[18,37] Several studies agreed with our results emphasizing that Lava Ultimate depicted a higher color change in comparison to ceramics.[6,14,25,43]

Regarding Vita Suprinity, zirconia enriched lithium silicate reinforced glass ceramic, results showed that this material exhibited the least color change below the clinically accepted value when immersed in coffee, cola or distilled water, which was in agreement with several studies.[1,14,24,45] This can be attributed to the hydrophobicity of ceramic structures that may not undergo any water absorption thus no dye molecules can penetrate the surface implying high color stability of the dense microstructure formed of crystalline mineral and glass matrix.[10,14,21,24,45] Coffee produced the least color change in Vita Suprinity followed by cola which resulted in significantly higher discoloration, but both were below the AT. This was in disagreement with Demirkol and Ozen who found that coffee and cola adversely affected ceramic color where discoloration was above the clinically acceptable level.[25] The findings of the present study can be attributed to the weak erosive effect of cola on dental materials especially ceramics due to the phosphate ion content of cola that may hinder the surface breakdown according to several studies.[17,37,38,49] Generally, discoloration of dental ceramics is extrinsic that could be almost totally removed by polishing.[10,21] However, distilled water produced higher color change than coffee and cola which can be attributed to the surface roughness caused by LTD of zirconia as explained previously. However, according to the presented results the null hypothesis was rejected as there was a difference in the color between the tested materials after immersion in the different beverages.

CONCLUSION

According to the limits of the present study, the following conclusions could be inferred:

1. Coffee is a potential staining beverage that may adversely affect the color of esthetic restorations based on their microstructure and compositional variation.
2. Cola can induce unacceptable color change in resin-containing materials but with less staining effect compared to coffee.
3. Vita Suprinity can be considered the most color stable material compared to Vita Enamic and Lava Ultimate due to its dense highly stable ceramic structure.
4. Vita Enamic exhibited high discoloration exceeding the clinically acceptable threshold after coffee immersion. Coffee drinkers could be advised to follow meticulous oral hygiene measures and frequent clinical visits for polishing the restoration.
5. Lava Ultimate has undergone extensive discoloration on immersion in coffee, cola and distilled water which may highlight questionability of its esthetic application and the need for further investigations of the combined effects of different factors affecting its color change.

Limitations

In vitro study imposes a serious limitation of imitating the intra-oral conditions as saliva effect on restorative materials, intra-oral hygiene measures and combined effect of different consumed beverages.

In addition, clinically, only the external surface of the restoration is exposed to the oral environment while the inner one is bonded which makes the color change values recorded in vitro higher than those occurring in vivo indicating false more discoloration.

Recommendation

Further studies are advised to detect the effect of saliva on color change of different CAD/CAM monolithic esthetic restorative materials to mimic the in vivo situation. Evaluation of the effect of the bonding cement on the CAD/CAM monolithic esthetic restorations cut in different thicknesses is recommended. In addition, the effect of different polishing protocols on color change of the tested materials needs further investigation.

REFERENCES

1. Aydın, N., Karaoğlanoğlu, S., Oktay, E. A. & Kılıçarslan, M. A. Investigating the color changes on resin-based CAD/CAM Blocks. J. Esthet. Restor. Dent. 32, 251–256 (2020).
2. Al-Angari, S. S. et al. The effect of coffee and whitening systems on surface roughness and gloss of CAD/CAM lithium disilicate glass ceramics. J. Appl. Biomater. Funct. Mater. 19, (2021).
3. Saba, D. A., Salama, R. A. & Haridy, R. Effect of different beverages on the color stability and microhardness of CAD/CAM hybrid versus feldspathic ceramic blocks: An in-vitro study. Futur. Dent. J. 3, 61–66 (2017).
4. Colombo, M. et al. Color stability of CAD/CAM Zirconia ceramics following exposure to acidic and staining drinks. J. Clin. Exp. Dent. 9, e1297–e1303 (2017).

5. Alp, G., Subasi, M. G., Johnston, W. M. & Yilmaz, B. Effect of surface treatments and coffee thermocycling on the color and translucency of CAD-CAM monolithic glass-ceramic. J. Prosthet. Dent. 120, 263–268 (2018).
6. Gürdal, I. et al. Color change of CAD-CAM materials and composite resin cements after thermocycling. J. Prosthet. Dent. 120, (2018).
7. Mansour, C. H., Kheiralla, L. S. & Ghanem, L. A. Color Stability and Surface Roughness of CAD/CAM Ceramill Composite and Cerasmart Endocrowns. IOSR J. Dent. Med. Sci. 17, 13–24 (2018).
8. Sarıkaya, I. & Hayran, Y. Effects of Polishing on Color Stability and Surface Roughness of CAD-CAM Ceramics. Meandros Med. Dent. J. 19, 153–159 (2018).
9. Çakmak, G., Donmez, M. B., Kashkari, A., Johnston, W. M. & Yilmaz, B. Effect of thickness, cement shade, and coffee thermocycling on the optical properties of zirconia reinforced lithium silicate ceramic. J. Esthet. Restor. Dent. 33, 1132–1138 (2021).
10. Jalali, H., Mostafavi, A. S. & Balaghi, F. The Effect of Coloring Beverages on Color Stability of Hybrid Ceramics with Different Surface Treatments. Pesqui. Bras. Odontopediatria Clin. Integr. 22, 1–11 (2022).
11. Della Bona, A., Corazza, P. H. & Zhang, Y. Characterization of a polymer-infiltrated ceramic-network material. Dent. Mater. 30, 564–569 (2014).
12. Ruse, N. D. & Sadoun, M. J. Resin-composite blocks for dental CAD/CAM applications. J. Dent. Res. 93, 1232–1234 (2014).
13. Stamenković, D. D. et al. Staining and aging-dependent changes in color of CAD-CAM materials. J. Prosthet. Dent. 126, 672–678 (2021).
14. Liebermann, A., Vehling, D., Eichberger, M. & Stawarczyk, B. Impact of storage media and temperature on color stability of tooth-colored CAD/CAM materials for final restorations. J. Appl. Biomater. Funct. Mater. 17, 1–7 (2019).
15. M. Salah El Din, M., Tawfik, A. & Wahsh, M. Effect of Different Storage Media on the Surface Roughness of two CAD/CAM Materials. Ain Shams Dent. J. 21, 1–11 (2021).
16. Lauvahutanon, S. et al. Discoloration of various CAD/CAM blocks after immersion in coffee. Restor. Dent. Endod. 42, 9 (2017).
17. Seyidaliyeva, A. et al. Color stability of polymer-infiltrated-ceramics compared with lithium disilicate ceramics and composite. J. Esthet. Restor. Dent. 32, 43–50 (2020).
18. Wendler, M. et al. Mechanical degradation of contemporary CAD/CAM resin composite materials after water ageing. Dent. Mater. 37, 1156–1167 (2021).
19. Sara H. Younis, R. H. A. and M. A. Effect of Different Immersion Solutions on Color Stability of One Bulk-Fill Resin Composite and Two Types of CAD/CAM Ceramics. Egypt. Dent. J. 66, 1657–1665 (2020).
20. Özarslan, M. M. et al. Assessing staining resistance of a CAD/CAM interpenetrating network composite material. Head Face Med. 14, 1–7 (2018).
21. Al Amri, M. D. et al. In Vitro Evaluation of Translucency and Color Stability of CAD/CAM Polymer-Infiltrated Ceramic Materials after Accelerated Aging. J. Prosthodont. 30, 318–328 (2021).
22. Coldea, A., Swain, M. V. & Thiel, N. Mechanical properties of polymer-infiltrated-ceramic-network materials. Dent. Mater. 29, 419–426 (2013).
23. Sherif, R. an in Vitro Study To Evaluate the Color Stability of Four Different Cad/Cam Ceramics. Egypt. Dent. J. 63, 2721–2735 (2017).
24. Sağlam, G. & Cengiz, S. The Evaluation of the Effect of Coffee Staining and 16% Carbamide Peroxide Bleaching on the Color Change of Chairside CAD/CAM Ceramics Gaye. J Dent Mater Tech 10, 198–205 (2021).
25. Demirkol, N. & Ozen, F. Color stability of CAD/CAM materials with colored beverages thermocycling. Ann. Med. Res. 26, 1721 (2019).
26. Poggio, C. et al. Color Stability of New Esthetic Restorative Materials: A Spectrophotometric Analysis. J. Funct. Biomater. 8, 26 (2017).
27. Mundim, F. M., Garcia, L. da F. R. & Pires-de-Souza, F. de C. P. Effect of staining solutions and repolishing on color stability of direct composites. J. Appl. Oral Sci. 18, 249–254 (2010).
28. Al-Samadani, K. H. Color stability of restorative materials in response to Arabic coffee, Turkish coffee and Nescafe. J. Contemp. Dent. Pract. 14, 681–690 (2013).
29. Mostafa, D. H., Abdel Hamid, D. M. & Esawi, A. K. the Effect of Filler Size, Storage Media and Brushing on the Surface Durability of Resin Modified Glass Ionomer.

Egypt. Dent. J. 56, 1–15 (2010).

30. Paravina, R. D. et al. Color difference thresholds in dentistry. J. Esthet. Restor. Dent. 27, S1–S9 (2015).

31. Jivănescu, A., Răzvan, R., Gogu, L. & Nica, L. M. Color stability of CAD / CAM hybrid versus leucite -reinforced ceramic blocks : an in vitro study . Med. Evol. XXIV (3), 246–251 (2018).

32. Sokkary, A. El, Elguindy, J. & Shihi, O. El. Effect of Surface Finish and Acidic pH Media on the Surface Roughness and the Color Stability of Zirconium Reinforced Lithium Silicate Glass Ceramics (An In-Vitro Study). Acta Sci. Dent. Sci. 2, 21–27 (2018).

33. Pop-Ciutrila, I. S. et al. Shade correspondence, color, and translucency differences between human dentine and a CAD/CAM hybrid ceramic system. J. Esthet. Restor. Dent. 28, S46–S55 (2016).

34. Gunal, B. & Ulusoy, M. M. Optical properties of contemporary monolithic CAD-CAM restorative materials at different thicknesses. J. Esthet. Restor. Dent. 30, 434–441 (2018).

35. Haralur, S. B., Alqahtani, N. R. S. & Mujayri, F. A. Effect of hydrothermal aging and beverages on color stability of lithium disilicate and zirconia based ceramics. Med. 55, 4–11 (2019).

36. Abdel Hamid, D. M. & El-Sharkawy, F. Color Stability of Acetal Resin Tooth-Colored Clasp Materials Against Various Staining Beverages. Egypt. Dent. J. 59, 2429–2439 (2015).

37. Eldwakhly, E., Ahmed, D. R. M., Soliman, M., Abbas, M. M. & Badrawy, W. Color and translucency stability of novel restorative CAD/CAM materials. Dent. Med. Probl. 56, 349–356 (2019).

38. Elsaka, S., Taibah, S. & Elnaghy, A. Effect of staining beverages and bleaching on optical properties of a CAD/CAM nanohybrid and nanoceramic restorative material. BMC Oral Health 22, 1–9 (2022).

39. Pedrosa, M. da S., Nogueira, F. N., Baldo, V. de O. & Medeiros, I. S. Changes in color and contrast ratio of resin composites after curing and storage in water. Saudi Dent. J. 33, 1160–1165 (2021).

40. Fontes, S. T., Fernández, M. R., de Moura, C. M. & Meireles, S. S. Color stability of a nanofill composite: Effect of different immersion media. J. Appl. Oral Sci. 17, 388–391 (2009).

41. Sarikaya, I., Yerliyurt, K. & Hayran, Y. Effect of surface finishing on the colour stability and translucency of dental ceramics. BMC Oral Health 18, 1–8 (2018).

42. Shetty, P., Purayil, T. P., Ginjupalli, K. & Pentapati, K. C. Effect of polishing technique and immersion in beverages on color stability of nanoceramic composites. J. Oral Biol. Craniofacial Res. 11, 53–56 (2021).

43. Jorquera, G. et al. Hybrid Ceramics in Dentistry: A Literature Review. J. Clin. Res. Dent. 1, 1–5 (2018).

44. Biradar, B., Biradar, S. & MS, A. Evaluation of the Effect of Water on Three Different Light Cured Composite Restorative Materials Stored in Water: An In Vitro Study. Int. J. Dent. 2012, 1–5 (2012).

45. Dellazzana, F. Z., Rodrigues, C. S., Mallmann, A. & Jacques, L. B. Optical Properties of a Glass Ceramic and an Indirect Resin Composite: Effects of Polishing and Staining. J. Heal. Sci. 21, 512–517 (2019).

46. Sayed, A., Niazy, M. & Motawee, I. Effect of Food Simulating Liquids and Thermo-cycling on flexural strength and surface hardness of a Resin Nano-Ceramic CAD/CAM Material. Al-Azhar Dent. J. Girls 3, 125–133 (2016).

47. Sonmez, N. et al. Evaluation of five CAD/CAM materials by microstructural characterization and mechanical tests: A comparative in vitro study. BMC Oral Health 18, 1–13 (2018).

48. Horvath, S. D. Key Parameters of Hybrid Materials for CAD/CAM-Based Restorative Dentistry. Compend. Contin. Educ. Dent. 37, 638–643 (2016).

49. Aliping-Mckenzie, M., Linden, R. W. A. & Nicholson, J. W. The effect of Coca-Cola and fruit juices on the surface hardness of glass-ionomers and ‘compomers’. J. Oral Rehabil. 31, 1046–1052 (2004).