EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 2451:2459, July, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 26-02-2024 • Accept Date : 26-03-2024 • Available online: 10-07-2024 • DOI : 10.21608/EDJ.2024.272943.2957

# EFFECT OF COMMONLY CONSUMED BEVERAGES ON COLOR STABILITY OF HYBRID CERAMICS: AN IN VITRO STUDY

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## ABSTRACT

**Background**: In everyday life, many different beverages and meals are ingested in varied amounts, acidity and colors. Each beverage has distinct influence on the oral cavity structures including the color stability of esthetic dental restorations.

**Objective**: The current study aims to assess the color change of polymer infiltrated ceramic (Vita Enamic) after being immersed in different types of beverages, like coffee, tea and cola in comparison to distilled water as control over a 28-day test period which equals to 28 months of beverages' consumption.

**Materials and methods**: A total of 40 specimens were sliced from Vita Enamic blocks as each slice measures about 0.5 mm thick. Four groups were tested based on the immersion solutions. All samples were thermocycled at 15000 cycles between 5 and 55 degrees then samples were kept in 20 ml of each solution (Water, coffee, tea and cola) for at 37 °C for 28 days for each group. The color parameters (L-a-b) of the specimens were recorded before immersion and at the end of the $7^{th}$ (D1), $14^{th}$ (D2), $21^{st}$ (D3) and $28^{th}$ (D4) days after immersion. Color measurements were statistically analyzed with a significance threshold of $P<0.05$.

**Results**: There was significant difference between four groups where ($p<0.001$). The differences in the color change ($\Delta E$) after staining from the highest to the lowest through all storage periods were as follows: tea > coffee > cola > water.

**Conclusion:** Regarding the limitations of the present study, commonly consumed staining beverages influenced the color stability of the polymer infiltrated ceramics. Tea and coffee beverages produced the greatest color change beyond the acceptance range.


**KEYWORDS**: Ceramics, Hybrid, Color stability, Beverages, Spectrophotometer.

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## INTRODUCTION

Successful esthetic restoration requires knowledge of the optical characteristics of restorative material. The problem of matching the color of natural teeth and gaining color stability and minimum color change is critical factor for restoration success [1].

In 2012 hybrid ceramics or polymer infiltrated ceramics started to make its entry into the world of computer aided design / computer aided manufacturing (CAD/CAM) trying to compromise between the supreme mechanical and physical properties of ceramics and the resilience, case of reparability and maintenance of resin composite. It's worth mentioning that these materials require no further heat treatment after the milling process, thus speeding the delivery process which serves one of the purposes of CAD/CAM technology [2].

In 2013 the appearance of hybrid machinable ceramic made it to the market of dentistry which is VITA Enamic resin infiltrated hybrid ceramic. The resin infiltrated ceramic according to microstructure seems to be the total opposite of the LAVA Ultimate nano-ceramic, having the matrix being the ceramic and the resin infiltrated to reinforce it[3] .

Vita Enamic has been reported to yield mechanical properties between porcelains and resin-based composites which reflects its microstructural components. Such a property makes it a good candidate for inlays, onlays, laminate veneers, crowns and implant superstructures. Its resilience provided improved edge stability after the milling process. Also manufacturers' recommendations for amount of reduction is much more conservative than the other machinable ceramics, Vita Enamic has shown significantly fastest machining of all one-step materials and shows least opposing enamel abrasion of all ceramics apart from zirconium dioxide [4].

The ability of the ceramic restorations to withstand discoloration over time is critical to its performance and durability of these restorations, particularly in hostile oral environments [5]. The commonly consumed drinks, such as cola and coffee sometimes include colorants or have an acidic pH, which may harm esthetic restorations and cause discoloration [6, 7].

In everyday life, many different drinks and meals are ingested in varied amounts, colors, temperatures, and compositions. Each drink and meal have a distinct influence on the structures that are present in the oral cavity [8]. Beverages consumed by the population have shown a variation of their influence on the color stability of esthetic dental restorations leading to perceptible color changes. These beverages have come to increase the complexity of the oral environment, producing a continuous alteration within the ph value, and are accompanied by colorants and staining pigments like coffee, tea and cola [9].

The color shift may be precisely evaluated using the Commission Internationale de l'Eclairage (CIE) L*a*b* system, which has shown its effectiveness in identifying tiny color changes, as well as its sensitivity and repeatability[10]. L* represents the color-opponent dimensions of lightness. a* represents the color-opponent dimensions of redness–greenness range whereas b* represents the color-opponent dimensions of blueness–yellowness range. The color change was measured as $\Delta E$ using these three parameters. Studies imply that color change in restorative materials should be $\Delta E > 1$ to be visually visible, and $\Delta E > 3.3$ is regarded an undesirable number for clinical effectiveness of the restoration [11].

It is evident that color stability is a critical quality for esthetic restorations to ensure their success. As a result of the contradiction between researches in the effect of different beverages on the ceramic restorations, this research aims to evaluate the color change of Vita Enamic after aging and soaking in commonly consumed beverage which are coffee, tea and cola solutions in comparison to artificial saliva as control. The null hypothesis suggested that the color of the tested materials would not differ after being immersed in different types of beverages.

## MATERIAL AND METHODS

### - Specimen's preparation

Forty slices of Vita Enamic and with dimensions (14mm x 12mm x 0.5mm) of Vita Enamic block (VITA Zahnfabrik, Bad Säckingen, Germany) were cut by Isomet 4000 with precesion cut micro-saw 4 (Fig.1) at 2500 rpm cutting speed using a diamond disc 0.5mm thickness under a cooling system (water: anti-corrosive agent) in a ratio of 30:1. All slices were measured using a digital caliper (Fig.2) by the same operator to standardize the dimensions of all slices [12]. One surface only was polished by low-speed handpiece with instruments of the VITA Polishing kits (VITA Zahnfabrik) at first using diamond-coated instruments at a speed of 7,000 rpm for 15 seconds in vertical and horizontal motion all over the surface using a water coolant spray to reduce the generation of heat during polishing [13].

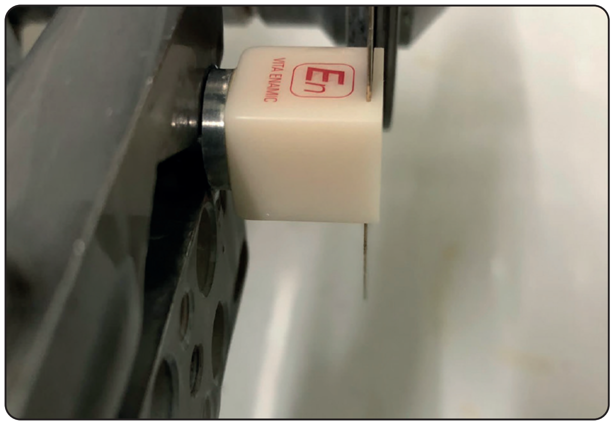


Fig. (1) Sectioning of Vita Enamic block by Isomet Device


Fig. (2) Sample thickness verification by digital caliper

### - Color measurement

All samples were measured for color stability and translucency using a Vita Easyshade V spectrophotometer device (VITA Zahnfabrik). Calibration of the spectrophotometer was done in the calibration slot based on the manufacturer`s instructions to ensure accuracy of every measurement. The Vita Easyshade spectrophotometer aperture was centralized on the center of each sample and given the order to measure its CIE L* a* and b* under neutral grey background for all subgroups samples A &B (Fig. 3). Three measurements for each coordinate for each sample and their average was recorded [14].

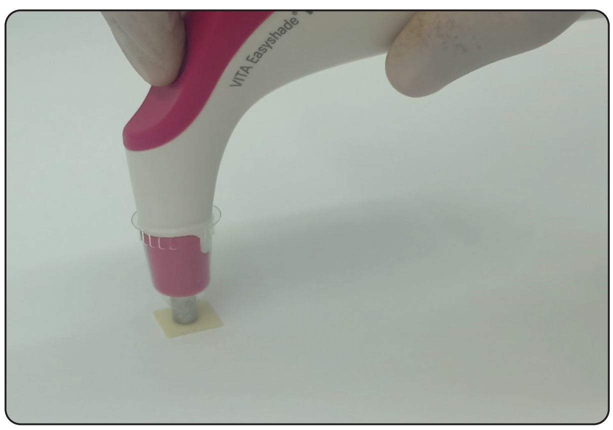


Fig. (3) Color parameters measurement over neutral grey background

**- Thermocycling and staining process**

The samples were subjected to 15000 cycles of thermocycling in deionized water, between 5 - 55 degrees with 30 sec dwell time in THE-100 SD Mechanotronic thermocycle for replicating the oral environment as an extrinsic factor [15]. The specimens were divided randomly using web site (www.RANDOM.ORG) into four different groups (10 each) based on the type of solution that they will be immersed in.

**- Immersion solution preparation**

***For group A (distilled water),*** Samples were kept in 200 mL of distilled water (control medium) in an incubator temperature 37°C for 28 days [16]. ***In group B (cola),*** A about 1 ml of Coca-cola was distributed in to 10 glass containers using plastic syringe and samples were immersed in these firmly closed containers [17]. ***In group C (Instant coffee),*** the instant coffee solution was prepared by dissolving 1.8 gram of coffee in 150 ml of hot water [14]. The samples were stored in firmly closed containers at 37˚C (Figure 4). ***In group D (tea),*** Tea solution was prepared via soaking three pre-fabricated teabags in 200 ml of boiling water for about 5 min [17]. The samples were stored in firmly closed containers in an incubator temperature of 37°C. All Tested solutions were changed every day. Samples were then washed under running water for ten seconds then dried using sterile cotton [17]. The color was measured after 7, 14, 21 and 28 days.

Fig. 4: Samples immersed in coffee solution inside incubator

Color evaluation was repeated at the end of immersion period in different storage media to assess the color change or stability by the equation:

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

L* for the color-opponent dimensions of lightness

a* for the color-opponent dimensions of redness–greenness

b* for the color-opponent dimensions of blueness–yellowness

**Statistical analysis of the data**

IBM SPSS software version 20.0 was utilized to perform statistical analysis of the obtained data. (IBM Corp, Armonk, NY). Collected data was explored for normality using Shapiro-Wilk and Kolmogorov Smirnov tests. One way ANOVA test was used to compare the four studied groups followed by Tukey's Post Hoc test for pairwise comparison. For comparisons involving more than two periods, an ANOVA with repeated measurements was employed, and for pairwise comparisons, the modified Bonferroni Post Hoc Test was utilized. The significance level was judged at the 5% level. Furthermore, the color difference of the Vita Enamic after immersion in different beverages through the four storage periods is illustrated in (Fig 5,6)

**RESULTS**

Quantitative data were presented as mean, standard deviation for normally distributed quantitative variables are listed in Table 1. Furthermore, the color difference of the Vita Enamic after kept in different beverages through the four storage periods is illustrated in (Fig 5,6).

TABLE (1) Comparison between ΔE after different beverage immersion according through four periods of storage (n=10/ each)

| Duration \ BEV | Water | Cola | Coffee | Tea | $F_2$ | $p_2$ |
|---|---|---|---|---|---|---|
| D1 | $0.55^{cD} \pm 0.12$ | $1.19^{dC} \pm 0.24$ | $2.51^{cB} \pm 0.56$ | $3.52^{dA} \pm 0.73$ | 76.909* | <0.001* |
| D2 | $0.64^{bD} \pm 0.11$ | $1.70^{cC} \pm 0.25$ | $3.36^{bB} \pm 0.54$ | $4.68^{cA} \pm 0.78$ | 130.996* | <0.001* |
| D3 | $0.72^{aD} \pm 0.12$ | $2.32^{bC} \pm 0.27$ | $3.50^{bB} \pm 0.66$ | $6.13^{bA} \pm 0.97$ | 141.359* | <0.001* |
| D4 | $0.78^{aD} \pm 0.11$ | $3.15^{aC} \pm 0.28$ | $5.73^{aB} \pm 0.99$ | $8.06^{aA} \pm 1.04$ | 183.890* | <0.001* |
| $F_1$ | 58.134* | 245.183* | 122.259* | 86.834* | | |
| $p_1$ | <0.001* | <0.001* | <0.001* | <0.001* | | |

***Data was presented as Mean ± SD.*** ***F1: F test (ANOVA) with repeated measures***
***F2: F for One way ANOVA test*** ***p1: p value to compare between the four studied periods in each group***
***p2: p value to compare between the four studied groups in each period*** ****: Statistical significance at p ≤ 0.05***
***Means in the same Column with any Small Common letter (a-d) are not significant (OR Means with totally Different letters (a-d) are significant)***
***Means in the same Row with any Capital Common letter (A-D) are not significant (OR Means with totally Different letters (A-D) are significant)***

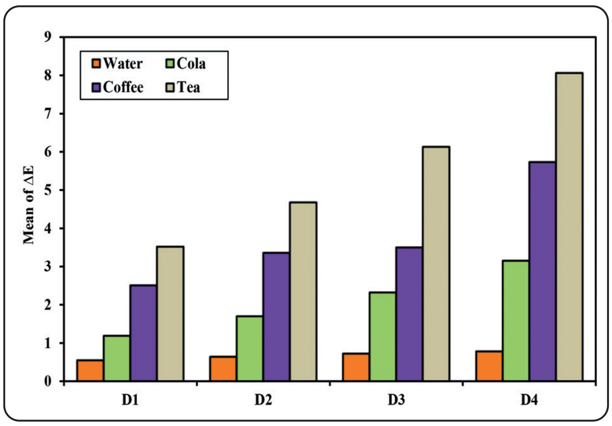


Fig. (5) Comparison between ΔE of Vita Enamic after immersion in different solutions through four periods of storage

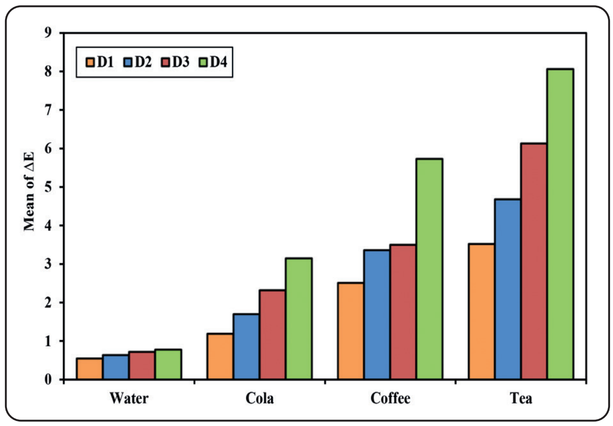


Fig. (6) Comparison between ΔE of Vita Enamic after immersion in different solutions through four periods of storage

The highest color difference (8.06±1.04) in the tea group, which was stored for 28 days. The differences in the color change (ΔE) after staining from the highest to the lowest in all storage periods were as follows: tea > coffee > cola > water. Vita Enamic revealed significant color change after staining in tea, coffee, cola and water through all storage periods (7, 14, 21, and 28 days) (p<0.001). The intra-group comparison of ΔE between storage periods revealed significant difference (p<0.001) in all groups except between D3 and D4 in water group and between D2 and D3 in coffee group.

Color change of Vita Enamic in water group in all storage periods is unperceivable to the naked eye (ΔE<1). Color change in cola group in all storage periods and in $D_1$ in coffee group is in acceptability range (1< DE< 3.3). Color change in D2, D3 and D4 in coffee group and in all storage periods in tea group is beyond the acceptability range (DE> 3.3).

## DISCUSSION

Over the past decade, rapid advancements in CAD/CAM materials have demonstrated their efficacy, necessitating thorough investigation of their optical behavior to meet patients' high aesthetic expectations. Gaining color stability and minimum color change is crucial factor for patient satisfaction and restoration success [1,18,19].

In this study, all specimens were sliced with the Isomet 4000. To guarantee a standardized thickness for all samples as saws reduce specimen deformation and kerf loss during cutting materials, preventing any potential optical changes caused by changes in thickness [20, 21].

The use of rectangular samples instead of discs is used to ensure better light reflectance and eliminate factors affecting color parameter evaluations, such as surface curvature or natural tooth discoloration, at the same distance and level from the sample surface [22].

The thickness of 0.5 mm was chosen to mimic the restoration thickness for better results in color changes. The thickness of all specimens was confirmed by the assistance of digital caliper to ensure standardization [23].

Based on the protocol followed by Ertas et al [24], the total time of immersion in beverages solutions was 28 days which equals to 28 months of beverages' consumption. Then samples were maintained at 37°C in an incubator In order to replicate the oral cavity temperature and avoid any temperature fluctuations that might affect the staining potency of the solutions [25, 26].

The utilization of the Vita Easyshade spectrophotometer in our study to obtain the CIELAB coordinates is frequently employed in dental research field [27], accordingly it was used in our study to obtain the DE for the specimens. One study proving the accuracy of Easyshade spectrophotometer was done by Kenovic et al [25] who evaluated the intra-device accuracy and repeatability of dental shade-matching device using both in vitro and in vivo models. They concluded that the precision of the device tested was 93.75% and that VITA Easyshade V dental shade-matching device gave dependable and precious measurement.

In the present study, the color changes in coffee and tea were found to be more intense than those in cola and distilled water after immersion [19, 28]. The greater staining power of tea and coffee could be attributed to the yellow pigments' capacity to permeate the porous ceramic structure of these substances, which is penetrated by a polymer. Water and pigments from severely stained chromogenic food are reported to be absorbed by the polymer. Studies show that color absorption in polymer-infiltrated ceramics is caused by the hydrophilic nature of the TEGDEMA component [9,19, 29]. Tea and coffee have different tannin content, with tea containing more tannins, which enhance the binding capacity of chromogens to material surfaces, promoting staining [30]. Both the coffee and tea solutions' low polarity can cause color changes by enabling pigments to penetrate the resin matrix more deeply [19, 20]. It has been reported that solutions with a pH between 4 and 6 are more likely to contaminate resin compounds [31]. Whereas coffee comprises roughly 22 different types of acids, most of which are high molecular weight acids like acetic, citric, and malic acid. Also tea contains different types of acids such as citric, malic, and oxalic acids so it enables us to understand the justification of the high capability of staining of polymer infiltrated ceramic restorations [30]. Furthermore, cola drinks have higher acidity (pH value of cola drinks about 2.7) which can result in filler particle surface erosion and resin matrix degradation[8]. It has also been demonstrated that cola drinks are more titrable acidic than other popularly used acidic beverages and it contributes to fastening of saliva neutralization and causing less staining effect on teeth restoration [19, 32, 33]. In addition, Cola drinks have high polarity which diminished their absorption effect and decreased their ability to adhere or stick to the teeth surface when washed and be more easily removed with washing. Also, the presence pf phosphate ions in cola drinks appeared to have comparable effects on teeth surfaces [19, 34].

In the present study, color change after the four storage periods was the highest in tea group (DE = 8.06 ± 1.04) followed by the coffee group change (DE = 5.73 ± 0.99) and color change in both groups were beyond the acceptability range (DE> 3.3). In contrast, color change in cola group (DE =3.15 ± 0.28) was in the acceptability range (1< DE< 3.3). These findings agree with that of Eldwakhly et al [19] who studied the influence of various staining solutions (coffee, cola, ginger, and water) on color stability of five ceramic materials including polymer infiltrated ceramic and they verified that the highest color difference of polymer infiltrated ceramics was caused with coffee immersion. In addition, this result is in harmony with the study performed by Saba et al [35] who studied the effect of various staining solutions (water, red wine and coffee) on color stability of hybrid ceramic after 28 days and they found high color change for Vita Enamic ($\Delta E = 4.9$) after coffee solution immersion. Also in agreement to the finding of Stamenković et al [36] who studied the influence of artificial aging as well as staining solutions (coffee and wine) on color stability of five ceramic materials including polymer infiltrated ceramics and they found high color change after artificial aging and immersion of Vita Enamic samples in coffee solution for 120 hours ($\Delta E = 3.9$). And finally in accordance with that of Yerliyurt et al [37] who studied the effect of artificial aging of polymer infiltrated ceramics and immersion in different beverages combinations including water, cola, coffee and tea. They found significant color changes after immersion of Vita Enamic specimens in coffee-tea beverage ($\Delta E = 12.68$) followed by coffee ($\Delta E = 7.63$) followed by coffee-coke beverage ($\Delta E = 3.09$). So, the null hypothesis of this study was rejected due to storage with various combinations of water, tea, coffee, and cola had a significant effect on color change of polymer infiltrated ceramics.

## CONCLUSION

Regarding the limitations of the current study, the commonly consumed staining beverages influenced the color stability of the polymer infiltrated ceramics. Tea and coffee beverages had the greatest color change beyond the acceptance range.

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