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COLOR CHANGES OF DIFFERENT CAD/CAM CERAMIC BLOCKS AFTER IMMERSION IN USUAL BEVERAGES

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ABSTRACT: The objective of this study was to verify the color stability after immersion of leucitic, feldspathic, and disilicate ceramic blocks, which are used for chairside CAD/CAM restorations, in frequently used beverages. A total of 48 ceramic discs were made from leucitic, feldspathic, and lithium disilicate ceramic blocks. The discs were divided into four subgroups and immersed in different solutions for 4 weeks: distilled water for control, green tea, coffee, and red wine. A dental spectrophotometer was used to determine the color parameters, and the measurements were obtained during the initial stage, 2 weeks after immersion, and after 4 weeks. The color changes, compared to the reference values, were analyzed by calculating ΔE00. The results of this study revealed that all materials exhibited color changes after immersion in red wine, which slightly exceeded the perceptibility and acceptability threshold. The most significant color changes were observed after immersion in coffee, especially for the feldspathic CAD/CAM ceramic blocks. Within the limitations of this study, it can be concluded that the usual beverages may affect the color stability of the CAD/CAM ceramic blocks, which can compromise the esthetics of the restorations.

KEYWORDS: color stability, ceramics, cad/cam, spectrophotometer.

1. INTRODUCTION

The oral cavity has a complex environment. Restorative materials are in direct contact with saliva and frequently subjected to pH changes due to the consumption of food and various beverages [1]. Exogenous color changes of the teeth and artificial substitutes can occur because of their ability to absorb the pigments of various substances present in the oral cavity [2].

An esthetically acceptable all-ceramic prosthetic restoration should have optical properties similar to those of the teeth, and it should reflect, transmit, disperse, and absorb light. Translucency is crucial for esthetics, and it is an essential factor in the selection of materials [3].

There are several criteria for classifying all-ceramic systems. Based on their structures, they are classified into feldspathic ceramics, glass ceramic reinforced with low and medium leucite content, glass ceramic reinforced with high leucite content (lithium disilicate), and polycrystalline ceramic systems. Regarding the manufacturing process, they can be obtained (1) by mixing two components of liquid/powder, (2) with pressing technology, or (3) with CAD/CAM technology.

Feldspathic ceramic consists of quartz, feldspar, and kaolin. Feldspathic ceramics have low mechanical properties because of their high glass content, which makes them more susceptible to fracture when subjected to mechanical stress [4]. The CAD/CAM feldspathic ceramics are produced under well-controlled conditions; therefore, they have very fine crystals without pores and better mechanical resistance [4]. This class of materials can have one single shade or three or four stratified shades for the same block [5].

Lithium disilicate has a glassy ceramic structure, and it is composed mainly of lithium meta-silicate. After milling the restoration, the material should undergo a thermic crystallization process followed by glazing [6]. Lithium disilicate ceramic is delivered in an “ivory state,” and during combustion, its color ions (Vanadium) change their oxidation state, which leads to a visible change in color [7].

Leucitic ceramic is a glassy ceramic composed mainly of leucite, silicon, and potassium; it has special biocompatibility and is available in monochrome blocks with different degrees of translucency, as well as polychromatic blocks. Leucite ceramic blocks allow the optical properties of natural teeth to be imitated almost identically [8].

The color of a ceramic restoration is influenced by the shade of the material and its thickness, the layering techniques and the extrinsic dyes, the color of the tooth, and the type of cement [9]. To obtain a biomimetic prosthetic restoration, two steps are mandatory: proper shade selection using a tooth shade guide or an electronic device and accurate shade reproduction with a suitable material [10].

The spectrophotometer is an electronic device used to determine color in dentistry; it has an accuracy of 93.3% [11]. The data collected with this instrument can be expressed using three coordinates (L*, a*, and b*) established by the Commission Internationale de l’ Eclairage (CIE) [12]. The L* coordinate represents the brightness of the object, and it can have values between 0 and 100. The a* coordinate represents the chroma on the red (positive value) to green (negative value) scale, and the b* coordinate represents the chroma on the yellow (positive value) or blue (negative value) scale [10,13].

The purpose of this study was to determine the color stability of different CAD/CAM ceramic blocks after exposure to various extrinsic dyes, simulating the clinical state of all-ceramic restorations after use for more than 2 years.

2. MATERIALS AND METHODS

Three types of CAD/CAM ceramic blocks were chosen: leucitic ceramics (IPS-Empress CAD HT, Ivoclar Vivadent), feldspathic ceramic (TriLuxe Forte, Vita, Zahnfabrik), and lithium disilicate ceramic (IPS e.Max CAD, Ivoclar Vivadent). A total of 16 ceramic discs were made from each material, resulting in a total of 48 discs.

a) Sample preparation:

For each material included in this study, 16 ceramic discs were made (1 mm thick, 14 mm long, and 12 mm wide) using the microtome (IsoMet 1000-Buehler, Germany) and a disc for cutting hard materials and structured ceramic (IsoMet Diamond Wafering Blade, 15LC-Buehler) at a speed of 100 rotations per minute. All samples were assessed using the digital caliper; to reach the desired thickness and smoothness, they were finished with abrasive paper (Klingspor) with different granulations (P240, P400, P800, P1000, P1200).

b) Artificial staining:

Three solutions were used for artificial staining: green tea, coffee, red wine, and distilled water for the control group. Specimens of each ceramic group were divided into 4 subgroups (n = 4) and immersed in 100 mL staining solutions. For the preparation of the solutions, a tea bag and 1.8 g of coffee were used per 100 ml of water. The ceramic discs were immersed in solutions and stored in an incubator (Cultura, Ivoclar) at a temperature of 37 °C for 4 weeks. The solution was changed once every 72 h after the discs were washed and brushed with a toothbrush to simulate oral hygiene.

c) Determination of chromatic coordinates:

Color determination was performed using a spectrophotometer (VITA Easyshade V) before immersion. The color determination was repeated after 2 weeks and 4 weeks to evaluate color changes. The color determination was preceded by removing the ceramic discs from the solution, rinsing and brushing them with distilled water, and drying them on a paper napkin. Using spectrophotometry, the optical parameters were determined (L*- brightness, a*- chroma on a red-green scale, b*-chroma on a yellow-blue scale). For lithium disilicate and leucitic ceramic discs, only one measurement was performed in the center of the piece. For the feldspathic ceramic discs (Triluxe Forte), which are blocks with a color gradient, three measurements were obtained: in the cervical, in the body, and incisal region.

The CIEDE2000 formula was used to calculate the color difference:

$$\Delta E00 = \sqrt{\left(\frac{\Delta L'}{kLSL}\right)^2 + \left(\frac{\Delta C'}{kCSC}\right)^2 + \left(\frac{\Delta H'}{kHSH}\right)^2 + RT\frac{\Delta C'}{kCSC}\frac{\Delta H'}{kHSH}}$$

where SL, SC, and SH are weighting functions for brightness, saturation, and hue; KL, KC, and KH are correction terms for the variation in the experimental conditions.
The perceptibility and acceptability threshold are important factors for assessing the color stability of the materials. According to the literature, the perception threshold was set to 1.30, and the acceptability threshold was set to 2.25 for ΔE00 [15].
The Kolmogorov-Smirnov test was used to check the distribution of the variables, and the ANOVA test, with the Bonferroni correction, was used to check the color differences that observed after the immersion of the ceramic discs. The MEDCALC software was used for statistical data analysis.

3. RESULTS

The mean ΔE00 values and standard deviations for the materials in various storage solutions at different times are presented in Table 1. The difference between the color changes of the groups after 2 weeks and 4 weeks was statistically significant, and the paired t-test showed that this difference in ΔE was significant for lithium disilicate (e.max CAD) immersed in green tea, Empress CAD immersed in coffee and red wine, and TriLuxe Forte immersed in red wine (fig.1)

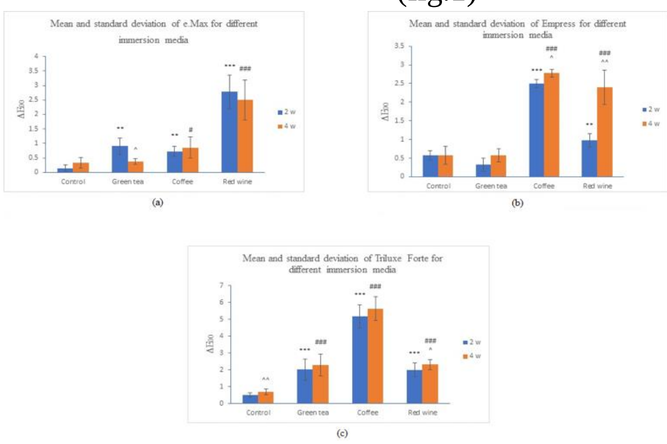

Figure 1. (a) mean and standard deviation of ΔE00 for e.max CAD ceramic discs at 2 and 4 weeks; (b) mean and standard deviation of ΔE00 for Empress CAD ceramic discs at 2 and 4 weeks; (c) mean and standard deviation of ΔE00 for Triluxe Forte ceramic discs at 2 and 4 weeks.

The average color change of the ceramic discs 2 weeks and 4 weeks after storage in different immersion media are shown in Figure 2 (fig.2).

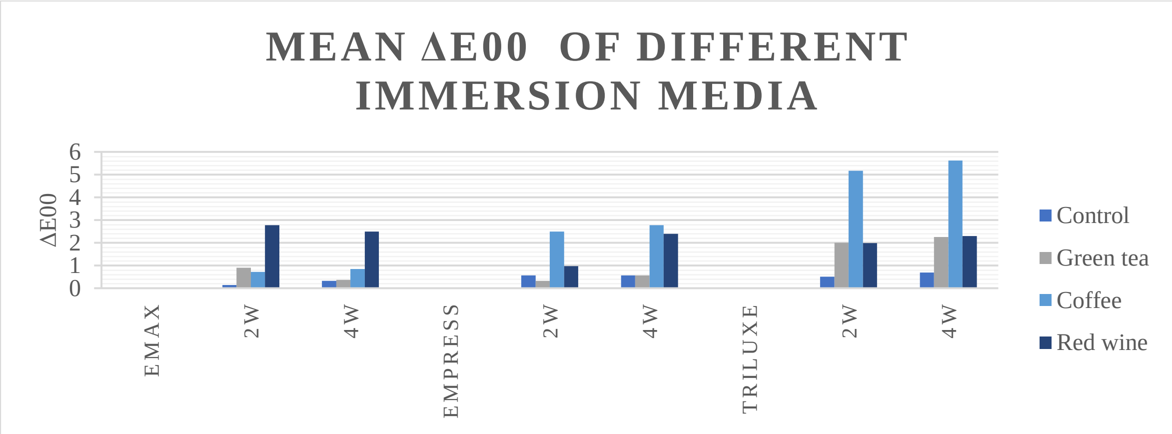

Figure 2. Mean ΔE00 2 weeks and 4 weeks after storage in different immersion media

3.1. COLOR CHANGES OF CERAMIC MATERIALS AFTER IMMERSION IN DISTILLED WATER

A slight discoloration was observed after immersing the samples in distilled water for 4 weeks: E-max, ΔE00 = 0.3 ± 0.1; Empress, ΔE00 = 0.5 ± 0.2; TriLuxe Forte, ΔE00 = 0.6 ± 0.1. These indicated that the materials were capable of absorbing liquids.

3.2. COLOR CHANGES OF CERAMIC MATERIALS AFTER IMMERSION IN GREEN TEA

It was observed that Triluxe Forte had slightly modified ΔE00 values compared with the other materials included in this study; ΔE00 of 2.2 ± 0.6 was measured after 4 weeks of storage. ANOVA showed that there was a significant effect on the ΔE00 color value ($p < 0.0001$).

The immersion of e.max CAD (ΔE00 = 0.3 ± 0.06) and Empress (ΔE00 = 0.5 ± 0.1) ceramic discs in green tea did not have a major impact on the color. ΔE00 remained within the limits of the acceptability and perceptibility threshold.

3.3. COLOR CHANGES OF CERAMIC MATERIAL AFTER IMMERSION IN COFFEE

For the feldspathic ceramic discs, three measurements were made for each disc.

Triluxe Forte underwent a major visible change (ΔE00 = 5.6 ± 0.7, a value that far exceeds the threshold of acceptability and perceptibility). The two-way ANOVA showed that the immersion media and material type had a significant effect on the ΔE00 value ($p \leq 0.001$).

Empress ceramic discs also underwent a minimal change in ΔE00 values after 4 weeks of immersion (ΔE00 = 2.7 ± 0.09).

For the e.max CAD discs, the L*, a*, and b* coordinates were not affected by the coffee solution (ΔE00 = 0.8 ± 0.3). ANOVA showed a high significance ($p \leq 0.05$).

3.4. COLOR CHANGES OF THE CERAMIC MATERIALS AFTER IMMERSION IN RED WINE

All the materials included in the study had changes in their L*, a*, and b* coordinates and ΔE00 values.

Two-way ANOVA showed that all the results were statistically significant: e.max CAD, ΔE00 = 2.5±0.3 ($p \leq 0.001$); Empress CAD, ΔE00 = 2.4 ± 0.4 ($p \leq 0.001$); Triluxe Forte, ΔE00=2.3±0.3 ($p \leq 0.001$).

All the values exceeded the threshold of perceptibility and acceptability.

Color changes of the ceramic discs can be observed, especially for Triluxe Forte after immersion in coffee and red wine(fig.3).

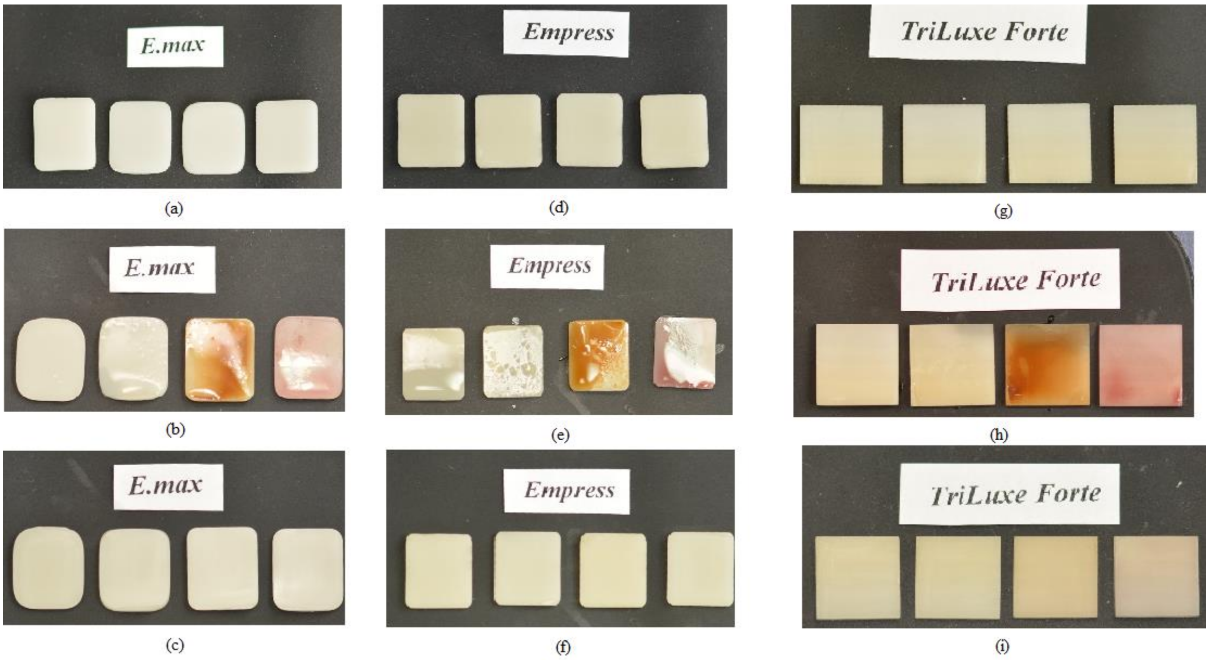

Figure 3. (a,d,g) Ceramic discs at the beginning of the experiment before immersion; (b,e,h) ceramic discs after storage in solution before washing; (c,f,i) ceramic discs after 4 weeks of storage in different storage liquids.

4. DISCUSSION

In prosthodontics, the reproduction of natural teeth translucency and natural color is the main objective. The success of any prosthetic restoration is represented by the maintenance of an appropriate esthetic throughout the surgery in the oral cavity.

When choosing the restoration material, its characteristics should be taken into account, as well as the environment to which they will be exposed. All-ceramic systems have different microstructures, crystal contents, and phases, which influence their optical properties [3].

According to ISO/TR 28642:2016, two formulas can be used to calculate the color change: ΔE00 and ΔEab. In this study, only the ΔE00 formula was used, which has been shown to be better correlated with visual perception as opposed to ΔEab [16].

Color modifications can be assessed visually or by using a dental spectrophotometer. Vita Easyshade V was used to obtain L*, a*, and b* coordinates before immersion and after 2 weeks and 4 weeks of immersion. The values of the L*, a*, and b* coordinates changed remarkably within 2 weeks of immersion, and this led to a greater ΔE00 value after 4 weeks of immersion, except for e-max CAD immersed in green tea and red wine, where the ΔE00 value measured at 4 weeks of immersion was lower than the values at 2 weeks.

To correlate the obtained results with the clinical situation, Seyidaliyeva et al. stated that if 1-day storage would be equal to 1-month consumption of staining solution, then 4-weeks of immersion would correspond to 2 years and 4 months in a clinical setting [17].

All the ceramic discs have minimal changes in their ΔE00 values, and they were capable of absorbing water. Feldspathic ceramics have the highest absorption capacity, which means they are capable of absorbing other fluids that can cause discoloration of the restorations.

For the feldspathic ceramic discs (Triluxe Forte), which are blocks with a color gradient, three measurements were taken: in the cervical, body, and incisal regions. It was observed that the incisal region had a greater ΔE00 value, both after 2 and 4 weeks of immersion, which led to the conclusion that the incisal region had a greater color change than the rest of the disc.

In this study, red wine caused color changes for all materials. In a previous study, Alencar-Silva et al. reported the coloration of lithium disilicate ceramics after immersion in red wine for glazed samples (ΔE00 = 1.61 ± 0.28) and polished ones (ΔE00 = 1.91 ± 0.36); both values were within the threshold of acceptability and perceptibility [2]. In this study, the coloration of lithium disilicate ceramics after 4 weeks exceeded the threshold of perceptibility and acceptability (ΔE00 = 2.5 ± 0.3).

According to Douglas et al., 50% of the subjects would change the restoration because of the color mismatch after a color change of ΔE00 = 5.5, whereas the dentists could observe a color difference at ΔE00 = 2.6 [17]. Feldspathic ceramics showed the greatest staining in this study after immersion in coffee (ΔE00 = 5.6 ± 0.7); the change exceeded the value at which the subjects would change their restorations due to color differences. The color change for feldspathic ceramics following immersion in coffee is clinically unacceptable, as D. A. Saba et al. also stated [1].

In a previous study, CAD/CAM materials underwent a discoloration greater than the acceptable threshold after 7 days of immersion in colorant beverages, especially after immersion in coffee and red wine [18].

Another study, conducted by Barutçugil and Çağatay et al., measured the color parameters after 24 h and 1 month of immersion in colorant beverages and concluded that CAD/CAM materials had greater discoloration after immersion in red wine and coffee [19].

Lithium disilicate ceramics showed the best color stability. The values of the L*, a*, and b* coordinates changed only after immersion in red wine. After immersion in green tea, the ΔE value remained within the threshold of acceptability and perceptibility.

For the leucitic ceramics, the ΔE values appeared modified (ΔE00 = 2.5 ± 0.1) after 2 weeks of storage in coffee. After 2 weeks of storage in wine, the chromatic coordinates did not exceed the threshold of acceptability and perceptibility (ΔE00 = 0.9 ± 0.1); this was not the case for ceramic discs immersed in red wine for 4 weeks (ΔE00 = 2.4 ± 0.4).

The limitations of this study include the short duration of immersion and the staining of both surfaces of the ceramic material, which is different from the clinical situation where the material is stained only on one surface.

5. CONCLUSIONS

Within the limitations of this study, it can be concluded that the usual beverages may affect the color stability of CAD/CAM ceramic blocks, which can compromise the esthetics of the restorations.

Feldspathic ceramics showed the highest degree of impregnation after immersion in coffee, followed by immersion in wine and green tea. In this study, all the CAD/CAM ceramic blocks showed color changes after immersion in red wine.

Conflicts of Interest: The authors declare no conflicts of interest.

REFERENCES

1. Dalia A Saba, Rania A Salama, Rasha Haridy. Effect of different beverages on the color stability and microhardness of CAD/CAM hybrid versus feldspathic ceramic blocks: An in-vitro study. Future Dental Journal 2017, 3:61-66
2. Flávia J Alencar-Silva, Joel O Barreto, Wagner A Negreiros, Paulo GB Silva, Lívia Maria S Pinto-Fiamengui, Rômulo R Regis. Effect of beverage solutions and toothbrushing on the surface roughness, microhardness, and color stainability of a vitreous CAD-CAM lithium disilicate ceramic. Journal of Prosthetic Dentistry 2019, 121:711.e1-711.e6
3. Alvaro Della Bona, Audrea D Nogueira, Oscar E Pecho. Optical properties of CAD-CAM ceramic systems. Journal of Dentistry 2014, 42:1202-1209
4. Nasrin R. Sadaqah. Ceramic laminate veneers: Materials advances and selection. Open Journal of Stomatology 2014, 04:268-279
5. Hugo Lambert, Jean-Cédric Durand, Bruno Jacquot, Michel Fages. Dental biomaterials for chairside CAD/CAM: State of the art. Journal of Advanced Prosthodontics 2017, 9:486-495
6. Alec Willard, Tien-Min Gabriel Chu. The science and application of IPS e.max dental ceramic. The Kaohsiung Journal of Medical Sciences 2018, 34:238-242
7. Vivadent ivoclar. Scientific Documentation IPS e.max CAD. Liechtenstein. 2011
8. Christian Ritzberger, Elke Apel, Wolfram Höland, Arnd Peschke, Volker Rheinberger. Properties and clinical application of three types of dental glass-ceramics and ceramics for CAD-CAM technologies. Materials 2010, 3:3700-3713
9. Tariq F Alghazzawi, Jack Lemons, Perng-Ru Liu, Milton E Essig, Gregg M Janowski. Evaluation of the optical properties of CAD-CAM generated yttria-stabilized zirconia and glass-ceramic laminate veneers. Journal of Prosthetic Dentistry 2012, 107:300-308
10. Paul Hooi, Owen Addison, Garry JP Fleming. Journal of Dentistry 2013, 41:24-30
11. Laís A Pires, Pollyanna MR Novais, Vinícius D Araújo, Luiz F Pegoraro. Effects of the type and thickness of ceramic, substrate, and cement on the optical color of a lithium disilicate ceramic. The Journal of Prosthetic Dentistry 2017, 117:144-149
12. Brian Stevenson, Richard Ibbetson. The effect of the substructure on the colour of samples/restorations veneered with ceramic: A literature review. Journal of Dentistry 2010, 38:361-368
13. Eva Niu, Marcus Agustin, R Duane Douglas. Color match of machinable lithium disilicate ceramics: Effects of cement color and thickness. The Journal of Prosthetic Dentistry 2014, 111:42-50
14. Razvan Ghinea, María M Pérez, Luis J Herrera, María José Rivas, Ana Yebra, Rade D Paravina. Color difference thresholds in dental ceramics. Journal of Dentistry 2010, 38 Supplement 2:e57-e64
15. Oscar E Pecho, Razvan Ghinea, Rodrigo Alessandretti, María M Pérez, Alvaro Della Bona. Visual and instrumental shade matching using CIELAB and CIEDE2000 color difference formulas. Dental Materials: Official Publication of the Academy of Dental Materials 2016, 32:82-92
16. Aida Seyidaliyeva, Stefan Rues, Zinonas Evagorou, Alexander J Hassel, Peter Rammelsberg, Andreas Zenthöfer. Color stability of polymer-infiltrated-ceramics compared with lithium disilicate ceramics and composites. Journal of Esthetic and Restorative Dentistry: Official Publication of the American Academy of Esthetic Dentistry ... [Et Al.] 2020, 32:43-50
17. R Duane Douglas, Tad J Steinhauer, Alvin G Wee. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of the shade mismatch. Journal of Prosthetic Dentistry 2007, 97:200-208
18. SHQ Quek, AUJ Yap, V Rosa, KBC Tan, KH Teoh. Effect of staining beverages on color and translucency of CAD/CAM composites. Journal of Esthetic & Restor Dentistry 2018, 30:e9-e17
19. Çağatay Barutçugil, Dilber Bilgili, Kubilay Barutcigil, Ayşe Dündar, Ulviye Şebnem Büyükkaplan, Burak Yilmaz. Discoloration and translucency changes of CAD-CAM materials after exposure to beverages. Journal of Prosthetic Dentistry 2019, 122:325-331