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Color Changes of Ceramic Materials Used for Inlay and Veneers Restorations after Staining with Different Time Intervals

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Stain color of CAD/CAM prosthetic materials is important for the long-term of these materials without affecting daily beverage consumption habits.
Aims: To assess the influence of aging with Coca-Cola drinks on the color of the CAD/CAM materials used for inlay and veneer restoration over different time intervals.

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Methods: 48 specimens were fabricated from Vitablocs Mark II and zirconia CAD/CAM ceramic materials. Each group comprised 24 specimens with eight samples for every background (white [W], black [B], and gray). Baseline readings were taken by a spectrophotometer before staining (Baseline T0). After Coca-Cola staining and aging, the color measurement was repeated after 15 and 30 days (T1 and T2), while T3 was the difference between T2-T0. The data were analyzed with descriptive statistics, one-way ANOVA, and post hoc tests.

Results: The ΔE_{00} color parameters of Mark II and zirconia materials were higher against the W background than other backgrounds. However, the zirconia materials recorded higher values than Mark II for the same parameters (L, a, and b) against the gray background during 15 and 30 days of immersion in Coca-Cola. Translucency parameters (TP) exhibited significant differences between ceramic types and immersion periods, with the TP values of zirconia being slightly higher than those of Mark II. The ΔE_{00} values for the three-time intervals were within clinically acceptable ranges. The ΔE_{00} values of both ceramic types at T3 were within 1.38–1.53 and 3.11–3.62 and lacked significant differences.

Conclusions: Coca-Cola staining was obvious after 15 and 30 days of immersion and had a marked effect on the TP and ΔE_{00} of the tested CAD/CAM materials. Increasing the staining time resulted in a reduction in TP values at all time intervals. Zirconia samples had higher ΔE_{00} values than Mark II materials at different time periods. All of the colors of the tested materials had changed from B1 to different light colors in accordance with the Vita classical shade guide.

Keywords: Coca-Cola; color measurements; feldspathic ceramic; translucency parameter; Zirconia.

1. INTRODUCTION

The use of CAD/CAM systems in dentistry is increasing. These system technologies allow for an entirely digital workflow beginning with the impression to the final framework and use materials that present outstanding mechanical properties [1] and decent accuracy [2]. CAD/CAM restorative materials are predesigned in the form of presintered ceramic blocks from which inlays or veneers are milled out. After milling, inlays or veneers are completely sintered at standardized pressures and temperatures to obtain the desired biological and mechanical properties [3].

CAD/CAM inlays and veneer restorative materials had unacceptable clinical performance because of their low survival rate in the oral cavity. In 1991, Vita Mark II (Vita MII) with improved mechanical properties was presented to the market. Vita MII ceramic blocks utilize fine created particles, and a different machining technique is applied to improve mechanical properties and strength [4]. These blocks are monochromatic or available in multishaded layers that permit a shade gradient and enhance optical properties [4-6].

Among the materials for dental ceramics inlays and veneers, zirconia has undergone an obvious increase in application in dentistry because of its white color and functional results [7]. In contemporary dentistry, CAD/CAM is the only technique that is used to fabricate zirconia restorations. The most popular route for zirconia prosthesis fabrication is the use of partially sintered zirconia blanks via the soft-milling technique. The blank must be sintered to achieve the final density and maximum strength of the material. This sintering procedure is accompanied by the relatively high sintering shrinkage of approximately 20%–30% [8].

Whether the CAD/CAM ceramic material is a significant factor in the surface discoloration of ceramic inlays or veneers has not yet been demonstrated. The color stability of a ceramic material has been found to be affected by eating behaviors and the frequent consumption of certain beverages, i.e., Coca-Cola, coffee, and tea. Cola and cold drinks are considered to be the main reasons for porcelain material staining. Nonetheless, whether Coca-Cola discoloration differs with respect to the surface manipulation of CAD/CAM ceramic restorations or existing ceramic materials remains unclear [9-11].

Commission Internationale de l' Eclairage (CIE) Lab color coordinates are demonstrative color parameters. L* represents the lightness of an object; a* represents greenness (+) and redness (–); and b* represents yellowness (+) and blueness (−). The color parameters L*, a*, and b* of restorative materials can be measured from reflectance or transmittance [12]. In 2001, the CIE Lab formula was improved for the calculation of the differences between two shades; the improved formula is more effective than the original formula in perceiving differences [13,14].

Usually, dentists require frequent minor occlusal reduction and highpoint removal during the cementations of CAD/CAM-fabricated prostheses. Such modifications include the elimination of a portion of the glazed layer from the outer prosthetic surfaces, thus leaving some pores in the exposed material and producing a coarse surface. These modifications may cause the discoloration of the CAD/CAM prostheses that requires either the reglazing or polishing of the prostheses to maintain the smoothness of the prosthesis color [15-16]. Hence, the current study was conducted to evaluate the effect of Coca-Cola staining on the translucency parameter (TP), mean color change (ΔE_{00}), of feldspathic Mark II, and multilayered zirconia CAD/CAM ceramic materials at different time intervals. This work also aimed to compare the color changes of the above specimens on the basis of the Vita classical shade guides. The null hypothesis is the absence of differences in the TP and color changes (ΔE_{00}) of both materials and background type in accordance with the acceptability and perceptibility threshold (AT and PT) of 50%:50%. Also, no color changes between materials in relation to Vita Classical shade guide.

2. MATERIALS AND METHODS

2.1 Study Design and Sample Calculation

This study was conducted at Jazan University, College of Dentistry, Saudi Arabia, in May 2021. In this study, the effect of Coca-Cola on the TP and ΔE_{00} of the samples were evaluated, and the color changes of the above specimens were compared on the basis of the Vita Classical shade guide. Power analysis was performed, and at least 12 samples were found to be sufficient per group at the 0.05 level with 97% power (Fig. 1).

2.2 Specimen Fabrication and Surface Treatments

A total of 48 specimens were fabricated from feldspathic (Vitablocs Mark II) and multilayered zirconia (Ceramill Zolid PS) CAD/CAM ceramic materials (Vita Zahnfabrik) by using the CAD/CAM system. The samples were in form of a disc-shaped with dimensions were 16 mm × 12 mm × 1.2 ± 0.2 mm [2,5]. The thicknesses of the specimens were measured by using a digital caliper (Absolute Digimatic Caliper, Mitutoyo Corporation, Aurora, IL, USA). Each group comprised 24 specimens. The specimens were sintered and glazed in a furnace for 2 h at 1550°C.

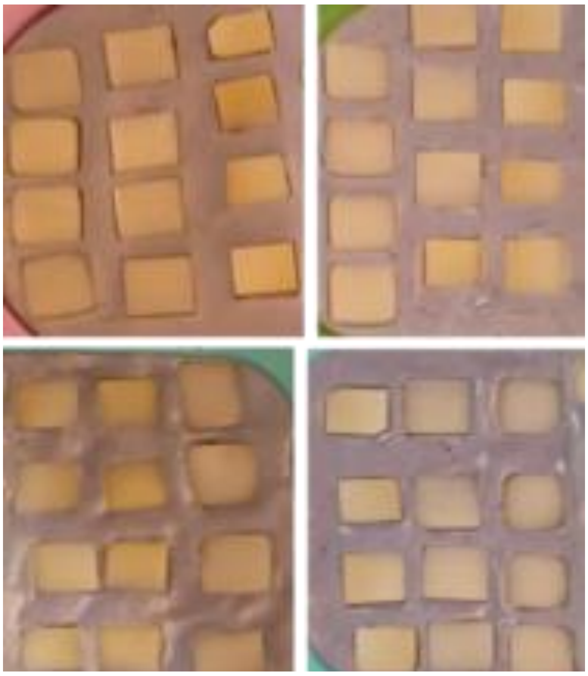

Fig. 1. Samples in a mold with an exposed outer surface (staining surfaces)

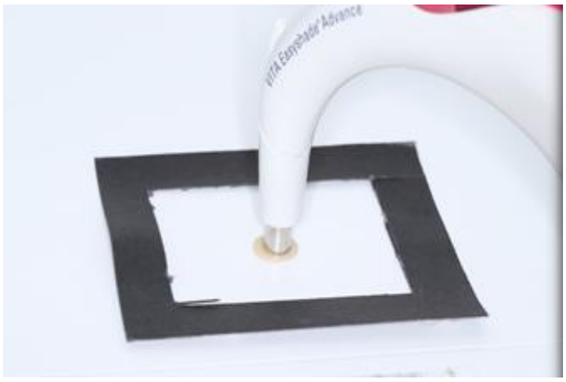

Fig. 2. Samples during color parameter measurements in an outer box against a W background

2.3 Color Measurements

The color parameters L, a, and b were assessed by using a spectrophotometer with a 6 mm diameter tip (Vita Easyshade3 Advance, Vita Zahnfabrik, Bad Säckingen, Germany). The device was calibrated before each assessment in accordance with the manufacturer's instructions. For each specimen, measurements were taken from two different points against black (B), white (W), and gray backgrounds. Then, the average values were obtained.

The CIE color system uses three coordinates to measure color. The CIE recommends the following uniform color scales: CIE (L*a*b*). When a color is displayed in the CIE Lab, L* represents lightness, a* represents the red-green value, and b* represents the yellow–blue value (ISO 2004). Color parameters, such as the L0, a0, and b0 values of the specimens, were measured by using a spectrophotometer against W, B, and gray backgrounds. A square window opening with the dimensions of 2 cm × 2 cm was used and fixed to B and W backgrounds to ensure that the specimen remained in the same area during the recording of the optical reading (Fig. 2). TP measurements were obtained by calculating the color difference of the specimen against B and W backgrounds and were calculated by using the following formula:

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

where subscript B refers to the color coordinates against the B background and subscript W refers to those against the W background [17-19]. ΔE_{00} is the color difference calculated on the basis of the color coordinate differences between two objects or between a restoration and a tooth/target. The mean color changes of the samples against a gray background were recorded as L0, a0, and b0. At this time, the shade of the samples was recorded with the same device in accordance with the Vita classical shade guide (Vita Classical Guide, Vita Zahnfabrik, Germany) and documented as the baseline reading (B1).

2.4 Application of Staining Solutions

The baseline or first measurements of the color parameters were considered as L0, a0, and b0. All samples were then immersed in Coca-Cola (Coca-Cola Industrial Co., Jeddah, Saudi Arabia) drink for 15 and 30 days as was done in previous in vitro studies [11,20,21]. The staining material was changed daily and following the manufacturer's instructions.

During and after the immersion period, colors were measured again by the same operator with the same settings against the same B and W backgrounds. The color parameters for all samples were recorded after 15 and 30 days as L1 and L2; a1 and a2; and b1 and b2 for the calculation of T1 (from 0 days to 15 days) and T2 (from 0 days to 30 days). T3 was the time interval between 15 and 30 days. ΔE_{00} values were calculated by using the following equation:

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

where $\Delta L^* = L^*0 - L^*1$, $\Delta a^* = a^*0 - a^*1$, and $\Delta b^* = b^*0 - b^*0$ for time intervals. Three readings for ΔE_{00} values were obtained, namely, T1 ΔE_{00}, T2 ΔE_{00}, and T3 ΔE_{00} [19-21]. In addition, the shade of the specimens was measured at three-time points by using the VitaPAN classical shade guide: as the baseline before immersion, as the first reading after 15 days of immersion, and as the second reading after 30 days of immersion. Refer to Fig. 3 for details.

2.5 Data Analysis

The average TP (TPs 1, 2, and 3) and average ΔE_{00} based on the first, second, and third values of the Mark II and zirconia CAD/CAM prosthetic materials were evaluated by comparing the color change exhibited by each type of ceramic material after aging and immersion in Coca-Cola drinking solution for 15 and 30 days. IBM SPSS 20.0 package program (Chicago, USA) and Excel Microsoft 10 were used to input and analyze the data. The ANOVA test was used followed by *Bonferroni tests* to detect the significance between and within the groups with a p-value < 0.05. Then, the color change values were compared with a perceptible threshold of 2.8 and a clinically acceptable threshold of 4.2 [21]. The comparison of the color changes between the basic colors of the VitaPAN classical shade guide and those of the tested specimens after staining with Coca-Cola at the baseline, 15 days, and 30 days were recorded as the baseline, first, and second readings, respectively.

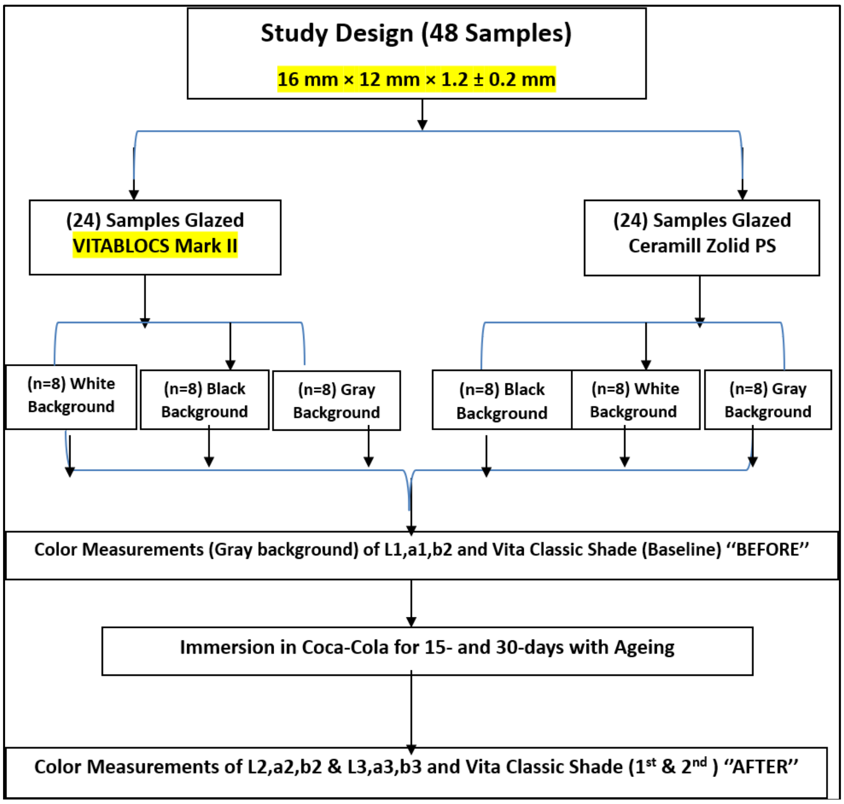

Fig. 3. Schematic showing the sample size and the steps followed in this research

3. RESULTS

The color coordinates L, a, and b were measured by using a spectrophotometer tip against W, B, and gray backgrounds separately. The means of the color components of Mark II and zirconia before and after aging and staining through 15 and 30 days of immersion in Coca-Cola are summarized in Table 1. At different time intervals, the mean values of the basic color parameters (L, a, and b) of the Vitablocs Mark II and zirconia materials were slightly higher against the W background than against the B background. Against the gray background, the color parameters (L, a, and b) values of the zirconia CAD/CAM restorative materials were higher than those of the Mark II material at 15 and 30 days of immersion in Coca-Cola.

Table 1. Parameters of Mark II and zirconia at T1 (L1, a1, and b1), T2 (L2, a2, and b2), and T3 (L3, a3, and b3) after immersion in Coca-Cola and aging against B, W, and gray backgrounds

Ceramic Material	Background	L0 − L1	L0 − L2	L2 − L3	a0 − a1	a0 − a2	a2 − a3	b0 − b1	b0 − b2	B2 − b3
Translucency parameter (TP)										
Vitablocs Mark II	B	75.52	73.89	73.20	2.98	2.22	2.00	16.92	16.21	15.86
	W	76.46	75.68	74.88	2.36	2.02	1.89	16.82	16.24	15.94
Zirconia	B	77.20	76.94	75.48	2.94	2.80	2.18	17.40	16.88	16.04
	W	77.65	77.22	76.92	3.02	2.88	2.22	18.24	17.82	16.28
Mean Color Change (ΔE_{00})										
Vitablocs Mark II	Gray	76.25	74.98	74.22	3.02	2.92	2.18	16.29	16.12	15.78
Zirconia	Gray	78.02	77.90	77.12	3.44	3.04	2.86	18.04	17.94	17.32

where L0 − L1, a0 − a1, and b0 − b1 are the differences between the readings at the baseline and after 15 days of immersion (T1); L0 − L2, a0 − a2, and b0 − b2 are the differences between the baseline and after 30 days of immersion (T2); and L1 − L2, a1 − a2, and b1 − b3 (T3) are the differences between 15 and 30 days of immersion.

Table 2 shows that the mean and SD of the TP values of the Mark II material at T1 and T2 (beginning and after 15 days) were almost the same and were 16.39 and 16.23, respectively, then decreased to 14.20 at T3 after 30 days of immersion in Coca-Cola. The CAD/CAM zirconia exhibited the highest TP at T1, then decreased at T2 and T3. The TPs of CAD/CAM zirconia at T1, T2, and T3, was 18.82, 17.81, and 16.64 respectively. The TPs of both materials showed significant differences at different time intervals with a *p-value* > 0.050*.* The post hoc test revealed significant differences between the types of ceramic and time intervals with a *p-value* ≥ 0.001 (Table 2).

The ΔE_{00} values for the Mark II and zirconia groups after each procedure are presented in Table 3. The highest ΔE_{00} values at T1 and T2 were shown by zirconia and were 3.62 and 3.17, respectively. Zirconia and Mark II recorded the lowest mean color changes of 1.53 and 1.38, respectively, at T3, which was the difference between the reading on day 15 and that on day 30. The ΔE_{00} did not significantly differ between the two ceramic material types and among the different time intervals (Table 3).

Table 4 shows the changes in the basic colors of the VitaPAN classical shade guide (A1–D4) of the tested groups. The greatest changes were observed in zirconia (100%), which changed into A2 and C1 after 15 days. Then, the color of 75% of the samples remained at A2, whereas that of 25% of the samples changed into C1. After 15 days of immersion in Coca-Cola, the color of 75% and 25% of the Mark II samples changed into A2 and C1, respectively. The color of the samples then returned to B1 Vita.

Table 2. Descriptive statistics and ANOVA, *followed by Bonferroni* tests of the TPs of the tested materials stained with Coca-Cola at different time intervals

TP	Type of ceramic (Mean ± SD)	Mark II	Zirconia	P-value 'ANOVA'
TP (T1)	Mark II (16.39 ± 0.93)	------	0.000[a]	0.040*
	Zirconia (18.82 ± 1.38)	0.000[a]	----------	
TP (T2)	Mark II (16.23 ± 0.72	------	0.000[a]	0.0.52*
	Zirconia (17.81 ± 01,12)	0.000[a]	----------	
TP (T3)	Mark II (14.20 ± 0.82)	------	0.048[a]	0.036*
	Zirconia (16.64 ± 1.14)	0.048[a]	----------	

**p-value > 0.050 is significant. Different superscript letters indicate statistically significant differences inside the respective subgroup (p < 0.05) based on ANOVA tests followed by Bonferroni tests.*

Table 3. Descriptive statistics and ANOVA test followed by *Bonferroni tests* of the ΔE_{00} values of the tested materials stained with Coca-Cola at different time intervals

Mean Color Change	Type of ceramic (Mean ± SD)	Vitablocs Mark II	Zirconia	P-value ''ANOVA''
ΔE_{00} (T1)	Vitablocs Mark II (3.11 **±** 0.32)	------	0.247	1.461
	Zirconia (3.62 **±** 0.03)	0.247	----------	
ΔE_{00} (T2)	Vitablocs Mark II (3.41 **±** 0.72)	------	0.146	1.348
	Zirconia (3.17 **±** 0,26)	0.146	----------	
ΔE_{00} (T3)	Vitablocs Mark II (1.38 **±** 0.82)	------	0.332	0.128
	Zirconia (1.53 **±** 0.41)	0.332	----------	

Table 4. Comparison of the color changes in the basic colors of the VitaBAN classical shade guide shown by the tested specimens after staining with Coca-Cola at the baseline and 15 and 30 days

Ceramic type	Vitablocs Mark II (Feldspatheic)			Ceramill Zolid (Zirconia)		
Time interval	**Baseline**	**First**	**Second**	**Baseline**	**First**	**Second**
Shade	B1	A2 & C1	B1	B1	A2	A2 &C1
Percentage	100%	50% & 50%	100%	100%	100%	75% & 25%
P values	0.251			0.642		

where the baseline reading is taken at the beginning of the immersion and the first and second readings are taken after 15 and 30 days of immersion, respectively.

Table 5. Extended visual rating scale (EVRSAM) [25]

ΔE_{00}	Clinical significance
0	Excellent aesthetics with accurate color choice, not clinically perceptible or perceptible only with great difficulty.
2	Very slight differences in color with very good aesthetics.
4	Obvious difference but with average acceptability to most patients.
6	Poor aesthetics but within the limit's acceptability.
8	Aesthetics are very poor and unacceptable to most patients.
10	Aesthetics is totally unacceptable.

4. DISCUSSION

The considerably improved visual and survival properties of all CAD/CAM inlays and veneers ceramic restorations have met patients' desires. Nevertheless, these materials are still susceptible to several factors that may cause discoloration and some degrees of color changes. One of these factors are cola beverages, which contain distinct additive stains and pigments [11]. In the present in vitro study, the TP and ΔE_{00} of Mark II and zirconia CAD/CAM ceramics in the form of inlays and veneers with different thicknesses were evaluated. TP and ΔE_{00} were calculated before and after aging and staining with Coca-Cola for 15 and 30 days. In addition, changes in the Vita Classical shade guide were recorded at different time intervals.

The null hypothesis, which stated that the TP values will not significantly differ against different backgrounds and at different time intervals after immersion in Coca-Cola, was rejected because the TP1, TP2, and TP3 of the ceramics against different backgrounds changed after immersion in the staining material for different time intervals and aging. Similarly, the null hypothesis for ΔE_{00} values at different time intervals was partially accepted because the ΔE_{00} values remained the same at T1 and T2 but decreased at T3 (15–30 days). The null hypothesis stating that the colors of the tested materials based on the Vita Classical shade guides will not change after immersion in Coca-Cola and aging at different time intervals was partially rejected because of the color changes observed at 15 and 30 days and was partially accepted given the absence of significant differences between the two ceramic materials at different time intervals.

Overall, the values of TP ranged from 18.82 and 14.20 for zirconia at TP (T1) and for Mark II at T3, respectively; these values coincided with those publications recorded for the materials used for inlays and veneer ceramic materials [17-19,22-23]. The ΔE_{00} values at different time intervals were within the clinically acceptable range reported by previous studies [17-18,22, 24]. The mean color changes were decreased at T3 (between 15 and 30 days) in parallel with previously reported values mentioned by (Koseoglu et al. 2019; Eldwakhly et al. 2019; Vasiliu et al. 2020; Abdalkadeer et al. 2020; Cui et al. 2020) [11,13,17-18,22]. Table 5 represented the different values of ΔE_{00} (Extended visual rating scale) and the interpretation of those values [25].

A high TP value is associated with the high actual translucency of the material. Therefore, a value of 0 corresponds to completely opaque material. The overall TP values of Mark II were low (14.20–16.39) at T3; 18.82 at T1; and reduced to 16.64 at T3. Those values can be considered acceptable because many recent and previous studies have reported the same values [18,22-23]. Other works have recorded TP values of 15.00–22.00 for zirconia samples and 13.00–18.00 for feldspathic ceramic CAD/CAM materials after 2 weeks of immersion in khat extract [19]. The reduction in TP values coincided with that reported by Şişmanoğlu and Gürcan 2021, who tested the TP of feldspathic ceramic after immersion in coffee for a period of time and found a slight reduction in the TP values of zirconia samples and feldspathic CAD/CAM ceramic materials after staining [26]. Yildirim et al. 2021 recorded the same results in the assessment of the TPs of hybrid ceramic and leucite-reinforced feldspar ceramic materials after different procedures. Specifically, they reported TP values between 13.70 and 16.90 before and after thermocycling [14]. These values were within the ranges of values obtained in the current study. Koseoglu et al. 2019 obtained TP values of between 14.00 and 17.00, which significantly differed between time intervals, for zirconia CAD/CAM prosthetic materials after immersion [17].

The same values were recorded by Pîrvulescu et al. 2021, who assessed the TP before and after 18 h of gastric acid immersion. They recorded

TPs with the mean of 24.20 for zirconia CAD/CAM monolithic materials and TP values of 18.43 and 19.51 for feldspathic CAD/CAM material after and before acid exposure [23]. Vasiliu et al. 2020 recorded slightly lower values of between 12.00 and 14.00 for zirconia and feldspathic CAD/CAM ceramic materials before and after thermocycling. These slight differences could be related to the surface type of the examined samples given that the samples in the present work were glazed, whereas those in previous studies were glazed and polished. Most of the polished surfaces recorded lower TP values than the glazed specimens [18]. Finally, Eldwakhly et al. 2019 assessed the TP of CAD/CAM restorative materials before and after being subjected to Coca-Cola immersion and thermocycling. The zirconia and hybrid ceramic recorded reduced TP values after thermocycling and immersion in Coca-Cola [22]. All studies recorded a slight reduction in TP values after aging or thermocycling with any staining and immersion materials.

Table 5 clearly shows that ΔE_{00} values equal to 2 or 4 are considered as “Excellent aesthetics with accurate color choice, not clinically perceptible or perceptible only with great difficulty” or ‘’Obvious difference but with an average acceptability to most patients.’’ Therefore, all of the values recorded in the current study for both types of materials and at different time periods were clinically acceptable.

Şişmanoğlu and Gürcan, 2021, recorded similar values for feldspathic Mark II CAD/CAM ceramic materials after immersion in coffee for 30 days [26]. Yousief et al. obtained marginal values after immersion in acid or fluoride staining materials [27]. Pîrvulescu et al. 2021 reported considerably lower ΔE_{00} values for feldspathic and zirconia CAD/CAM prosthetic materials [23]. This difference could be attributed to the staining media used. In previous works, the materials were immersed for less than 24 h in gastric acids, which acted on the surfaces of the tested materials due to their acidic pH and thus reduced ΔE_{00} values. Similarly, low values were recorded by Abdalkadeer et al. 2020, who stained materials with Coca-Cola [11], and Koseoglu et al. 2019 reported low ΔE_{00} values that could be attributed to the different types of zirconia ceramic materials tested and the existing thermocycling and finishing of the samples that resulted in rough external surfaces [17]. Equal values were recorded in a clinical study reported by Cui et al. 2020, who recorded ΔE_{00} values between 2.45 ± 1.60 and 4.55 ±1.54 $_{00}$ for CAD/CAM zirconia crowns on premolars. By contrast, the ΔE_{00} values documented in this work were 3.62 ± 0.03 to 3.11 ± 0.32 after 15 and 30 days of staining and aging, respectively.

Another recent clinical study published by Rajamani et al. in December 2021 concluded that ceramic materials for zirconia CAD/CAM inlays presented a good aesthetic outcome after 24 months of clinical survival in posterior teeth [28]. Eldwakhly et al. 2019 assessed the ΔE_{00} of CAD/CAM restorative materials before and after Coca-Cola immersion and thermocycling. They reported that the zirconia and hybrid ceramic materials recorded low ΔE_{00} values of 2.29 ± 0.25 and 0.88 ± 0.04, respectively, after immersion in Coca-Cola [22].

Most of the color changes caused by Coca-Cola drinks in Mark II and zirconia were not measurable by the human eye (ΔE_{00} < 2.4). However, all of the changes in the ΔE_{00} values of both materials at T1 and T2 (after 15 and 30 days) caused by Coca-Cola drinks can be perceived by the human eye (ΔE_{00} > 2.4). This result indicated that Coca-Cola beverages resulted in measurable stains that can cause color changes in different ceramic materials [11]. Alghazali et al. 2012, reported that the perceptible and clinically acceptable thresholds in their in vivo clinical study were 2.4 and 4.8, respectively [21]. Overall, all ΔE_{00} values recorded in this study were within the clinically acceptable range as mentioned in Table 5.

In reference to the VitaPAN classic shade guide (B1), the colors of 50% of the Vita Mark II specimens changed into A2 and C1 and those of the remaining 50% remained light after 15 days of staining. After 30 days of staining, the color of 100% of the samples remained at B1 (lighter color). Similar percentages were recorded by Al Moaleem et al. 2020b, who observed changes in the VitaPAN classic shades of different feldspathic ceramics. They found that an average of 75% of all Mark II and zirconia samples showed changes after staining and immersion. Moreover, Greta et al. 2020, reported high percentages of color changes based on the basic Vita Classical shade guide and recorded changes of 90%, 70%, and 30% for feldspathic ceramic [29]. A published study reported similar color changes and percentages of the color change categories after immersion in cold and hot coffee [24]. These results guaranteed that feldspathic inlays and veneers CAD/CAM ceramic materials will continue to exhibit the lowest color change and stainability because they do not contain glass fillers, which will permanently preserve the smoothness of surfaces.

Zirconia prosthetic materials are promising materials because of their strength, biocompatibility, and optical and mechanical properties. The color of 100% of the zirconia CAD/CAM samples changed into A2 after 15 days and that of 50% of the samples partially stayed at A2. Derafshi et al 2017, reported parallel findings and demonstrated that the color of zirconia samples darkened after 24 h but lightened after 72 h and 7 days of immersion in chlorhexidine mouth wash [30]. These results suggested that feldspathic ceramics should be utilized whenever possible for aesthetic treatments. Greta et al. 2020, performed a clinical study by using the Vita Classic shade guide with the Vita Easy Shade Advance to measure color. They concluded that the color difference between the restoration and the reference tooth exceeded perceptibility thresholds [31]. Similar findings were recorded by al Moaleem et al. 2020b, and Adawi et al. 2021 [24,29]. Bratner et al. 2020, compared the shade matching of the Vita 3DMater and Vita Ban Classic and found no significant difference between the subject's shade selection and the shade guides likely because the sizes of the triangular areas improved the distribution of the tooth color shades within the color space [32].

One of the limitations of the current study is the fact that the materials were not exposed to the oral cavity and its environments, including saliva, and thus failed to mimic the actual oral cavity fully. Exposing ceramic materials to saliva, other fluids, and different pH levels may simulate clinical conditions. Another limitation of this in vitro study is that it allowed the staining of ceramic materials on both sides of the tested porcelain inlays and veneers. However, in clinical situations, one surface of the veneer is cemented to a tooth structure, and only the outer surface is exposed to Coca-Cola and susceptible to staining.

5. CONCLUSION

The following conclusions could be drawn within the limitations of this in vitro laboratory study: Coca-Cola staining solutions had a marked effect on the TP and ΔE_{00} of the tested CAD/CAM materials at different time intervals. Prolonging the staining time resulted in a reduction in the TP values of L, a, and b at all time intervals. The color parameters of zirconia CAD/CAM materials were higher than those of Mark II with gradual reductions in TP values at different time points. The TP values significantly differed in each group and within groups as a function of time. The ΔE_{00} values of zirconia samples were higher than those of Mark II at different time periods. No significant differences were found between the tested parameters. The color changes of both ceramic materials were obvious at 15 and 30 days of immersion and staining periods. All colors of the tested materials changed from B1 to different light colors in accordance with the Vita classical shade guide.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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