Abstract

Background. The wide range of restorative materials available for use in the computer-aided design/computer-aided manufacturing (CAD/CAM) technology requires a better understanding of their esthetic properties.

Objectives. The aim of the study was to assess the stability of the color and translucency of different CAD/CAM restorative materials before and after being subjected to different staining solutions.

Material and methods. A total of 160 disc-shaped specimens were prepared from glass ceramic (IPS-e.max®-CAD and Celtra Duo®), high-translucency zirconia (Lava™ Plus), resin nanoceramic (Lava™ Ultimate), and hybrid ceramic (VITA ENAMIC®) CAD/CAM blocks (5 groups, n = 32). The specimen color and translucency parameter (TP) were assessed using a spectrophotometer at baseline and after subjecting the specimens to different staining solutions (coffee, cola, ginger, and water). Changes in color (ΔE) and TP (ΔTP) were calculated. The data was analyzed using the analysis of variance (ANOVA) and Tukey’s post hoc test (p < 0.05). The correlation between ΔE and ΔTP was investigated using Pearson’s correlation coefficient.

Results. Staining significantly affected the baseline color of all specimens. Ginger had the most significant effect on Lava Plus (ΔE = 4.01 ±1.2), cola on Celtra Duo (ΔE = 2.29 ±0.25) and coffee on Lava Ultimate (ΔE = 2.59 ±0.17). Generally, IPS-e.max-CAD showed the smallest ΔE. No significant differences in ΔTP were found between different staining solutions. Increased ΔE correlated with decreased translucency for all the tested materials and staining solutions.

Conclusions. Staining had a marked effect on the color and translucency of the tested CAD/CAM materials. The color change was staining solution- and material-dependent, with IPS-e.max-CAD showing the greatest color stability.

Key words: computer-aided design/computer-aided manufacturing, translucency parameter, color change

Słowa kluczowe: komputerowo wspomagane projektowanie/komputerowo wspomagane wytwarzanie, parametr przezierności, zmiana koloru
Introduction

The use of computer-assisted design/computer-aided manufacturing (CAD/CAM) has rapidly increased in recent years due to spectacular technological advances. The main advantage of this technology is the possibility of using homogenous and defect-free ceramic blocks in the production of esthetic restorations during a single appointment. The range of currently available materials includes glass ceramics, zirconia, resin nanoceramics, and - most recently - hybrid ceramics.

Conventional glass ceramics are generally highly esthetic but inherently brittle, which limits their use in the areas of high occlusal stresses. Two variations of glass ceramics have been introduced to provide sufficient mechanical strength without affecting the esthetic outcome of the restoration – lithium disilicate and zirconia-reinforced lithium silicate ceramics. Restorations made of lithium disilicate are initially milled in a partially crystallized form, and then subjected to crystallization firing to reach their ultimate strength and esthetic potential. Zirconia-reinforced lithium silicate materials, on the other hand, are milled in their final form and may undergo an additional sintering cycle to enhance their mechanical properties. In addition to zirconia, which reinforces the ceramic structure and interrupts crack propagation, the material contains small silicate crystals in the lithium silicate glassy matrix, which has been shown to enhance the translucency of the material.

In contrast, the zirconia-based ceramic restorative material has strong mechanical properties yet very low translucency, and thus is mainly used as a core structure to be veneered by a more translucent ceramic material. To overcome this limitation, which often poses problems with maintaining the structural integrity of the restoration, high-translucency monolithic zirconia has been introduced to the market. This material is claimed to have adequate esthetic properties for use without the need for an overlay material. The manufacturers of high-translucency zirconia attribute the improved optical properties to the use of high-quality zirconia processing techniques and to a reduction in the aluminum content (0.1% weight). These modifications are claimed to reduce light scattering, and thus to improve translucency.

One alternative attempt to ensure the optimal properties of CAD/CAM restorative materials, such as adequate translucency, ease of polishing and high fracture resistance, involved combining the advantages of both ceramics and resins. To this end, resin nanoceramics have been produced in machinable CAD/CAM blocks, and are claimed to have satisfactory mechanical and esthetic properties. Another attempt involved the production of hybrid ceramics. These materials have a dual-network structure, in which the dominant porous sintered feldspathic ceramic network is strengthened by the methacrylate network, forming a ‘double network hybrid’ (DNH) or a ‘polymer-infiltrated ceramic network’ (PICN). The reported high flexural strength, good internal and marginal fit, and superior optical properties make hybrid ceramics a valuable restorative option.

In terms of optical properties, all CAD/CAM restorative materials are currently available in different shades and degrees of translucency to better match the clinical situation. Reports on CAD/CAM material translucency vary. Several studies have demonstrated a higher translucency for zirconia-reinforced glass ceramics than for lithium disilicate ceramics. The differences are attributed to the different grain size and crystalline structure of the materials. Resin nanoceramics have also been shown to have high translucency owing to their nano-sized zirconia and silica particles, decreasing light scattering. Hybrid ceramics, on the other hand, have been reported to have a lower translucency than other ceramics, which is attributed to their higher alumina content.

However, in addition to the initial color match and translucency of the material, its clinical esthetic stability is an important factor affecting its performance in oral conditions. It has been demonstrated that certain ceramic restorative materials may change color when subjected to staining solutions that simulate the consumption of regular beverages. Nevertheless, how different beverage ingredients and acidities affect the color stability of different CAD/CAM restoratives based on their composition and structure requires further investigation. Furthermore, limited literature has been found to assess a potential change in the translucency of materials in the oral environment. In the case of esthetic restorative materials, their stain susceptibility as well as a change in their translucency after being subjected to common beverages are of utmost concern. The aim of this study was to assess changes in the color and translucency of currently available CAD/CAM restorative materials after being subjected to different staining solutions. The tested null hypothesis was that the color and translucency of the tested CAD/CAM restorative materials would not be significantly affected by immersion in different staining solutions.

Material and methods

The properties and composition of the materials as well as their manufacturers are listed in Table 1.

A total of 160 ceramic specimens were prepared from the 5 tested CAD/CAM ceramic material groups (n = 32). The specimens from each ceramic group were divided into 4 subgroups (n = 8) according to the assigned staining solution. The color and translucency of the materials were assessed before and after staining. Thirty-two disc-shaped specimens (10 mm × 2 mm) were prepared from the 5 CAD/CAM restorative materials using a water-cooled low-speed diamond saw (Isomet®; Buehler, Lake Bluff, USA). The EMC (IPS-e.max®-CAD; Ivoclar Vivadent,
Schaan, Liechtenstein) specimens were subjected to a crystallization cycle for 10 min at 850°C in an appropriate oven (Programat® EP 5000; Ivoclar Vivadent) according to the manufacturer’s instructions. The LP (Lava™ Plus; 3M ESPE, Maplewood, USA) specimens were shaded with Lava Plus Dyeing Liquid shade A2, and then sintered according to the manufacturer’s instructions.

The surfaces of all specimens were polished under water cooling conditions with P400, P600, P800, P1000, and P1200 silicon carbide paper at 300 rpm. The thickness of all specimens was confirmed using a digital micrometer (Mastercraft Electronic Caliper; Canadian Tire Corporation Ltd., Toronto, Canada) to be 2.0 ±0.01 mm. All specimens were then ultrasonically cleaned in distilled water for 10 min. The specimen color was measured using a reflective spectrophotometer (model RM200QC; X-Rite GmbH, Neu-Isenburg, Germany). The aperture size was set to 2.0 ±0.01 mm. All specimens was measured using the same spectrophotometer against white (CIE \( L^* \)) and black (CIE \( L^* \)) backgrounds relative to the CIE standard illuminant D65.

The translucency parameter (TP) values were obtained by calculating the difference in the color of the specimens against black and white backgrounds using the following formula:

\[
TP = \left[ (L^*_b - L^*_w)^2 + (a^*_b - a^*_w)^2 + (b^*_b - b^*_w)^2 \right]^{1/2}
\]

where:
- \( TP \) – translucency parameter;
- \( L^* \) – degree of lightness;
- \( a^* \) – color coordinate on the red/green axis;
- \( b^* \) – color coordinate on the yellow/blue axis;
- the subscripts \( b \) and \( w \) refer to the color coordinates against black and white backgrounds, respectively.\(^{18}\)

The specimens from each tested group were randomly divided into 4 subgroups \((n = 8)\) according to the immersion medium (coffee, cola, ginger, and distilled water). To prepare the coffee solution, 20 g of coffee (Nescafé® Classic; Nestlé S.A., Vevey, Switzerland) was poured into 1,000 mL of boiled distilled water. The solution was stirred every 5 min for 10 s until it cooled to room temperature, and then it was filtered through a paper filter.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Brand</th>
<th>Composition</th>
<th>Average particle size</th>
<th>Code</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium disilicate</td>
<td>IPS-e.max-CAD (LT, A2)</td>
<td>58–80% silicon dioxide, 11–19% lithium oxide, 0–13% potassium oxide, 0–8% zirconium dioxide, 0–5% aluminum oxide</td>
<td>3–4 μm</td>
<td>EMC</td>
<td>Ivoclar Vivadent, Schaan, Liechtenstein</td>
</tr>
<tr>
<td>Zirconia-reinforced lithium silicate</td>
<td>Celtra Duo (LT, A2)</td>
<td>58% silicon dioxide, 10.1% crystallized zirconium dioxide, 10% zirconium dioxide, 5% phosphorous pentoxide, 2.0% ceria, 1.9% alumina, 1% terbium oxide</td>
<td>400–800 nm</td>
<td>CD</td>
<td>Dentsply Sirona, York, USA</td>
</tr>
<tr>
<td>High-translucency zirconia</td>
<td>Lava Plus (Lava Plus Dyeing Liquid A2)</td>
<td>tetragonal polycrystalline zirconia partially stabilized with 3% yttria, 0.1% alumina (details withheld as a trade secret)</td>
<td>400 nm</td>
<td>LP</td>
<td>3M ESPE, Maplewood, USA</td>
</tr>
<tr>
<td>Resin nanoceramic</td>
<td>Lava Ultimate (LT, A2)</td>
<td>80% w/w ceramic (69% silicon dioxide and 31% zirconium dioxide)</td>
<td>20 nm</td>
<td>LU</td>
<td>3M ESPE, Maplewood, USA</td>
</tr>
<tr>
<td>Hybrid ceramic</td>
<td>VITA ENAMIC (2M2-T)</td>
<td>86% w/w fine-structure feldspathic ceramic (58–63% silicon dioxide, 20–23% aluminum oxide, 9–11% sodium dioxide; 4–6% potassium oxide, and 0–1% zirconium dioxide)</td>
<td>–</td>
<td>VE</td>
<td>VITA Zahnfabrik, H. Rauter GmbH &amp; Co. KG, Bad Säckingen, Germany</td>
</tr>
</tbody>
</table>

LT – low-translucency; T – translucent; Bis-GMA – bisphenol A-glycidyl methacrylate; Bis-EMA – ethoxylated bisphenol-A dimethacrylate; UDMA – urethane dimethacrylate; TEGDMA – triethylene glycol dimethacrylate.

**Table 1.** Computer-aided design/computer-aided manufacturing (CAD/CAM) materials used in the study (data provided by the manufacturers)
Cola (Coca-Cola®; Coca-Cola Company, Atlanta, USA) at room temperature was used as the 2nd staining solution. The ginger solution was prepared by pouring 20 g of ginger (Royal Herbs S.A.E, Ottoman Group, Shabram, Giza, Egypt) into 1,000 mL of boiled distilled water. The solution was stirred every 5 min for 10 s until it cooled to room temperature, and then it was filtered through a paper filter. Distilled water (Health Aqua, Alexandria, Egypt) was used as the 4th immersion medium. After preparation, the pH of the solutions was measured using a pH meter (AD11; Adwa Instruments, Szeged, Hungary) and determined to be 2.5, 5.5, 8, and 6.9 for cola, the coffee solution, the ginger solution, and water, respectively.

The specimens were immersed individually in closed vials containing 5 mL of each immersion medium and stored in an incubator (model 431/V; C.B.M. S.r.l. Medical Equipment, Torre de’ Piscenardi, Italy) at 37°C for 28 days. The solutions were freshened daily to avoid yeast or bacterial contamination. To reduce the precipitation of particles in the staining solutions, the solutions were stirred twice a day. At the end of the immersion period, the specimens were rinsed with distilled water and wiped with gauze. Color and translucency were then reassessed.

The specimen color was assessed after employing different staining protocols as described for the baseline measurements. The color change (ΔE) of each specimen was calculated using the following formula:

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

where:

- \(\Delta L^*\) – change in color;
- \(\Delta L_{baseline} = L_{after staining} - L_{baseline}\);
- \(\Delta a^*\) – change in redness/greenness color parameter after staining – \(a_{baseline}\);
- \(\Delta b^*\) – change in yellow-blue color parameter after staining – \(b_{baseline}\).

The ΔE values greater than 1.2 were considered perceptible, whereas values greater than 2.7 were considered clinically unacceptable, according to the 50:50% threshold. Differences in the \(TP\) values were calculated using the following formula:

$$\Delta TP = TP_{after staining} - TP_{baseline}$$

where:

- \(\Delta TP\) – change in the translucency parameter.

The \(\Delta TP\) values greater than 2 were considered perceivable. The mean and standard deviation (SD) values of ΔE and \(\Delta TP\) were calculated for each subgroup. The data was explored for normality using the Kolmogorov–Smirnov test and the Shapiro–Wilk test, and showed a parametric (normal) distribution. For ΔE, the two-way analysis of variance (ANOVA) was performed to evaluate the effect of each variable (material group and staining solution). The one-way ANOVA followed by Tukey’s post hoc test was used if ANOVA showed a significant \(p\)-value. For \(\Delta TP\), the three-way ANOVA was performed to evaluate the effect of each variable (before vs after staining, material group and staining solution). The correlation between ΔE and \(\Delta TP\) was investigated using Pearson’s correlation coefficient. The significance level was set at \(p < 0.05\) throughout all statistical tests. The statistical analysis was performed with IBM SPSS Statistics for Windows, v. 20 (IBM Corp., Armonk, USA).

### Results

The means and SDs for ΔE are presented in Table 2. Irrespective of the staining solution, LP generally showed the most significant ΔE, whereas EMC showed the smallest ΔE, as proven by the two-way ANOVA (\(F = 19.15\); \(p \leq 0.0001\)).

The effect of different staining solutions on ΔE in the tested materials also varied significantly. Ginger and coffee had the most significant effect, followed by cola, whereas water had the least effect on ΔE, as demonstrated by the two-way ANOVA (\(F = 5.03\); \(p = 0.0035\)).

Ginger had the most significant effect on LP (ΔE = 4.01 ±1.2), cola on CD (Celtra Duo®; Dentsply Sirona, York, USA) (ΔE = 2.29 ±0.25) and coffee on LU (Lava® Ultimate; 3M ESPE) (ΔE = 2.59 ±0.17).

### Table 2. Color change (ΔE) values

<table>
<thead>
<tr>
<th>CAD/CAM restoring materials</th>
<th>Staining solutions</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cola</td>
<td>coffee</td>
</tr>
<tr>
<td>IPS-e.max-CAD</td>
<td>1.05 ±0.25</td>
<td>1.23 ±0.29</td>
</tr>
<tr>
<td>Celtra Duo®</td>
<td>2.29 ±0.25</td>
<td>0.82 ±0.17</td>
</tr>
<tr>
<td>Lava Plus®</td>
<td>1.83 ±0.04</td>
<td>3.88 ±1.50</td>
</tr>
<tr>
<td>Lava Ultimate®</td>
<td>1.65 ±0.40</td>
<td>2.59 ±0.17</td>
</tr>
<tr>
<td>VITA ENAMIC®</td>
<td>0.88 ±0.04</td>
<td>1.60 ±0.09</td>
</tr>
<tr>
<td>Total</td>
<td>1.53 ±0.46</td>
<td>2.05 ±1.01</td>
</tr>
</tbody>
</table>

Data presented as mean ± standard deviation (SD). Different superscripts indicate significant differences within the same restorative material group after being subjected to different staining solutions. Different subscripts indicate significant differences between different restorative materials after being subjected to the same staining solution.
The means and SDs for ΔTP are presented in Table 3. In general, TP was significantly higher before staining than after staining, as indicated by the three-way ANOVA (F = 35.56; p ≤ 0.0001). There were no significant differences in ΔTP between the different types of ceramic material groups (p > 0.05). There were no significant differences in ΔTP between the different types of staining solutions as well (p > 0.05).

The correlation test showed that there was a moderate negative (inverse) correlation between ΔTP and ΔE (r = −0.693), indicating that with increased ΔE, a decreased translucency was observed for all the materials and all the immersion solutions tested (Fig. 1).

**Discussion**

A thorough understanding of the optical properties of currently available CAD/CAM restorative materials is crucial for predicting the longevity of the esthetic outcome of monolithic restorations.

The consumption of a variety of foods and beverages exposes restorations to staining and pH fluctuations, which may influence their esthetic properties while in service. In the current study, the effects of commonly consumed beverages (coffee, cola, ginger, and water) on the color and translucency of CAD/CAM restorative materials was investigated. The specimens were immersed in different solutions for 4 weeks, simulating an average of 2½ years of clinical aging.

The results of the current study indicate that the most significant ΔE after immersion in different staining solutions occurred in the LP group. Lava Plus is a high-translucency zirconia material, formulated to produce monolithic restorations without the need for a veneering ceramic. For this material, all changes were considered perceptible (above the 1.2 threshold), whereas changes resulting from immersion in coffee and ginger were above the 2.7 threshold of being clinically unacceptable. It has been shown that zirconia, when in contact with water, can undergo a progressive phase transformation, also known as low-temperature degradation (LTD), which can occur as soon as in 7 days of in vitro exposure.

This transformation process, from the tetragonal to monolithic phase (T-M transformation), is accompanied by the roughness of the surface, particle displacement and water penetration within the material. This transformation can clearly explain a significant ΔE observed in the high-translucency zirconia material after immersion in different staining solutions, even after immersion in distilled water. Notably, the ginger solution had the most significant effect on the color of LP. The ginger drink prepared in the current study had an alkaline pH. It has been shown that the exposure of zirconia to corrosive alkaline media may lead to an enhanced loss of the yttria stabilizer, more surface irregularities and an increase in the T-M transformation, ultimately resulting in an increase in the staining potential. In fact, Novak and Kalin demonstrated the significance of the pH of an aqueous solution in terms of the wear of zirconia ceramics. The authors noted that in alkaline media, zirconia exhibited exaggerated wear, probably due to a localized, hydrothermally induced phase transformation; this wear was accompanied by the severe fracture and degradation of the surface layer of the material.

**Table 3. Translucency parameter change (ΔTP) values**

<table>
<thead>
<tr>
<th>CAD/CAM restorative materials</th>
<th>Staining solutions</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cola</td>
<td>coffee</td>
</tr>
<tr>
<td>IPS-e.max-CAD</td>
<td>−2.39 ±1.70</td>
<td>−0.87 ±0.07</td>
</tr>
<tr>
<td>Celtra Duo</td>
<td>−1.09 ±0.02</td>
<td>−0.34 ±0.72</td>
</tr>
<tr>
<td>Lava Plus</td>
<td>−0.90 ±0.35</td>
<td>−2.34 ±1.00</td>
</tr>
<tr>
<td>Lava Ultimate</td>
<td>−0.61 ±1.20</td>
<td>−0.97 ±1.30</td>
</tr>
<tr>
<td>VITA ENAMIC</td>
<td>−0.57 ±0.29</td>
<td>−1.44 ±0.89</td>
</tr>
<tr>
<td>Total</td>
<td>−0.86 ±0.63</td>
<td>−1.05 ±0.22</td>
</tr>
</tbody>
</table>

Data presented as mean ±SD.
For the LU group, all ΔE values were considered perceptible, except for a change resulting from water immersion. No changes were higher than 2.7, or clinically unacceptable. The greatest change was observed in the case of immersion in coffee. For EMC and VE (VITA ENAMIC®; VITA Zahnfabrik, H. Rauter GmbH & Co. KG, Bad Säckingen, Germany), only immersion in coffee and ginger resulted in changes that were above 1.2, or perceptible. Changes after immersion in cola and water were below the 1.2 threshold.

These results indicate that the tested ceramic materials having a resin component (LU and VE) generally showed a greater discoloration than the tested glass ceramics (EMC and CD). This greater discoloration tendency may be attributed to a greater water sorption potential of the resin than compared to the glass ceramic materials. According to the manufacturers, VE contains the urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA) monomers, while LU contains a mixture of monomers comprising bisphenol A-glycidyl methacrylate (Bis-GMA), ethoxylated bisphenol-A dimethacrylate (Bis-EMA), UDMA, and TEGDMA. Differences in the staining potential between the 2 materials, although statistically non-significant (1.42 ±0.54 and 1.59 ±0.66 for VE and LU, respectively), may be explained by the different monomer composition of their resin components. For both VE and LU, immersion in coffee resulted in perceptible color changes. A greater potential of coffee to stain resin-containing materials could primarily be due to the capacity of the yellow pigments in coffee to penetrate the microstructure of these materials. This change may also be enhanced by the low polarity of the coffee solution, which facilitates a deeper ingress of the pigments into resin matrices. It has also been reported that solutions with pH ranging from 4 to 6 have a greater potential for ingress into resin materials, which in the case of the mildly acidic coffee solution (pH 5.5) would be an enhancing factor. Our results are supported by those of Saba et al., who found that the VE material stained significantly compared to a feldspathic ceramic when subjected to coffee solutions. If the same theory applied, i.e., that resins have a higher tendency to stain in mildly acidic media, then cola drinks, with their higher acidity, would have a reduced staining effect on resin-containing ceramic materials, as was observed in this study in the LU and VE groups. In fact, several studies have shown that despite their acidity, cola drinks result in minimal staining of resinous materials compared to other dark beverages. Another factor that could reduce the staining effect of cola on resins is its phosphate ion content, which may decrease the dissolution of the resin surface, as these ions have been shown to have a similar effect on the tooth surfaces.

In contrast, it was observed that cola had the greatest staining effect on the CD specimens. Interestingly, CD is composed of 5% w/w phosphorous pentoxide, which is the same compound used to produce phosphorous acids for cola drinks. This may have enhanced the affinity of cola to the material. In addition, it has been reported that phosphorous pentoxide is highly hygroscopic, having extreme affinity for water, which may have resulted in a greater sorption of the cola liquid into the CD material than into other tested CAD/CAM blocks containing no phosphorous pentoxide.

In addition to evaluating ΔE, the current study aimed to assess a potential change in the translucency of CAD/CAM restorative materials after being subjected to different common beverages. The importance of translucency in determining the esthetics of the restoration has been well-recognized, as translucency refers to the passage of light through the material, which can give the restoration a life-like appearance. The transparency parameter measures the difference in the color of the material of a uniform thickness when placed against white and black backgrounds, and has been shown to directly correspond to a visual assessment of translucency. Variations in material translucency have been attributed to the different chemical composition, grain size, crystal line structure, pores, additives, defects, and surface texture of the materials. Since preliminary options vary and can match the initial clinical situation, the current study focused on a potential change in the translucency of CAD/CAM restorative materials after being subjected to different common beverages rather than on their original translucency. The analysis of the change would allow a better understanding of the optical behavior of the material in different oral conditions and facilitate material selection to conform to different clinical situations.

In the current study, the TP values recorded after staining were significantly lower than those at baseline in all the tested materials; nevertheless, according to Lee, these changes would not be regarded perceptible, as they did not exceed the limit of 2. Changes in translucency can generally be attributed to changes in either the material body or surface texture. There were also no significant differences between different materials or between different staining solutions. However, the greatest ΔTP was recorded in the LP group, which may be attributed to possible LTD, which occurs on the surface of the material when in contact with moisture, as discussed for ΔE. On the other hand, a decreased translucency of the tested resin-containing materials (VE and LU) may be attributed to changes in the material body resulting from possible water sorption by the resin component. The smallest ΔTP was generally recorded for CD, which may be due to its structural composition, comprising nano-sized silicate crystals in the lithium silicate glassy matrix, enhancing its translucency and possibly stabilizing the material.

The correlation test indicated a moderate negative correlation between ΔTP and ΔE (r = −0.693), suggesting that increased ΔE corresponded to a decreased translucency for all the materials and all the immersion solutions.
tested. This correlation could imply that $\Delta E$ occurring due to the adsorption or absorption of pigments, water sorption, or a change in surface texture will be accompanied by a change in the light scattering properties of the materials.

The results of the current study have led to the rejection of the null hypothesis tested, as the color and translucency of the tested CAD/CAM restorative materials were significantly affected by immersion in different staining solutions. A factor that warrants further investigation is the surface texture of the material, since this feature has a determining effect on the optical properties of the material.

In the present study, the finishing of the surfaces of all specimens was standardized at baseline using the same procedure; nevertheless, surface texture could have been affected by different immersion media, and in turn could have influenced $\Delta E$ and $\Delta TP$. Studying changes in surface texture in response to immersion in different staining solutions was beyond the scope of this study and would require further investigation.

**Conclusions**

Within the limitations of this in vitro study, the following could be concluded. Staining solutions had a marked effect on both the color and translucency of all the tested CAD/CAM materials. IPS-e.max-CAD showed the greatest color stability. Lava Plus stained with ginger and coffee showed a clinically unacceptable color change. The resin-containing materials were most affected by the coffee and ginger solutions, whereas the zirconia-reinforced lithium silicate material by cola drinks. Despite the differences in the initial translucency of the materials, staining had an equal effect on all materials.

The clinical judgment could include the consideration of the patients’ beverage consumption habits, which might be a decisive factor when selecting the restorative material of choice.

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