Comparative assessment of various composite materials and natural tooth tissue translucencies

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Abstract

Objectives: The aim of this study was to compare the translucency levels of various composite materials that are positioned by their manufacturers as ‘dentin,’ ‘opaque,’ ‘body,’ and ‘enamel’ in relation to natural tooth tissues.

Methods: Sixteen commercial composite materials and 10 natural tooth tissue samples (enamel and dentin) were studied. The differences in color of dried and hydrated samples were measured on a black-and-white background using CIELab coordinates. Analysis of variance (ANOVA) and Kruskal-Wallis tests were used to compare the translucency parameter (TP) values of the different materials (P < 0.05), and t test was used to compare the TP values for the dried and hydrated samples, with the significance set at P < 0.001.

Results: The TP values of opaque shades for the studied composite materials ranged from 1.5 to 3.9, and those of enamel shades from 3.9 to 10.9. According to the obtained results, a body shade sample had a high level of translucency, comparable with some enamel shades of the materials studied (TP = 4.489 ± 0.505 after polymerization, and 3.916 ± 0.566 after 48 h of water storage). The translucency levels of dry composite samples and samples after hydration were not significantly different, while significant changes were observed for dentin and enamel (P < 0.05).

Significance: Choosing a composite material that is suitable for different clinical situations is a major challenge in everyday dental practice. Information about the relative translucency of various composites on the market and their compliance with natural tissues can help dentists to choose optimal restorative materials.

Introduction

Composite materials are among the most commonly used restorative materials in dental practice due to their high esthetic characteristics, relatively high strength and resistance to abrasion, good adhesive properties, and acceptable price compared with ceramic materials. Currently, the world market offers a wide variety of materials for esthetic restoration. To imitate the color, morphology, and optical properties of natural teeth, the manufacturers offer not only a large number of composite shades, but also materials with various translucency/opacity levels. To achieve the optimal esthetic result, it is very important to choose a composite material individually for each clinical situation.

The restoration of Black’s class III and IV cavities is challenging for clinicians due to the absence of underlying tooth tissue for the available restorative materials. Without sufficient opacity, even an ideally shaded composite material looks gray, since the relatively transparent material is not able to hide the darkness of the oral cavity. The opaque shades can also be used to mask discolored natural tooth tissue before applying more transparent enamel composite layers.

The successful restoration of discolored teeth or teeth with through defects largely depends on such factors as the color of the underlying tissue and the restorative material, the composite layer thickness, and the composite opacity level. According to Kim et al., a 0.5- to 1-mm-thick opaque composite layer is sufficient to cover a C4 background, whereas a thicker layer (1 to 2 mm) is needed to cover a black background. That is, the amount of an opaque shade composite may be small in the case of a slight change in tooth tissue color, but more material is typically required for a restoration of through defects or pronounced discolorations.

If there is no need to mask the tooth tissue discoloration or metal structures in order to achieve the best esthetic results, it is advisable to choose a restorative material that is as close as possible to enamel and dentin in terms of its optical properties. However, despite the large variety of composite materials on the market, not all of them meet the necessary requirements.

This issue has recently received a lot of attention because the esthetic requirements for direct restorations are very high nowadays among dentists and patients. According to various studies, the translucency level of composite materials differs significantly, not only between different shade groups (dentin, opaque, body, and enamel), but also within each group, thus significantly complicating the clinician’s choice of restorative material. Another important issue is the dependence of the translucency level of different composite materials and natural tooth tissues on the degree of moisture/dehydration. According to Ozakar Ilday et al., the translucency level of some composites can change with prolonged exposure to a liquid medium. It was also reported that the main changes in the translucency of materials occur after a short exposure time. These changes may lead to some differences between the optical properties of the composite and the natural tooth tissue some time after the restoration procedure.

To achieve more predictable results, both during the treatment procedure and in the long term, dentists require comprehensive information, not only about the composition and strength characteristics of the material used, but also about optical properties and factors that can affect them.

The objective of this study was a comparative assessment of the translucency levels of various composite materials, positioned by their manufacturers as ‘dentin,’ ‘opaque,’ ‘body,’ and ‘enamel,’ in relation to natural tooth tissue.
Table 1  Comparative characteristics of the studied composite materials

<table>
<thead>
<tr>
<th>Brand</th>
<th>Manufacturer</th>
<th>Type of composite</th>
<th>Shade</th>
<th>Loading (%)</th>
<th>Size and type of filler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtek Ultimate</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td>Nanofilled composite resin</td>
<td>A2 enamel (A2E)</td>
<td>78.5 (by weight)</td>
<td>Non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A2 dentin (A2D)</td>
<td>63.3 (by volume)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A2 body (A2B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premise</td>
<td>Kerr, Scafati, Italy</td>
<td>Nanohybrid composite resin with prepolymerized fillers</td>
<td>A2 enamel (A2E)</td>
<td>84 (by weight)</td>
<td>Barium-aluminum-borosilicate glass (mean particle size 0.4 μm), silica nanofiller (20 nm), prepolymerized filler</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>XL1 enamel (XL1E)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A2 dentin (A2D)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herculite Ultra</td>
<td>Kerr, Scafati, Italy</td>
<td>Nanohybrid composite resin with prepolymerized fillers</td>
<td>A2 enamel (A2E)</td>
<td>75 (by weight)</td>
<td>Barium-aluminum-borosilicate glass (mean particle size 0.4 μm), silica nanofiller (50 nm), prepolymerized filler</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A2 dentin (A2D)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gradia Direct Anterior</td>
<td>GC Corp, Tokyo, Japan</td>
<td>Microhybrid composite resin with prepolymerized fillers</td>
<td>A2 enamel (A2E)</td>
<td>73 (by weight)</td>
<td>Silica filler (mean particle size 0.85 μm), fluoride-alumino-silicate glass (mean particle size 0.85 μm), prepolymerized filler</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A2 opaque (AO2)</td>
<td>64 (by volume)</td>
<td></td>
</tr>
<tr>
<td>Ceram X duo</td>
<td>Dentsply De Tray GmbH, Germany</td>
<td>Nanohybrid composite resin with prepolymerized fillers</td>
<td>E2</td>
<td>77–79 (by weight)</td>
<td>Barium-aluminum-borosilicate glass, silicon dioxide nano filler, pre-polymerized SphereTEC fillers (3.5–15.0 μm), non-agglomerated barium glass and ytterbium fluoride</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D2</td>
<td>59–61 (by volume)</td>
<td></td>
</tr>
<tr>
<td>Estelite Sigma Quick</td>
<td>Tokuyama Dental Corp, Tokyo, Japan</td>
<td>Submicron-filled composite resin</td>
<td>A2 enamel (A2E)</td>
<td>82 (by weight)</td>
<td>Silica-zirconia filler (0.1–0.3 μm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A2 opaque OPA2</td>
<td>71 (by volume)</td>
<td></td>
</tr>
<tr>
<td>Enamel Plus HRI</td>
<td>GDF GmbH, Rosbach, Germany</td>
<td>Nanohybrid composite resin</td>
<td>UE2</td>
<td>80 (by weight)</td>
<td>Glass filler: mean particle size 0.7 μm, Highly dispersed silicone dioxide: mean particle size 0.04 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UD2</td>
<td>75 (by weight)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microhybrid composite resin</td>
<td></td>
<td>53 (by volume)</td>
<td></td>
</tr>
</tbody>
</table>
Materials and methods

In this study, a comparative assessment of the translucency levels of 16 different methacrylate-based composite materials (Table 1) of A2 shade according to the Vita scale was carried out. In the absence of such a shade in the color palette of a chosen material, the nearest equivalent color was selected. The study also included an XL1 shade (Premise; Kerr), which refers to enamel shades (very light-toned/bleached teeth); however, clinically it shows a high opacity level. For each composite, five samples were prepared.

Methods

The samples were prepared using special plastic molds in the form of discs with a diameter of 5 mm and a thickness of 2 mm. The molds were filled with the tested composite materials, then placed between two glass plates covered with parchment paper. A load weight was placed on the surface to achieve uniform thickness and to extrude the excess material. A polymerization procedure was carried out with the high-power Demi Plus LED light-curing system (1100 to 1330 mW/cm²) (Kerr). The enamel composite shades (2-mm depth) were cured for 5 s, and the opaque composite shades (2-mm depth) for 10 s, in accordance with the manufacturers’ recommendations. Samples of enamel (n = 5) and dentin (n = 5) with a thickness of 2 mm were prepared and used as controls.

The use of extracted teeth for scientific research was approved by the Local Ethics Committee of Sechenov University (no. 0417 of 17 April 2017). The teeth were extracted in the context of the treatment plan, and all patients gave their written informed consent for the use of their extracted teeth for scientific research.

The translucency of the samples: level determination

The ability of the tested composites to mask the discoloration and darkness of the oral cavity was determined by measuring the difference in color of samples on black (L* = 4; a* = 0.1; b* = -0.37) and white (L* = 91.1; a* = 0.89; b* = -2.86) backgrounds in CIELab coordinates (Fig 1).

Using the SpectroDens Premium spectrophotometer (Techkon) with an aperture size of 4 mm, the following indexes for the prepared samples on a black-and-white background were recorded: index L – brightness coordinate that varies from 0 (black) to 100 (white); index a – red-green color coordinate; index b – blue-yellow color coordinate. The translucency parameter was then calculated according to the following formula:

![Images of enamel samples on a black-and-white background.](image-url)
Table 2  TP values of enamel shades of the studied composites

<table>
<thead>
<tr>
<th>No.</th>
<th>Material</th>
<th>After polymerization</th>
<th>After 48 h of water storage</th>
<th>t test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>t value</td>
<td>P value</td>
<td>t value</td>
</tr>
<tr>
<td>1</td>
<td>Ceram X duo E2</td>
<td>10.91 ± 0.11</td>
<td>10.50 ± 0.14</td>
<td>5.69</td>
</tr>
<tr>
<td>2</td>
<td>Filtek Ultimate A2E</td>
<td>5.45 ± 0.29</td>
<td>5.27 ± 0.27</td>
<td>1.29</td>
</tr>
<tr>
<td>3</td>
<td>Gradia Direct Anterior A2E</td>
<td>5.4 ± 0.14</td>
<td>5.21 ± 0.13</td>
<td>1.80</td>
</tr>
<tr>
<td>4</td>
<td>Enamel Plus HRI UE2</td>
<td>4.88 ± 0.25</td>
<td>4.78 ± 0.29</td>
<td>0.53</td>
</tr>
<tr>
<td>5</td>
<td>Estelite Sigma Quick A2E</td>
<td>4.57 ± 0.12</td>
<td>4.25 ± 0.14</td>
<td>3.81</td>
</tr>
<tr>
<td>6</td>
<td>Herculite Ultra A2E</td>
<td>4.24 ± 0.10</td>
<td>4.29 ± 0.09</td>
<td>0.68</td>
</tr>
<tr>
<td>7</td>
<td>Filtek Ultimate A2B</td>
<td>4.49 ± 0.51</td>
<td>3.92 ± 0.57</td>
<td>1.09</td>
</tr>
<tr>
<td>8</td>
<td>Premise A2E</td>
<td>3.86 ± 0.24</td>
<td>4.06 ± 0.19</td>
<td>2.44</td>
</tr>
<tr>
<td>9</td>
<td>Natural human enamel</td>
<td>7.99 ± 0.85</td>
<td>9.59 ± 0.73</td>
<td>6.49</td>
</tr>
<tr>
<td></td>
<td>ANOVA test</td>
<td>F value</td>
<td>326.2</td>
<td>235.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P value</td>
<td>&lt; 0.001*</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td></td>
<td>Kruskal-Wallis test</td>
<td>H value</td>
<td>35.12</td>
<td>36.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P value</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

* The difference is statistically significant.

\[ TP = \sqrt{(L_1^*-L_2^*)^2 + (a_1^*-a_2^*)^2 + (b_1^*-b_2^*)^2} \]

The TP values of the composite samples were determined 48 h after light curing (dark storage) to avoid the influence of post-cure polymerization on the results.

To determine the difference between the TP values before and after hydration, the prepared samples of the composite materials and the natural tooth tissue were kept in distilled water for 48 h at a temperature of 37°C for hydration. All measurements were repeated after water storage.

The TP values for enamel and dentin were calculated before and after the hydration procedure (37°C, 48-h water storage).

Statistical analysis

Data were calculated as mean ± standard deviation (SD). Analysis of variance (ANOVA) and Kruskal-Wallis tests were performed to compare the TP values of the different materials \((P < 0.05)\), and the \(t\) test was used to compare the TP values for dried and hydrated samples, with the significance set at \(P < 0.001\). The Kolmogorov-Smirnov test was performed to check the normality of distribution in all groups. The Pearson correlation coefficient \((r)\) was calculated to analyze the relationship between the filler loading and the TP values of the composite specimens.

Results

The results obtained are shown in Tables 2 and 3.

Both in the natural enamel and the enamel shade samples of the composite materials, the TP value exceeded 3.3. At the same time, the ANOVA and Kruskal-Wallis tests confirmed significant differences in the TP values of different samples within the dried and hydrated groups \((P < 0.001)\).

The highest TP values were obtained for Ceram X duo E2: 10.91 ± 0.11 after polymerization, and 10.50 ± 0.14 after the hydration.
procedure. These values were significantly higher than the TP values obtained for natural human enamel. For all the other materials, the TP values varied from 3.9 to 5.4, and were lower than the translucency level of natural human enamel. The minimum translucency was observed for Premise A2E samples: 3.86 ± 0.24 after polymerization, and 4.06 ± 0.19 after hydration.

No significant correlation was found between the filler loading and the TP values of the dried enamel shade specimens (r = -0.187), and the specimens after the hydration procedure (r = -0.176). Figure 2 demonstrates the relationships between the filler loading (FL, %) and the TP values of the dried and hydrated enamel shade specimens.

In most cases, the hydration procedure did not significantly influence the translucency levels of the tested composite materials. A relatively significant decrease was observed only for Estelite Sigma Quick A2E (P = 0.019) and Ceram X duo E2 (P = 0.005) composites, but the observed differences were not of clinical significance, since the changes were too small and the translucency of the samples remained high enough. By contrast, the translucency level of natural human enamel after 48 h of water storage significantly increased, from 7.99 ± 0.85 to 9.59 ± 0.73 (P = 0.003).

The TP values of the opaque shades for the tested composite materials ranged from 1.5 to 3.9. Compared with the enamel shades, the ANOVA and Kruskal-Wallis tests confirmed significant differences in the TP values of different samples within the dried and hydrated groups. The highest TP value was obtained for Enamel Plus HRi UD2: 3.00 ± 0.44 after polymerization, and 3.90 ± 0.21 after hydration. The lowest translucency levels were observed for the opaque shades Filtek Ultimate, Herculite Ultra, and Premise (TP < 2). For all the composite materials, the TP values were lower than for the natural human dentin.

<table>
<thead>
<tr>
<th>No.</th>
<th>Material</th>
<th>After polymerization</th>
<th>After 48 h of water storage</th>
<th>t test</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Enamel Plus HRi UD2</td>
<td>3.00 ± 0.44</td>
<td>3.90 ± 0.21</td>
<td>3.25</td>
<td>0.031*</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ceram X duo D2</td>
<td>2.77 ± 0.20</td>
<td>2.28 ± 0.21</td>
<td>6.37</td>
<td>0.003*</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Estelite Sigma Quick OPA2</td>
<td>2.69 ± 0.16</td>
<td>2.57 ± 0.19</td>
<td>0.93</td>
<td>0.406</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Gradia Direct Anterior AO2</td>
<td>2.68 ± 0.46</td>
<td>3.03 ± 0.46</td>
<td>1.85</td>
<td>0.139</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Premise A2D</td>
<td>1.85 ± 0.10</td>
<td>1.93 ± 0.11</td>
<td>1.04</td>
<td>0.359</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Premise XL1</td>
<td>1.61 ± 0.06</td>
<td>1.81 ± 0.08</td>
<td>3.93</td>
<td>0.017*</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Herculite Ultra A2D</td>
<td>1.56 ± 0.20</td>
<td>1.91 ± 0.22</td>
<td>2.23</td>
<td>0.089</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Filtek Ultimate A2D</td>
<td>1.47 ± 0.08</td>
<td>1.54 ± 0.08</td>
<td>2.11</td>
<td>0.102</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Natural human dentin</td>
<td>5.19 ± 0.99</td>
<td>6.96 ± 1.07</td>
<td>2.91</td>
<td>0.044*</td>
<td></td>
</tr>
</tbody>
</table>

ANOVA test

<table>
<thead>
<tr>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.94</td>
<td>&lt; 0.001*</td>
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</tbody>
</table>

Kruskal-Wallis test

<table>
<thead>
<tr>
<th>H value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.76</td>
<td>&lt; 0.001*</td>
</tr>
</tbody>
</table>

* The difference is statistically significant.
No significant correlation was detected between the filler loading and the TP values of the opaque shade specimens ($r = -0.393; P > 0.05$). After the hydration procedure, the correlation coefficient ($r$) was $-0.513; P > 0.05$ (Fig 3).

From a practical point of view, the hydration procedure did not significantly influence the translucency levels of the composite materials. A significant translucency decrease was observed only for Ceram X duo D2 samples ($P = 0.003$). By contrast, Premise XL1 and Enamel Plus HRI UD2 showed statistically significant TP increases ($P = 0.017$ and $P = 0.031\%$, respectively). However, in all cases, the changes were not significant enough to influence the clinical use.

The translucency level of natural human dentin after 48 h of water storage increased from $5.19 \pm 0.99$ to $6.96 \pm 1.07$, and the difference was statistically significant ($P = 0.044$).

**Discussion**

**The influence of composition on composite resin translucency**

The optical properties of composite resin materials can be modified by the addition of optical modifiers (pigments and opacifiers). Titanium dioxide and aluminum oxides in amounts of 0.001 to 0.007 (wt%) are commonly used as opacifiers.10,11

The manufacturers of the studied composites do not provide complete information about the type of optical modifiers in the resins, so the underlying reasons for the observed differences in the behavior of the tested materials are not clear. According to data in the literature, the composition of filler load and filler particles as well as the size and composition of resin matrix can influence composite translucency. Lee12 reported that the TP value is negatively correlated with the amount of filler if the filler size is unchanged.

In our study, no significant correlation was detected between the filler loading and the TP values of the enamel or the opaque shade specimens ($r = -0.187$ and $r = -0.393$, respectively). After the hydration procedure, the correlation coefficients ($r$) were $-0.176$ and $-0.513$, respectively.

Salgado et al13 studied three model composites with silica fillers in nanoscale of 7 nm, 12 nm, and 16 nm. The filler size did not influence the $\Delta E^*$ and TP values, although a trend was observed toward lower values in smaller filler materials. In our study,
one nanofilled-, four nanohybrid-, two microhybrid-, and one submicron-filled composite resin materials were tested. The TP values of the enamel shade composites were 5.4 (a microhybrid composite sample) and 4.6 (a submicron composite sample); they varied from 4.5 to 5.4 in the group of nanofilled samples, and from 3.9 to 10.9 in the group of nanohybrid samples. The TP values of the opaque shade composites were 1.5 (a nanofilled composite sample) and 2.7 (a submicron composite sample); they ranged from 2.7 to 3.0 in the group of microhybrid samples, and from 1.6 to 2.8 in the group of nanohybrid samples.

A limitation of our study was that no correlation was obtained between filler size and composite resin translucency, which could be due to the hybrid structure of most of the studied materials.

Azzopardi et al. studied three types of unfilled composite resin matrices (TEGDMA-, UDMA-, and BisGMA-based) and six experimental resins with constant filler loading but with various types of monomers. There were no statistically significant differences in translucency between the unfilled resins. However, with the addition of filler, the BisGMA-containing resins showed significantly higher transmittance values than the UDMA- and TEGDMA-based resins. Regression analysis revealed a linear correlation between the percentage of BisGMA in the resin matrix and the total resin translucency. Siloran-based materials are supposed to be less translucent than dimethacrylate-based composites. In our study, all the tested materials were based on methacrylate. However, the manufacturers do not give any information about the percentage of BisGMA and other matrix types in the composition of their restorative materials. It was therefore impossible to assess the correlation between matrix composition and composite resin translucency in this study.

Naemi Akbar et al. investigated the influence of color on the TP value of two commercially available composites, Filtek Supreme and Esthet-X. These authors concluded that the translucency within each shade category can be significantly influenced by color as observed within the body shade group. The translucency of Filtek Supreme body shades decreased significantly from A2B to D2B. A significant decrease was observed in the transmittance from A2 to C2 of regular body shades, and also from A4 to C4 of opaque dentin shades of Esthet-X composite resin. In our study, all the specimens were of one color (A2), so the influence of the color factor on the TP value was excluded.

**Other factors affecting composite resin translucency**

In laboratory studies, the results of TP value measurements can be influenced by specimen thickness and surface roughness, background color, light curing and finishing, time of water storage, and aperture size.

In a study by Ikeda et al., the translucency values of 2-mm-thick A2 shade composite specimens were investigated. The TP values were 3.6 to 5.1 for enamel shades, and 1.7 to 4.9 for opaque shades. Significant differences in the TP values were observed for various brands.

Ryan et al. evaluated the translucency of different composite materials. The resulting
range of translucency parameters for the studied 2-mm-thick specimens represented a continuum from the most- to the least-opaque samples (TP ranged from 2.7 to 13.4). Ceram X duo E2 was the most translucent composite (TP = 13.4 ± 0.5).

According to the experimental data obtained in our study, the TP of tested samples varied from 1.5 to 3.9 for opaque shades, and 3.9 to 5.4 for enamel shades. Ceram X duo E2 demonstrated the highest translucency (TP = 10.91 ± 0.11 after polymerization, and 10.49 ± 0.14 after the hydration procedure).

Deviations from mean values for the studied composite samples were insignificant, which can be explained by the homogeneity of their structure.

In general, the results of our study correlate with the data of other researchers, and some differences between the TP values can be explained by modified experimental conditions such as background color or aperture size.

Jonston noticed that the results of different studies are difficult to compare due to the variability of the experimental protocols.

Most studied samples demonstrated no significant differences in the TP values of dry and hydrated composite materials, probably due to the relatively short water storage period of 48 h, whereas according to Poiurovskaia et al., the main changes in composite materials take place during the first month.

When studying the influence of water storage on optical properties of composite resin materials, researchers demonstrated a wide range of results. Diamantopoulou et al. studied changes in the TP of different resin composites after 1 week and 1 month of water storage. These authors found that water aging for 1 week resulted in significant changes (both increases and decreases) in the TP of some composites. The most pronounced changes in the TP values were registered for HRI UD2. In our study, we also observed the changes in translucency of Enamel Plus HRI UD2 even after 48 h of water storage. An in-depth study on the dependency of optical properties of composite materials on the duration of water storage is planned for the future.

Translucency of natural tooth tissues

When studying differences in color of natural enamel and dentin samples on a black-and-white background, in both cases the TP was higher when compared with the composite samples. Only Ceram X duo E2 showed a higher translucency level than natural enamel.

In our study, the TP values of natural human enamel ranged from 8.0 to 9.6, while the TP values of natural dentin samples ranged from 5.2 to 7.0 for dried and hydrated samples, respectively. Significant changes were found for dentin and enamel samples; after hydration, the translucency of natural tooth tissues increased significantly ($P < 0.05$) (Fig 4).

When determining the translucency level of natural dentin, SD values were signifi-
cantly higher than those of composite and enamel samples, both before and after rehydration. It can be assumed that this is due to the irregular structure of dentin in various sections of the crown (parapulpar dentin, mantle dentin) (Fig 5).

According to Ryan et al, the mean translucency parameter for representative samples of 2-mm tooth enamel (11.6) was also relatively high, but lower than that of Ceram X duo E2.

According to Yu et al, the TP values for 1-mm-thick human enamel and human dentin were 18.7 and 16.4, respectively. Hasegawa et al reported a TP value of 15 for 1-mm-thick human enamel.

As regards the results of our study, the difference could be due to different specimen thicknesses, as the translucency of 2-mm-thick human tooth tissue was measured.

Dehydrated enamel typically shows a lower translucency. According to Soler et al, 2-mm-thick pure enamel shows significant changes in TP, even within the first day after tooth extraction.

According to Nakajima et al, dentin has different light transmission characteristics compared with resin composites, and these depend on the thickness of the material. However, regardless of the thickness, dentin has lower TP values than resin composites. At the same time, in the present study, the TP of dentin was higher than that of composite opaque samples (as mentioned above).

In the study by Ryan et al, the translucency of the specimens of human dentin was more variable compared with the enamel specimens. The mean translucency parameter for the samples of tooth dentin was 6.6, and fell between the parameters obtained for the dentin and opaque composites as well as those obtained for the universal and body composites.

The translucency of human dentin depends on localization, mineralization level, and aging. Pop-Ciutrila et al demonstrated the higher TP value of molar dentin compared with incisor and canine dentin.

**Clinical significance**

Researchers do not have a common approach to the clinical criteria of translucency graduation. Most researchers consider that $\Delta E \leq 1$ cannot be appreciated by the human eye. According to some studies, $\Delta E > 1$ and $< 3.3$ is clinically acceptable and can be recognized by skilled operators. In this range, $\Delta E > 1$ and $< 2$ is frequently detected by observers, and $\Delta E > 2$ is detected by all observers. Ragain and Johnston examined color difference acceptability and reported the average acceptability threshold as 2.72. Makeeva et al defined the allowed $\Delta E$ level as 2.8. Taking into account the individual features and differences in structure and morphology of organs and tissues, most researchers consider $\Delta E > 3.3$ to be clinically unacceptable. In studies on dental materials, translucency $\Delta E$ is equivalent to TP. In our study, therefore, TP $< 3.3$ was considered clinically acceptable.

According to the experimental data obtained in our study, the TP values below 2 were registered for three dentin/opaque samples (Filtek Ultimate A2D, Premise A2D, and Herculite Ultra A2D), and for one enamel sample (Premise XL1) (Table 3). These composites are able to mask altered color tissue, and can be recommended for direct restorations to correct discolorations. Filtek Ultimate A2D, Premise A2D, and Herculite Ultra A2D can also be materials of choice for the restoration of through defects in anterior teeth as well as for the restoration of defects in high-opacity teeth, eg, with fluorosis. Due to high brightness, Premise XL1 can be used for the same indications on bleached teeth.

For the remaining samples, clinically acceptable results were obtained (TP $\leq 3.3$).
although the dentin/opaque shades of Gradia Direct, Estelite Sigma Quick, and Enamel Plus HRI showed the greatest color difference (ie, translucency) (Fig 6).

For all the studied enamel shades, the TP exceeded 3.3, ie, they had a different degree of translucency (Fig 7). The lowest values were recorded for Premise A2E, Enamel Plus HRI UE2, Estelite Sigma Quick A2E, and Herculite Ultra A2E. When working with these composites, if a patient has a pronounced enamel translucency, it is necessary to additionally use increased translucency/opalescence composite shades, which are available in the color palette of each of the listed materials. The highest translucency level was shown by Ceram X duo E2 (TP > 10), which was more than two times higher than the values obtained for the other samples. This material can be recommended for the restoration of teeth with pronounced zones of translucency; however, it should be used with caution in elderly patients in the presence of fluorosis and in other clinical situations where there is considerable opacity of the hard tissue.

Paravina et al evaluated the TP values for 26 microhybrid shades and 7 shades of microfilled composites. According to the obtained results, the specimens were divided into three groups: materials of low (TP = 0.9 to 2.0), medium (TP = 2.1 to 3.1), and high (TP = 3.2 to 4.3) translucency. In our study, according to this gradation, after polymerization all opaque/dentin shades could be determined as low and moderately translucent. However, after 48 h of water storage, Enamel Plus HRI UD2 specimens became more translucent (from 3.0 to 3.9) and could be defined as highly translucent. Enamel and body shades are highly translucent, regardless of water storage.

Conclusions

The following conclusions can be drawn from the present study:
1. Due to their high degree of opacity (TP < 2), Filtek Ultimate A2D, Premise A2D, and Herculite Ultra A2D could be materials of choice for the correction of discolorations of different etiology and the res-
toration of through defects (class III and IV, according to Black’s classification).

2. All the studied dentin/opaque shade samples showed clinically acceptable results. However, the lowest opacity was recorded for Gradia Direct, Estelite Sigma Quick, and Enamel Plus HRi. These composites should be used with caution for the restoration of large-volume tooth tissue defects.

3. The studied enamel shade composite samples showed different degrees of translucency. The lowest values were recorded for Premise A2E, Enamel Plus HRi UE2, Estelite Sigma Quick A2E, and Herculite Ultra A2E. The greatest translucency was shown by Ceram X duo E2 (TP > 10).

4. The TP value of natural enamel was higher than that of composite enamel shades. The same results were obtained for natural dentin and dentinal composite shades. In fact, natural tissue was more translucent compared with the studied composite materials.

5. There was no significant difference in the translucency level of most dry composite samples compared with samples after hydration. At the same time, significant changes were noted for natural dentin and enamel.

6. The translucency level of natural dentin varied significantly compared with natural enamel and composite samples, which is obviously due to its uneven structure both in different teeth and within the same tooth.

7. No significant correlation between the filler loading and TP values of dried and hydrated enamel shade specimens or of opaque shades was detected.

References


