Comparative study of shade matching performance of dental students under natural daylight and daylight lamp conditions

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Abstract

Background: As visual shade matching is subject to light source variables, this study was conducted to compare shade matching performance of dental students under two lighting conditions, i.e., natural daylight and a commercially available daylight lamp.

Materials and methods: Two sets of porcelain discs were prepared. The first set consisted of eight porcelain discs of shades A2, A3, A3.5, B2, B3, C2, C3, and D3 of the Vitapan Classical Shade Guide system. The second set consisted of three porcelain discs of shade A2, B2, and C2, having exactly similar L*a*b* values to those of the corresponding shade discs in the first set. Forty dental students were asked to find the closest match for the shades A2, B2, and C2 in the second set from the first set under natural daylight and daylight lamp conditions. The average ΔE between the presented and selected shade was calculated for each participant under the two lighting conditions. The significance was statistically assessed using a paired t-test.

Results: The average ΔE between presented and selected shade for individual participants under natural daylight ranged from 0 to 4.84, with a mean of 2.24, while those under daylight lamp conditions ranged from 0 to 3.68, with a mean of 1.14. The difference was statistically significant, with \( P < 0.0001 \).

Conclusion: Daylight lamp conditions significantly improved the shade matching performance of dental students.

Introduction

One of the main goals of prosthodontic dentistry is to restore color and appearance of natural dentition. For accurate reproduction of color, shade matching is one of the most critical steps performed. Shade matching in dentistry can either be performed visually or instrumentally. Instrumental shade matching involving computerized quantification of color is not yet widely accepted because of its disadvantages, such as: cost; the need for accurate reproducible positioning; and the effect of translucency and tooth surface on color determination. Visual shade matching using a prefabricated shade guide is currently the standard and commonly followed method.\(^1\)

Visual shade matching is subject to number of variables, like age, gender, experience, and degree of color deficient vision of the individual choosing the shade,\(^2\) shape and texture of tooth being matched, and type of light source.\(^3,4\)

The quality of light source used for shade matching is usually described in two ways; color temperature in Kelvin, and spectral energy distribution in relative energy at each wavelength of the light emitted from the source. Natural northern daylight at noon is considered as the best lighting condition for shade matching, as this phase of daylight has full spectral energy distribution, compatibility with eyes and a color temperature of about 6,500°K.\(^5\) But this phase of daylight is not always achievable, because the spectral energy distribution and color temperature of daylight is constantly changing, depending upon the time of day, cloud cover, humidity and level of pollutants. To overcome this problem with natural daylight, a simulated lighting condition in the form of a daylight lamp, which has a color temperature of about 6,500°K and spectral energy distribution comparable to that of northern daylight at noon, is being used in color related industries.

Various authors have proved the improvement in shade matching performance of dental students by different commercially available daylight lamps, like Shademat Visual+,\(^4\) Demetron shade light,\(^6\) and Dialite color 7.\(^7\) In the present study, D65 lamps, which are easily available in the market as ceiling lights, were tested.

The aim of the present study was to investigate whether standardized lighting conditions created by using a daylight lamp is better than natural daylight for shade matching.

Materials and Methods

Permission for the study was obtained from the Institutional Ethical Committee, Government Dental College, Aurangabad, Maharashtra, India. Forty intern dental students, having at least one year of clinical experience, were selected for the study as participants after screening with Ishihara’s test for color blindness. All participants were male with a mean age of 25 (±1) years.

The Vitapan classical shade guide system (VITA Zahnfabrik) was used in the present study for shade matching. Disc-shaped ceramic specimens, 18 mm in diameter and 2.5 mm in thickness, were prepared so that they could fit in to the small viewing area of the spectrophotometer (SpectraScan, Premier Colorscan).
The discs were fabricated in two sets; the first set consisted of discs of shades A2, A3, A3.5, B2, B3, C2, C3, and D3, and the second set consisted of twin discs of shades A2, B2, and C2, having exactly CIE L*a*b* values to that of corresponding discs in first set (Table 1). Eleven putty molds were prepared in polyvinylsiloxane putty (Aquasil soft putty, Dentsply), the internal diameter of molds was 20 mm (to compensate for ceramic shrinkage after firing). Dentin Porcelain slurry (Ceramco3, Dentsply) was prepared according to the manufacturer’s instructions and poured into the molds on a vibrating surface. The discs were removed from the mold and fired in a ceramic furnace (Multimat NT press, Dentsply), according to manufacturer’s instructions, on platinum sheet. Resultant discs were polished and finally glazed. Clear acrylic handles were attached at the inferior rim of the discs in the first set using cyanoacrylate adhesive to form a shade guide (Fig 1). Three discs in the second set were fixed on three gray cards of similar dimensions (11 mm x 14 mm) using cyanoacrylate adhesive (Fig 2). Three cards, along with the discs, were attached to wooden table stands and were given an alphabetical code.

A 23-watt D65 lamp with a color-rendering index of 90 (Phillips Electronics) was fixed in a focusing cup attached to a table stand. The internal walls of the focusing cup were painted using a light gray color with a matte finish to minimize

### Table 1  Shades and shade groups of composite resins investigated

<table>
<thead>
<tr>
<th>Shade</th>
<th>L* value</th>
<th>a*value</th>
<th>b*value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>68.47</td>
<td>0.73</td>
<td>15.16</td>
</tr>
<tr>
<td>A3</td>
<td>69.06</td>
<td>2.71</td>
<td>15.72</td>
</tr>
<tr>
<td>A3.5</td>
<td>66.33</td>
<td>3.81</td>
<td>18.48</td>
</tr>
<tr>
<td>B2</td>
<td>72.31</td>
<td>1.81</td>
<td>15.96</td>
</tr>
<tr>
<td>B3</td>
<td>67.93</td>
<td>1.53</td>
<td>20.34</td>
</tr>
<tr>
<td>C2</td>
<td>66.91</td>
<td>0.56</td>
<td>13.73</td>
</tr>
<tr>
<td>C3</td>
<td>65.21</td>
<td>1.20</td>
<td>14.00</td>
</tr>
<tr>
<td>D3</td>
<td>68.25</td>
<td>1.67</td>
<td>14.29</td>
</tr>
</tbody>
</table>

![Fig 1](image1.png) Ceramic discs with clear acrylic handles.

![Fig 2](image2.png) Ceramic discs fixed to gray cards.
During shade matching, the light was focused from a distance of 10 inches at the center of the gray card (Figs 3a and 3b). Illuminance for shade matching was 1300 lux. All shade-matching procedures were performed in a room with walls that were painted in a gray color. Only one participant at a time was allowed to enter the room to complete the shade matching procedure. Shade matching was performed in a manner closely mimicking the intraoral shade matching, i.e., the shade disc to be matched was at eye level and at arm’s length (30 cm) of the observer under both lighting conditions (Figs 3a and 3b). Shades were presented randomly and codes given to shades were different under two lighting conditions in order to reduce the bias due to repetition. Time allotted to match a single shade was 1 min in order to reduce confusion. Shade matching in natural daylight was performed in the same room in a similar manner except that the lamp was turned off and the north-facing window was opened. All shade-matching procedures were carried out in the month of May between 11 am to 12 pm.

After the completion of shade matching by all participants, the average ΔE between the presented and the selected shade for individual participants for both lighting conditions was calculated. A paired t test was used to explore any statistically significant difference between shade matching under the two lighting conditions. Statistical analysis was performed using statistical software (GraphPad InStat, Version3).

Results

All forty study participants were male, having at least one year of clinical experience. All participants were screened for color blindness using Ishihara’s test for color blindness, and no one was found to be color blind. The average color difference (ΔE) between the presented and the selected shade for all participants under both lighting conditions was calculated. The average ΔE between the presented and the selected shade for individual participants under natural daylight ranged from 0 to 4.84, with a mean of 2.24, while the average ΔE under
daylight lamp conditions ranged from 0 to 3.68, with a mean of 1.14. The difference was statistically significant, with \( P < 0.0001 \) (Table 2).

Of the three test shades used in the present study, the B2 shade was more correctly matched followed by A2, while the C2 shade was the least correctly matched under both test conditions.

**Discussion**

According to the results of the present study, it is seen that the color difference (ΔE) between the presented and the selected shade was significantly greater under natural daylight conditions than daylight lamp conditions. The greater the ΔE, the less reliable the shade matching is, hence shade matching under natural daylight conditions is found to be less reliable than under D65 daylight lamp conditions.

Although shade matching visually is subjective, it is one of the most common prosthodontic procedures performed. In order to reduce the variability in shade matching, the use of northern daylight at noon has been recommended during the procedure. However, it is not always possible to choose the shades during day, and the quality of daylight is not always consistent. In the present study, shade matching was performed under a relatively consistent environment, during 11 am to 12 pm at the north-facing window in the month of May.

Monitoring of artificial daylight conditions is a very important factor that must be given consideration, because if the lamp has reached the optimum
lifetime in hours of use as specified by the manufacturer, the spectral output of the lamps will change and will need to be replaced. Also proper functioning of the lamp, proper switch cycle, i.e., On/Off time in minutes should be followed as recommended by the manufacturer.

Color blindness affects approximately 8% of males and up to 2% of females in the general population. Eight to 14% of dental personnel have been found to have defective color vision. In the present study, all participants were first screened by Ishihara’s test for color blindness in order to reduce variability in individuals choosing the shades.

Color shade tabs were found to be unreliable, as shade tabs from the same manufacturers may vary with unacceptable ΔE due to different L*a*b* values for some of the same tabs. Also, it has been reported that the overall disc-matching score is better than the tab matching score by 5%. Hence, the original shade tabs in the Vitapan Classical Shade Guide were not used in the present study. Instead, porcelain disc specimens were manufactured for the shade tabs.

The Vitapan Classical Shade Guide System is the oldest and most commonly used shade system for dental shade matching; hence in the present study, discs for Vitapan Classical Shade Guide system were used. The lightest and the darkest shades in each group of the Vitapan Classical Shade Guide were excluded because there was more chance of better matching. Discs were prepared for the shades A2, A3, A3.5, B2, B3, C2, C3, and D3. Shades A2, B2, and C2 were used as the test shades. Correct shade matching for three shades was in the order B2 > A2 > C2, under both lighting conditions (Table 3).

The lowest ΔE perceivable by human observers is reported to be 1, and ΔE greater than 2 is considered to be clinically unacceptable for the porcelain specimens. In a previous study by Corcodel et al, the mean ΔE under natural daylight and daylight lamp varied by 0.89. In the present study, the mean ΔE under natural daylight was 2.14, which will result in a clinically unacceptable color match. The mean ΔE under daylight lamp condition was 1.14, which will result in a more reliable color match than

### Table 3

<table>
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<tr>
<th>Shade</th>
<th>Natural Daylight</th>
<th>Daylight Lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>A2 17</td>
<td>A2 25</td>
</tr>
<tr>
<td>C2</td>
<td>C2 12</td>
<td>C2 23</td>
</tr>
</tbody>
</table>
under natural daylight. The mean ΔE under the two lighting conditions varied by 1, ie, to a visually perceivable level. The limitation of the present study is that it involved shade matching for disc-shaped specimens, which is different from more complex intraoral shade matching for natural teeth, with influence of surrounding structures. Also, the Vitapan Classical Shade Guide does not cover all shades for natural teeth; hence future study for natural tooth shade matching with a wide range of shades is required.

Conclusion
Within the limitations of this study, it can be concluded that standardized daylight condition as created in the present study using a D65 lamp results in more reliable color matching than under natural daylight. Hence the D65 lamp can be used for dental shade matching in daily practice, where ideal natural daylight condition is not achievable.

References