INFLUENCE OF DIFFERENT ESTHETIC POST AND CORE MATERIALS ON COLOR OF IPS EMPRESS 2 CERAMIC CROWNS

Emine Göncü Başaran, DDS, PhD  
Assistant Professor, Department of Prosthodontics,  
Faculty of Dentistry, Dicle University,  
Diyarbakır, Turkey

Emrah Ayna, DDS, PhD  
Associate Professor, Department of Prosthodontics,  
Faculty of Dentistry, Dicle University,  
Diyarbakır, Turkey

Ersin Uysal, DDS, PhD  
Assistant Professor, Department of Computerise Programming,  
Faculty of Junior Technical Collage, Dicle University,  
Diyarbakır, Turkey

ABSTRACT

Background and aim: Studies as to the evaluation of clinically relevant color assessment of full ceramic restorations supported by esthetic post and core materials has not been found in the related literature. Thus, this study is conducted to evaluate the color difference of Empress 2 ceramic crowns restored with 4 different esthetic post systems and two different core materials by using colorimeter and digital color analyses techniques.

Materials and Methods: Seventy two maxillary central incisors were used in this study. The coronal aspect of each tooth was resected. Teeth were randomly divided into 4 groups and post spaces were prepared. Four post materials, Glass fiber posts, Quartz fiber posts, Zirconia-fiber posts, polietilen fiber were used. Two core materials, dual-cured naturel colored and light-cured light colored, were applied to each group. IPS Empress 2 ceramic crowns with shade A2 were prepared. A human central incisor was selected for control group. Colorimeter and digital analyses were used for color matching in this study. CIE Lab color system was used with following formula for calculation;  

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

Results: The results were analyzed by oneway analyses of variance (ANOVA). According to the digital techniques, there was no significant difference among the post groups and between the core groups(p>.05). However, according to the colorimetric technique, significant differences were observed among the post groups and between the core groups(p<.05).

Conclusion: It can be concluded that \( \Delta E^* \) units of post and core groups are lower than perceptibility threshold. Quartz fiber post with light core showed the lowest \( \Delta E^* \) units among all groups.

Key words: Color matching, Colorimeter, Digital Photograps, Esthetic Post
INTRODUCTION

Endodontically treated teeth with coronal damages are restored with post-cores. Metal posts are commonly used because of their superior physical properties. In recent years the demand for esthetic restorations has increased. All ceramic crowns show similar characteristics with natural teeth regarding translucency and fluorescence. Metallic posts may lead to a gray discoloration and shadowing of all-ceramic crowns and the surrounding tissues. Tooth color and metal-free posts have been introduced to solve this esthetic problem. Esthetic posts are stated to be made of either reinforced resins or strengthened ceramic. Zirconia posts have high flexural strength and fracture toughness. However, fiber-reinforced posts reduce the risk of root fractures to the minimum level. Glass fiber-reinforced post systems consist of unidirectional glass fibers in the resin matrix that lead to a stronger structure of the post. Translucent quartz fiber post systems which can be light-polymerized during cementation may be an alternative to achieve optimal esthetics. A recently developed bondable reinforcement fiber is reported to be an alternative to conventional post materials because of its esthetic qualities, mechanical properties, and the natural color of the reinforcing material. It was reported that esthetic and flexible fiber-resin composite laminate post minimized microcrack propagation in the root. There are many difficulties in relation to dental esthetic restorations are related to shade matching. Achieving a color match depends on a series of visual assessments in dentistry. Colorimetry devices have the potential to find a way a number of sources of variation that influence the process of visual color assessment. The CIE (The Commission Internationale de l’Eclairage) color system describes the color of an object in terms of its position in three-dimensional space (L*a*b*) and calculates the difference in color between two specimens using the following equation:

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

where the initial “1” and final “2” are color descriptives. Currently, there is little agreement on the magnitude of minimally detectable color difference (perceptibility threshold) and unacceptable color difference (acceptability threshold) in clinical dentistry. Color detection varies considerably between individuals and within individuals over time. Yet some people have reported to have distinguished 0.5 color difference while some others can’t even have realized it.

The color of dental esthetic restorative materials is routinely measured with a colorimeter or spectrophotometer. Instrumental color analyses offers a potential advantage over visual color determination: instrumental readings are objective, quantifiable, and more rapidly obtainable. However, their intraoral use has some limitation related to the size, translucency, curvature of teeth, and the color difference across the tooth surface. Digital photography has gained popularity as a method to convey color information to dental laboratories. However, the quality of these images is also influenced by lighting conditions that can undermine the integrity of the color acuity.

There are many studies about mechanical properties of esthetic post systems. However a few studies are available including color evaluation, which compared dark colored posts with esthetic posts. The aim of the study is to evaluate the influence of four different esthetic posts and two different core materials on the color of IPS Empress 2 ceramic crown by using two color measurement methods. The null hypothesis was that ΔE* units of the posts and core systems were lower than perceptibility threshold.

MATERIAL AND METHODS

Sample Preparation

Three pre-shaped posts, glass fiber posts (GFP) (Cytec Blanco; Hahnenkratt, Königsbach-Stein, Germany), quartz-glass fiber posts (QFP) (D.T. Light-post; Bisco Inc, Schaumburg, USA), zirconia-glass fiber posts (ZFP) (Snow post; Carbotech, Ganges, France) one individually shaped post, resin-supported polyethylene woven fiber ribbon posts (PFP) (Ribbond; Ribbond, Inc, Seattle, USA) and two core materials, dual-cured naturel colored (DC) (Bis-core, Bisco Inc, Schaumburg, USA) and light-cured light colored (LC) (Light-core, Bisco Inc, Schaumburg, USA) were used in this study (Table 1).

Seventy-two extracted human permanent non-carious maxillary central incisors with straight root canals were stored in sterile saline solution at 4°C. The coronal part of each tooth was sectioned at the cemento-enamel junction using a low-speed diamond-coated disk (NTI-Kahla GmbH, Thüringen, Germany) to obtain roots approximately 18-19 mm in length. Remaining pulp tissue was extirpated. Working lengths terminated approximately 1 mm short of the radiographic apices. The root canals were prepared with K-files, irrigated with copious amounts of 2.25% sodium
After completion of canal preparation, the lateral condensation technique was used to fill the root canals with gutta-percha (Gapadent, Hamburg, Germany) and a root canal sealer (Diaket; 3M/ESPE, Seefeld, Germany). The sealer was introduced into the canals with a lentulo spiral instrument (Dentsply Maillefer, Tulsa, Okla). Master gutta-percha points were coated with the sealer and inserted into the canals. A finger spreader (Dentsply Maillefer, Tulsa, Okla) was then inserted into the canals. The gutta-percha was removed from the coronal part of the root canal with Peeso reamers (Dentsply Maillefer, Tulsa, Okla).

Post sizes were determined according to the suggestion of the manufacturer for central teeth (1.4-1.5 mm) and 2 mm wide polietilen fiber was also used (Figure 1).

All post spaces were prepared to a depth of 10 mm by using the drills supplied with each system, and 16 mm length posts were positioned. 6 mm of the post head extended above the coronal surface. All posts were cemented with an adhesive system (All Bond II Dental Adhesive System; Bisco Inc, Schaumburg, USA) and dual-polymerizing adhesive resin cement (Duolink, Bisco Inc, Schaumburg, USA) according to the manufacturer’s guidelines.

The root canal walls were etched with 32% phosphoric acid (Uni-Etch, All Bond II Dental Adhesive System; Bisco Inc, Schaumburg, USA) for 15 seconds, washed with water spray, and gently airdried for 1-2 seconds. Adhesive was applied to the walls of root canal dentin and thinned with a brush. A dual-polymerizing resin luting agent was mixed for 20 seconds and applied in the canal walls with the use of a lentulo spiral instrument. The posts were coated with cement except PFP and slowly seated into canal with finger pressure. Excess cement was removed with an explorer. The light source was placed directly on the flat coronal tooth surfaces, and the cement was polymerized for 20 seconds at 350 mW/cm² (Hilux 350; First Medica, Greensboro, NC, USA).

The custom-shaped posts were made with polyethylene woven fiber ribbon, as described by Eskitascioglu et al.9 The canals were prepared with the same reamer used for the pre-shaped posts. Two pieces of ribbon material was two
folded, twisted, and soaked with unfilled resin. Adhesive was applied to the walls of root canal dentin and thinned with a brush. A dual-polymerizing resin luting agent was mixed for 20 seconds and then placed in the post spaces with a lentulo spiral instrument.

All custom-shaped posts were prepared in the following manner. One piece of woven fiber was saturated with a bonding agent, horizontally and mesiodistally oriented, and placed over the coronal post space opening. It was then compressed into the post space with an endodontic plugger and aligned over the center of the opening. A second length of woven ribbon was prepared in the same manner, buccolingually oriented, placed over the first, and compressed into the post space. The free ends of the ribbons were folded over and compressed into the middle of the coronal opening. Compression was performed until the woven ribbons were pressed as tightly as possible into the post space. Excess resin was removed, and the entire post was polymerized for 40 seconds with the same light-polymerizing unit used for the pre-shaped posts.

Two core materials were applied in the same procedure for each group. Three increments of composite resin were applied from the center of each post to the buccal, palatal, mesial and distal sides. 2 mm of core material was placed to all sides and each increment was polymerized for 20 seconds to complete the coronal core. A water-cooled diamond rotary instrument (308; Intensiv SA, Grancia, Switzerland) was used to prepare the core to 4 mm in length, width, and thickness and with a 1 mm chamfer finish at the cemento- enamel junction (Figure 2). The remaining 2 mm length of post served as a guide for silicone putty indexes that were subsequently sectioned. Impressions (Elite HD; ZhermackSpA, Badia Polesine, Italy) were made from the prepared teeth. Acrilic core models duplicated from the impressions and silicone indexes were made for each tooth to provide core standardization.

The cores were crowned with IPS Empress 2 ceramic system (Ivoclar Vivadent AG, Schaan, Liechtenstein). Thickness of crowns were 1.5 mm and buccal side of crowns prepared as flat surface. Shade A2 was selected for the color of the crown. Porcelain etchent (4 % hidrofloric acid gel) was applied in to crowns for 3-4 minutes, washed and dried. Silan was applied for 1-2 minutes and dried for 5-6 seconds with air spray. Then, ceramic cores were cemented with a dual cured composite resin (Duo-link, Bisco Inc, Schaumburg, U.S.A.). The excess resin was removed and light cured for 40 seconds.

A human central incisor tooth with A2 shade was selected for control group.

**Color Measurements**

A colorimeter (technique A) (Minolta CR 300 Colorimeter, Minolta Co Ltd Radiometric instruments Operations, Osaka, Japan) and a digital camera (technique B) were used to determine the color of specimens. The colorimeter was configured with a 45-degree/0-degree viewing geometry. Three colorimetric recordings were taken at the mid-facial location of each restoration or tooth. The color parameters, in terms of CIE tristimulus values (L* a* b*) were recorded. The color parameters were then averaged for each tooth.

The average value was calculated by the following formula 12:

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

Digital Photos were taken in a clear day at 11:00 am by a professional photographer far from 40 cm to samples. Digital camera fixed to a tripod. All raw format files were converted to ‘tiff’ format files and saved. Adobe Photoshop 8.0 Program (Adobe Photoshop CS2, 8.0, USA) was started up from Windows (Windows XP). Related photo was opened from ‘file’ tab with ‘open’ order. Measuring tooth was selected and started up again in photoshop 8.0 with ‘new’ order. Tooth was framed by grids from gingival, insizal,
Evaluation of Esthetic Post and Core Materials

Mesial and distal sides. The framed area was opened as a new picture. The new picture was divided into three parts longitudinally and horizontally by grids (Figure 3). In this way, the middle point was determined. The picture was magnified 1600 times and the middle point of the tooth was assigned by eyedropper probe (Figure 4). \( \Delta E \) was calculated from that point. This procedure was carried out for each tooth.

In this study, 1.8 \( \Delta E^* \) units represents the perceptibility threshold, and 3.7 \( \Delta E^* \) units is the corresponding color difference for acceptability limit.

The results were analyzed by one-way analyses of variance (ANOVA). Descriptive data of posts, cores, and techniques are shown in Table 2. Tukey HSD analyses was used for evaluating differences.

RESULTS

The post groups with core DC and LC were evaluated using digital and colorimetric techniques. Regarding the digital technique, there were no significant differences among the post groups and between the two core groups; however, regarding the colorimetric technique, significant difference was observed \( (p=0.028) \).

Tukey HSD statistical test revealed that difference was significant between ZFP and GFP with DC core groups \( (p<0.05) \). Other groups showed no significant difference. Post groups with LC showed significant differences between the following pairs: GFP vs. PFP \( (p<0.05) \); ZFP vs. QFP \( (p<0.001) \); QFP vs. PFP \( (p<0.001) \).

When core groups compared each other, no significantly difference was seen according to technique B. However, according to technique A, significantly difference was found (Tables 2 and 4).

Also significantly difference was observed between two techniques.

DISCUSSION

The increase in demand for esthetic restorations in dentistry has led to the development of colored tooth and metal-free, post-and-core systems. Esthetic post cores are also recommended to be endodontically treated in addition to the damaged anterior teeth which is restored with full ceramic restorations.

This study evaluated the color difference of four different post systems and two different core materials restored with IPS Empress 2 crowns. IPS Empress 2 ceramic is composed of lithium disilicate and fluorapatite crystal and is indicated for indirect esthetic restorations.

Vichi et al.\(^{18}\) suggested that when ceramic (Empress) thickness was 1 mm, all other variables were visually appreciable. For ceramic thickness of 1.5 mm, color differences decreased and most differences were appreciable only with laboratory instruments. For ceramic thickness of 2.0 mm, there were no detectable, clinically relevant differences. 1.5 mm thickness was selected for IPS Empress 2 crowns in this study.

Instrumental color measurement has the potential for eliminating the subjective variables of shade selection. A number of color-measuring instruments are commercially available, such as colorimeter and spectrophotometer. Authors claimed that there weren’t any significant differences between the colorimeter and...
Table 2. Descriptive data of test groups.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Cores</th>
<th>Posts</th>
<th>n</th>
<th>X</th>
<th>Sd</th>
<th>Se</th>
<th>ΔE Max</th>
<th>ΔE Min</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>DC</td>
<td>GFP</td>
<td>9</td>
<td>1.4611</td>
<td>.300</td>
<td>.100</td>
<td>1.00</td>
<td>1.73</td>
<td>.560</td>
<td>.645 (ns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QFP</td>
<td>9</td>
<td>1.3444</td>
<td>.289</td>
<td>.096</td>
<td>1.00</td>
<td>1.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ZFP</td>
<td>9</td>
<td>1.3089</td>
<td>.253</td>
<td>.084</td>
<td>1.00</td>
<td>1.72</td>
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<tr>
<td></td>
<td></td>
<td>PFP</td>
<td>9</td>
<td>1.4256</td>
<td>.283</td>
<td>.094</td>
<td>1.00</td>
<td>1.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>LC</td>
<td>GFP</td>
<td>9</td>
<td>1.3089</td>
<td>.253</td>
<td>.084</td>
<td>1.00</td>
<td>1.72</td>
<td>.836</td>
<td>.484 (ns)</td>
</tr>
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<td></td>
<td></td>
<td>QFP</td>
<td>9</td>
<td>1.1367</td>
<td>.205</td>
<td>.068</td>
<td>1.00</td>
<td>1.41</td>
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<td></td>
<td></td>
<td>ZFP</td>
<td>9</td>
<td>1.1822</td>
<td>.216</td>
<td>.072</td>
<td>1.00</td>
<td>1.41</td>
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<tr>
<td></td>
<td></td>
<td>PFP</td>
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<td>1.2178</td>
<td>.276</td>
<td>.092</td>
<td>1.00</td>
<td>1.73</td>
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</tr>
</tbody>
</table>

* p<.05     ** p<.01     *** p<.001

Table 3. Evaluation of post groups with DC according to technique A.

<table>
<thead>
<tr>
<th>Posts</th>
<th>GFP</th>
<th>QFP</th>
<th>ZFP</th>
<th>PFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFP</td>
<td>.85(ns)</td>
<td>.993(ns)</td>
<td>.957(ns)</td>
<td></td>
</tr>
<tr>
<td>ZFP</td>
<td>.27(*)</td>
<td>.864(ns)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QFP</td>
<td>.146(ns)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ns: non significant  * p<.05

Table 4. Evaluation of post groups with LC according to technique A.

<table>
<thead>
<tr>
<th>Posts</th>
<th>GFP</th>
<th>QFP</th>
<th>ZFP</th>
<th>PFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFP</td>
<td>.052(ns)</td>
<td>.001 ***</td>
<td>.026 *</td>
<td></td>
</tr>
<tr>
<td>ZFP</td>
<td>.001 ***</td>
<td>.402 (n.s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QFP</td>
<td>.001 ***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ns: non significant  * p<.05     *** p<.001
spectrophotometer.\textsuperscript{19,20} Many studies are available about colorimeter.\textsuperscript{18,21,22} Tung et al.\textsuperscript{22} compared colorimeter and visual method for shade matching. They found that colorimeters had 82% repeatability; however, visual measurements had 55% repeatability.

Digital photography is widely used to color matching in dentistry. Dancy et al.\textsuperscript{23} suggested that digital photos analyzed by computer could successfully be used as an alternative for visual analysis. In the study of Jarad et al.\textsuperscript{17} spectrophotometer and digital photos were used to analyze the shade guides. They reported that digital photos could safely be used in clinical studies.

The literature is not in agreement with respect to the limit for the human eye to detect differences in color, considering that this limit differs from individual to individual.\textsuperscript{18,24,25} Clinically perceptibility threshold distance by human eyes was reported 1 ΔE* units,\textsuperscript{14,26} 1.9 ΔE* units,\textsuperscript{27} ΔE* units between 2-3.\textsuperscript{21,28,29} The clinically acceptibility threshold is also controversial. Previous studies determined different acceptibility threshold such as 2.75 ΔE* units,\textsuperscript{14,30} 3.3 ΔE* units,\textsuperscript{31} 3.7 ΔE* units,\textsuperscript{32} 4.2 ΔE* units.\textsuperscript{27}

Some studies suggested that the majority of patients could not detect any color difference when ΔE* units was less than 1.8 between the ceramic samples.\textsuperscript{20,21,34} In this study, by following the indications from the literature and referring to the ceramic material, the data were analyzed with 1.8 ΔE* units as the perceptibility threshold and 3.7 ΔE* units determined acceptibility threshold. It was found for post and core groups either colorimeter or digital technique, ΔE* units (ΔE ≤ 1.7) were lower than perceptibility threshold. This result supported the null hypothesis of this study.

QFP with LC core showed the lowest ΔE* units while ZFP with DC core showed the highest ΔE* units according to both digital and colorimeter technique.

Regarding the mathematical units, the ΔE values are expressed in percents when measured with the colorimeter, while they were expressed in whole numbers when measured with the digital techniques. Also, environmental factors may influence the results of the photos taken from digital technology, such as lighting.

Previous studies\textsuperscript{20,21} on the reliability of the digital technique clearly stated that digital technique could safely be used in the clinic to determine the color, a successful alternative to the visual method and the laboratory and the physician of communication could contribute. According to the results of present study, a statistically significant difference was found between the digital technique and the colorimetric measurements. However, the ΔE* units obtained from both techniques were lower than the perceptibility threshold. Therefore, in the color measurement, digital technique can be used safely as an alternative to colorimetric devices which are large, expensive, difficult to use intraorally, unsuccessful in curved and uneven surfaces.

There are limitations to the present study. In vivo and in vitro conditions effects ΔE* units. Intraoral use of colorimeter has some limitation. It needs some modifications when use in oral cavity. Also many factors can be effect digital photographs negatively. The quality of these images is also influenced by lighting conditions and an experienced, trained photographer is required.

**CONCLUSIONS**

- It was shown that the effect of each post material on final color of ceramic crowns were lower than perceptibility threshold. Each post system is applicable for clinical applications.
- Two of core materials were lower than perceptibility threshold.
- Quartz fiber post with light core showed the lowest ΔE* units.
- Two techniques used for the color determination in this study can be used in clinical applications.

**REFERENCES**


