Evaluation of the Color Adjustment Potential of Single-Shade Composite Resin in Primary Teeth

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Abstract
Restoring composite resins with the optimal shades for all primary teeth is a great challenge for pediatric dentists. A newly developed single-shade composite resin can exhibit a color similar to that of the surrounding tooth structure based on the structural color phenomenon. This study aims to evaluate the color adjustment potential (CAP) of a single-shade composite resin compared to conventional multi-shade composite resins in primary teeth. A single-shade composite resin and two conventional multi-shade composite resins were included in this study. Two types of specimens, a single specimen and a dual specimen, were evaluated. For single specimens, duplications of the primary second molar denture teeth were made using experimental composite resins. For dual specimens, cavities were prepared on the buccal surfaces of extracted primary second molars and restored with experimental composite resins. The L*, a*, and b* values were measured using a colorimeter for the extracted teeth and specimens. The mean ΔE*ab values for single and dual specimens and CAP were calculated. Bonferroni post-hoc analysis was performed to confirm the statistical significance between the ΔE*ab and CAP values of the experimental resins. Among the single specimens, the single-shade composite resin showed significantly higher ΔESingle compared to other composite resins (p < 0.0167). There was no significant difference between ΔEDual for all experimental resins. The single-shade composite resin showed highest CAP compared to other multi-shade composite resins. A single-shade composite resin can simplify shade matching and provide esthetic outcomes for the restoration of primary second molars. [J Korean Acad Pediatr Dent 2023;50(1):113-120]

Keywords
Composite resin, Esthetic restoration, Structural color, Color adjustment potential
Introduction

Recently, esthetic demands for dental treatment in children have increased, and esthetic restoration of primary teeth has become more important[1]. Esthetic restorative materials that can be used in primary teeth include glass ionomers, composite resins, and preformed zirconia crowns[2,3]. Among them, the composite resin is most commonly used for the restoration of primary teeth because it has excellent esthetics and allows the preservation of tooth structure[4,5].

Tooth shade varies among individuals. To address this issue, various shades are available for each commercially available composite resin product[6]. However, selecting composite resins that provide the perfect shade for all teeth is a great challenge for clinicians, especially in pediatric patients who require minimal chair time because of behavioral problems[7]. Furthermore, there is a scarcity of research on the color of primary teeth[8,9].

Therefore, clinicians have focused on the “blending effect”, which is the ability of a material to resemble the color of the adjacent tooth structures[10]. The blending effect is affected by the translucency and thickness of tissues or materials[11]. To quantify the physical elements of the blending effect, the concept of color adjustment potential (CAP) was introduced[12]. The CAP can be defined as the proportion of color difference values between two objects observed under two conditions: one enclosed with another and, in isolation[13].

The single-shade composite resin was developed based on the structural color phenomenon, which represents a color through the microstructure of the material that strengthens or weakens different wavelengths[14]. The single-shade composite resin does not contain dyes or pigments, and the specific microstructure formed by the uniform filler particles expresses the color of the material[15,16]. This color, combined with the color reflected from the surrounding tooth structure, exhibits a color similar to that of the adjacent tooth[16]. This material has the advantage of ensuring an esthetic restoration without using different shades of composite resin. Previous studies on artificial teeth[17] have shown excellent CAP of single-shade composite resins; however, studies on primary teeth are still insufficient.

Therefore, this study aimed to evaluate the color adjustment potential of a single-shade composite resin compared to conventional multi-shade composite resins in primary teeth.

Materials and Methods

This study was approved by the Institutional Review Board (IRB) of Gangneung-Wonju National University Dental Hospital (IRB No.: GWNUDH-IRB2022-A008)

1. Specimen preparation

1) Tooth preparation and experimental resins

Forty extracted human primary second molars, without caries, restorations, or obvious discoloration, were used in this study. All root portions below the cementoenamel junction were removed using a diamond disk. All the remaining organic substances in the teeth were removed, and the teeth were stored in saline at 4°C. The prepared teeth were classified according to the study process (Fig. 1).

A single-shade composite resin (Omnichroma [Tokuyama Dental, Tokyo, Japan] [OM]) and two multi-shade composite resins (Filtek Z350XT [3M ESPE, St Paul, MN, USA] [FT] and Estelite Sigma Quick [Tokuyama Dental [ES]) were used in this study (Table 1). The A1 shade of each multi-shade composite resin was selected by a previous study on the color of primary teeth[18]. Two types of specimens, single (Fig. 2) and dual (Fig. 3), were evaluated. For each experimental resin, 10 single and dual specimens were prepared, respectively.

2) Single specimen preparation

For the single specimens, duplications of the primary second molar denture teeth were performed using experimental composite resins. The mold for duplicating the denture teeth was made using silicon impression materials (Exafine Putty Type, GC Co., Tokyo, Japan). Each
Table 1. Experimental composite resins used in this study

<table>
<thead>
<tr>
<th>Material</th>
<th>Manufacturer</th>
<th>Filler content Wt%</th>
<th>Filler content Vol%</th>
<th>Filler type</th>
<th>Monomer</th>
<th>Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omnichroma (OM)</td>
<td>Tokuyama Dental, Tokyo, Japan</td>
<td>79.0</td>
<td>68.0</td>
<td>Uniform sized supranano spherical filler</td>
<td>UDMA TEGDMA</td>
<td></td>
</tr>
<tr>
<td>Filtek Z350XT (FT)</td>
<td>3M ESPE, St Paul, MN, USA</td>
<td>72.5</td>
<td>55.6</td>
<td>Nanofil</td>
<td>Bis-GMA UDMA TEGDMA Bis-EMA</td>
<td>A1B</td>
</tr>
<tr>
<td>Estelite Sigma Quick (ES)</td>
<td>Tokuyama Dental, Tokyo, Japan</td>
<td>82.0</td>
<td>71.0</td>
<td>Nanofil</td>
<td>Bis-GMA TEGDMA</td>
<td>A1</td>
</tr>
</tbody>
</table>

UDMA: Urethane dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; Bis-GMA: Bisphenol A-glycidyl methacrylate; Bis-EMA: Ethoxylated bisphenol A glycol dimethacrylate.

Fig. 2. Single specimens of each experimental composite resin. A denture tooth was replicated using experimental composite resins. (A) Omnichroma, (B) Filtek Z350XT, (C) Estelite Sigma Quick.

Fig. 3. Dual specimens of each experimental composite resin. Extracted primary second molars were restored with experimental composite resins. (A) Omnichroma, (B) Filtek Z350XT, (C) Estelite Sigma Quick.
experimental resin was incrementally filled three times in the manufactured mold, and photopolymerization was performed for a total of 45 seconds, 15 seconds per layer, using a VALO light-emitting diode (Ultradent Products Inc., South Jordan, UT, USA). The single specimens were polished using a series of Sof-lex™ Contouring and Polishing Discs (3M ESPE) under water cooling, according to the manufacturer’s instructions.

3) Dual specimen preparation
For the dual specimens, standardized 4.0 × 4.0 × 1.5 mm cavities were prepared on the center of the buccal surfaces of extracted primary second molars using a #330 carbide bur. The inner surfaces of the cavities were etched with a 37% phosphoric acid gel (Vericom Co., Ltd., Chuncheon, Korea) for 15 seconds. After washing and drying, an 8th generation bonding agent (Scotch-bond™ Universal Adhesive, 3M ESPE) was applied evenly inside the cavities and photopolymerized for 15 seconds. Each experimental composite resin was placed into the cavities of the teeth, followed by photopolymerization for 15 seconds and polishing. The prepared specimens were stored for 24 hours in saline at 4°C prior to color measurement.

2. Color measurement
The color parameters of the restorations were measured using a colorimeter (Shade Eye-NCC, Shofu Co., Kyoto, Japan). The colorimeter was calibrated according to the manufacturer’s instructions prior to each measurement. Immediately before the measurement, the remaining solution on the surface of each sample was removed using gauze. The color parameters were measured perpendicular to the center of the restorations or buccal surfaces three times for each specimen, and the average was obtained.

The CIELAB color difference formula was used for color measurements in this study. The color difference ($\Delta E_{ab}^*$) of each specimen was calculated using the following equation:

$$\Delta E_{ab}^* = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

where $\Delta L^*$, $\Delta a^*$, and $\Delta b^*$ correspond to lightness, red-green chromaticity, and yellow-blue chromaticity, respectively.

The CAP of each experimental resin was calculated using the following equation.

$$\text{CAP} = 1 - \frac{\Delta E_{\text{Dual}}}{\Delta E_{\text{Single}}}$$

$\Delta E_{\text{Single}}$ was calculated as the color difference between the single specimen and the unrestored primary second molar and $\Delta E_{\text{Dual}}$ was calculated as the color difference between the dual specimen and the primary second molar before fabricating the dual specimen. The means and standard deviations were determined for each experimental resin.

3. Statistical analysis
SPSS version 22.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. The normality of the data was checked using the Shapiro-Wilk test. The $\Delta E_{ab}^*$ and CAP values of the experimental resins were compared using Bonferroni post-hoc analysis ($p < 0.0167$).

Results
1. Color difference ($\Delta E_{ab}^*$)
Among the single specimens, OM showed the highest $\Delta E_{\text{Single}}$ compared with the other composite resins (Table 2, $p < 0.0167$). Between the other two multi-shade composite resins, FT showed a significantly smaller $\Delta E_{\text{Single}}$ than that of ES (Table 2, $p < 0.0167$). OM showed the smallest $\Delta E_{\text{Dual}}$, but there was no significant difference among the 3 experimental composite resins (Table 3).

2. Color adjustment potential
OM showed a significantly higher CAP than FT ($p < 0.0167$). OM also showed higher CAP than ES, but the difference was not statistically significant. There was no significant difference between the CAP for FT and ES.
Discussion

According to previous studies[19-22], the clinical acceptance threshold for ΔEab* ranges from 3.3 to 3.7. Any ΔEab* value higher than these thresholds cannot be considered clinically acceptable[21]. In this study, the average ΔEDual of OM was 3.2, which was lower than that of the other experimental resins; however, no statistically significant difference was observed. Nevertheless, from the results of previous studies, single-shade composite resins are expected to provide good esthetics in the restoration of the primary second molars.

The enamel and dentin of primary teeth are thinner than those of permanent teeth[23]. This provides an environment in which the color of the tooth structure beyond the restoration can be better permeated. Furthermore, the color of the crown is whiter and lighter in the primary teeth compared with that of the permanent teeth[23]. According to a previous study[16] that evaluated the shade matching ability of multiple composite resins in acrylic teeth of various shades, single-shade composite resin showed better shade matching for lighter-shade acrylic teeth. In this study, conducted for primary teeth, OM showed higher CAP values than the two multi-shade composite resins.

In the oral cavity, factors such as the shape or location of teeth and restoration, the dark background of the oral cavity, and surrounding soft tissues affect the shade matching of the restoration[16,24]. Furthermore, according to a study by Kim et al.[18], significant differences in color values were observed between the primary molars and primary incisors in both the maxillary and mandibular teeth. In most cases, the esthetics of anterior tooth restorations are considered critical. Therefore, the CAP of single-shade composite resin in primary incisors was evaluated in the pilot study. However, the enamel and dentin thicknesses of the primary incisors were too low to obtain an adequate cavity depth. Future in vitro studies on primary incisors should be designed to overcome these limitations. Moreover, the shade matching of single-shade composite resin for primary incisors should be clinically evaluated.

One of the limitations of this study was the lack of visual evaluation by the observers. The visual method is a subjective assessment, but the visual judgment of color matching is a decisive factor in patient acceptance[25]. Furthermore, in this study, color measurement was performed only once after 24 hours of specimen fabrication. Long-term studies are needed to evaluate the color stability of single-shade composite resins in comparison with conventional multi-shade resins.

Conclusion

Within the limitations of this current study, the results showed that the single-shade composite resin exhibited the most prominent color adaptability for primary
second molars compared with the conventional multi-shade composite resins. Single-shade composite resins can simplify shade matching and provide better esthetic outcomes for the restoration of primary second molars.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

References

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유치에서의 단일 색조 복합레진의 색조 적응력 평가

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