Original Article

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 ΔE_{Single} compared to other composite resins (p < 0.0167). There was no significant difference between ΔE_{Dual} for all experimental resins. The single-shade composite resin showed highest CAP compared to other multi-shade composite resins. A single-shade composite resin exhibited the most prominent color adaptability compared to other conventional multi-shade composite resins for primary second molars. 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]

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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[15] and extracted permanent 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
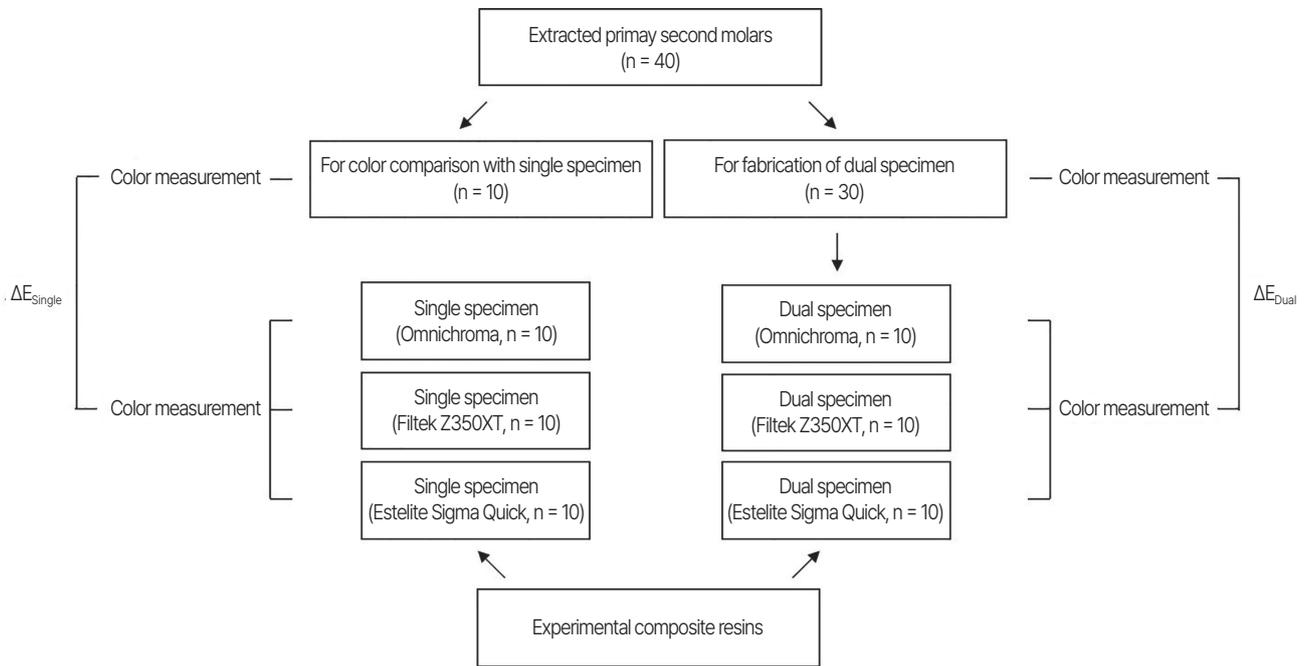
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┌──────────────────────────────┐
│  Extracted primay second molars │
│         (n = 40)             │
└──────────────────────────────┘
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Color measurement ─

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┌────────────────────────────┐        ┌────────────────────────────┐
│ For color comparison with   │        │ For fabrication of dual     │
│ single specimen (n = 10)    │        │ specimen (n = 30)           │
└────────────────────────────┘        └────────────────────────────┘
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─ Color measurement ─

ΔE_{Single}

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┌────────────────────────────┐        ┌────────────────────────────┐
│ Single specimen             │        │ Dual specimen               │
│ (Omnichroma, n = 10)        │        │ (Omnichroma, n = 10)        │
└────────────────────────────┘        └────────────────────────────┘
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Color measurement ─

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┌────────────────────────────┐        ┌────────────────────────────┐
│ Single specimen             │        │ Dual specimen               │
│ (Filtek Z350XT, n = 10)     │        │ (Filtek Z350XT, n = 10)     │
└────────────────────────────┘        └────────────────────────────┘
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─ Color measurement ─

ΔE_{Dual}

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┌────────────────────────────┐        ┌────────────────────────────┐
│ Single specimen             │        │ Dual specimen               │
│ (Estelite Sigma Quick, n=10)│        │ (Estelite Sigma Quick, n=10)│
└────────────────────────────┘        └────────────────────────────┘
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┌────────────────────────────┐
│ Experimental composite resins│
└────────────────────────────┘
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Fig. 1. Schematic diagram of the study process.

Table 1. Experimental composite resins used in this study

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

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.
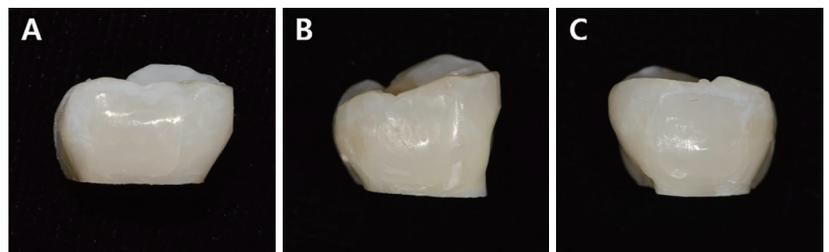
experimental resin was incrementally filled three times in the manufactured mold, and photopolymerization was performed for a total of 45 seconds, 15 seconds per layer, using a VALO light-emitting diode (Ultradent Products Inc., South Jordan, UT, USA). The single specimens were polished using a series 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 (Scotchbond™ 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 (ΔE_{ab}^*) of each specimen was calculated using the following equation:

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

where ΔL^*, Δa^*, and Δb^* correspond to lightness, red-green chromaticity, and yellow-blue chromaticity, respectively.

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

$$CAP = 1 - (\Delta E_{Dual} / \Delta E_{Single})$$

ΔE_{Single} was calculated as the color difference between the single specimen and the unrestored primary second molar and ΔE_{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 ΔE_{ab}^* and CAP values of the experimental resins were compared using Bonferroni post-hoc analysis ($p < 0.0167$).

Results

1. Color difference (ΔE_{ab}^*)

Among the single specimens, OM showed the highest ΔE_{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 ΔE_{Single} than that of ES (Table 2, $p < 0.0167$). OM showed the smallest ΔE_{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.

Table 2. ΔE_{Single} of the experimental composite resins

	Material (n=10)	Mean (SD)	p value
ΔE_{Single}	Omnichroma	10.2 (1.1)	
	Filtek Z350XT	4.1 (0.6)	< 0.0001
	Estelite Sigma Quick	6.4 (4.8)	0.001

p value from the Bonferroni's post-hoc test.
ΔE_{Single}: The color difference between the single specimen and the unrestored primary second molar; SD: standard deviation.

Table 3. ΔE_{Dual} of the experimental composite resins

	Material (n = 10)	Mean (SD)	p value
ΔE_{Dual}	Omnichroma	3.2 (1.3)	
	Filtek Z350XT	4.0 (2.7)	1.000
	Estelite Sigma Quick	5.2 (2.4)	0.833

p value from the Bonferroni's post-hoc test.
ΔE_{Dual}: The color difference between the dual specimen and the primary second molar before restoration; SD: standard deviation.

Table 4. The color adjustment potential of the experimental composite resins

	Material (n = 10)	Mean (SD)	p value
CAP	Omnichroma	0.69 (0.1)	
	Filtek Z350XT	0.01 (0.7)	0.006
	Estelite Sigma Quick	0.17 (0.4)	0.043

p value from the Bonferroni's post-hoc test.
CAP: Color adjustment potential; SD: standard deviation.

Discussion

According to previous studies[19-22], the clinical acceptance threshold for ΔE_{ab}^* ranges from 3.3 to 3.7. Any ΔE_{ab}^* value higher than these thresholds cannot be considered clinically acceptable[21]. In this study, the average ΔE_{Dual} 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.

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유치에서의 단일 색조 복합레진의 색조 적응력 평가

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　모든 유치에 알맞은 색조의 복합레진을 수복하는 것은 소아치과 의사에게 큰 어려움이다. 최근 개발된 단일 색조 복합레진은 구조색 현상을 기반으로 주변 치질과 유사한 색상을 나타낼 수 있다. 이 연구는 단일 색조 복합레진의 유치에서의 색조 적응력(Color adjustment potential, CAP)을 일반적인 다색조 복합레진과 비교하여 평가하기 위한 연구이다. 한 개의 단일 색조 복합레진과 두 개의 다색조 복합레진이 연구에 포함되었다. Single, dual 두 종류의 표본이 제작되어 평가되었다. Single 표본은 실험군 레진을 이용하여 제2유구치 인공치를 복제하여 제작하였다. Dual 표본은 발거된 제2유구치 협면에 와동을 형성한 뒤 실험군 레진을 수복하여 제작하였다. 측색계를 이용하여 발거된 치아 및 제작된 표본의 L^*, a^*, b^* 값을 측정하였다. Single, dual 표본에 대한 ΔE_{ab}^* 값과 CAP 값의 평균을 계산하였으며 Bonferroni 사후 분석을 이용하여 실험군 레진 간의 통계적 유의성을 확인하였다. 실험 결과 단일 색조 복합레진이 다른 복합레진들에 비해 유의하게 큰 ΔE_{Single} 값을 나타내었다(p < 0.0167). 모든 실험군 레진 간 유의한 ΔE_{Dual} 값의 차이는 관찰되지 않았다. 단일 색조 복합레진은 다른 다색조 복합레진들과 비교 시 가장 높은 CAP 값을 나타내었다. 단일 색조 복합레진은 제2유구치에서 다른 다색조 복합레진에 비해 준수한 색조 적응력을 나타내었다. 단일 색조 복합레진은 제2유구치에서 색조 선택 과정을 단순화하면서 심미적인 수복물을 제공할 수 있을 것이다. [J Korean Acad Pediatr Dent 2023;50(1):113-120]

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