

Color Matching of Single-Shade Composite Resin by Various Pulp Capping Materials in Anterior Teeth

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Abstract

This study aimed to compare color matching between single-shade composite resin-restored teeth with various pulp capping materials and the dentin surrounding the restoration through instrumental analysis and visual evaluation of the color difference. Fifty maxillary right central incisor acrylic resin teeth were prepared with standardized Class III cavities on the proximal surfaces. These teeth were divided into five groups: restored with single-shade composite resin only; Ultra-Blend™ plus followed by single-shade composite resin; TheraCal PT™ followed by single-shade composite resin; Endocem® MTA premixed followed by single-shade composite resin; and Well-root PT™ followed by single-shade composite resin. The color difference (ΔE_{ab}^*) between the restored area and the center of the resin teeth was measured using a spectrophotometer. No significant color difference was observed in groups restored with only single-shade composite resin, Ultra-Blend™ plus, and TheraCal PT™. The visual evaluation revealed that Ultra-Blend™ plus exhibited the best color matching score, whereas the Endocem® MTA premixed and Well-root PT™ groups showed significantly lower color matching scores than the single-shade composite resin-only group. When opting for single-shade composite resin usage for anterior tooth restorations with the aim of reducing chair time, pulp capping materials Ultra-Blend™ plus and TheraCal PT™ provide esthetically pleasing results. [J Korean Acad Pediatr Dent 2024;51(2):176-184]

Keywords

Single-shade composite resin, Color matching, Pulp capping material, Esthetic restorative dentistry, Anterior tooth restorative

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Article history

Received March 19, 2024

Revised April 19, 2024

Accepted April 26, 2024

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Introduction

In pediatric dentistry, anterior restorative treatments are performed in cases of

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caries or traumatic tooth fractures. In particular, deeply carious or fractured immature permanent incisors with visible or exposed pulp are treated with vital pulp therapy, which promotes root development, strengthens root structure, and induces root foramen closure[1]. With appropriate indications, pulp capping, a vital pulp therapy, may show favorable results in root growth compared with pulpotomy or pulpectomy[2].

Calcium hydroxide cements, resin-modified calcium silicate cement, and mineral trioxide aggregates (MTA) are used for pulp capping. These pulp capping materials are applied to the exposed pulp or dentin close to the pulp and then restored using different shades of resin[3]. In resin restorations, a tooth-like shade is achieved using the layering technique[4], wherein resins of various colors and transparency are filled in increments, considering the tooth color and transparency. Although this method increases esthetics, it also increases chair time, thus posing difficulty when treating patients with low cooperation[5].

Omnichroma (Tokuyama, Tokyo, Japan), a recently developed single-shade composite resin, comprises uniform spherical fillers 260 nm in size that combine with the color reflected from the surrounding teeth when ambient light passes through the resin to blend naturally with the various colors of the teeth[6]. This reduces the time spent choosing the right tooth shade, successively reducing the chair time for anterior resin restorations[7].

Omnichroma demonstrates superior color matching compared to various multi-shade composite resins commonly used in clinical practice[8]. Although numerous studies have been reported on evaluating color matching with the dentin surrounding the restoration in Omnichroma restorations, research on the differences in color matching of Omnichroma in conjunction with pulp capping materials is lacking[8-11]. Therefore, this study aimed to compare the difference in shade between Omnichroma-restored teeth and the dentin surrounding the restoration within the same tooth, treated using various pulp capping materials, by instrumental analysis and visual evaluation.

Materials and Methods

1. Materials

1) Acrylic resin teeth

The acrylic resin tooth used in this study was a maxillary right central incisor from Biotone® (Dentsply, York, USA), 266 Shape, 62 Shade (Fig. 1).

2) Restorative materials

The following four materials were selected for pulp capping (Table 1): Ultra-Blend™ plus (Ultradent Products, Inc, South Jordan, UT, USA; UB), TheraCal PT™ (Bisco Inc, Schaumburg, IL, USA; TC), Endocem® MTA premixed (Maruchi, Wonju, Korea; EM), and Well-root PT™ (Vericom Co., Chuncheon, Korea; PT). Omnichroma (Tokuyama, Tokyo, Japan; OM), a single-shade composite resin, was used as the restorative material. The group with teeth restored with Omnichroma alone was set as the control group, and the groups with teeth restored with Omnichroma after application of each of the four types of pulp capping materials were set as the experimental groups.

3) Spectrophotometer

The color measurements for each specimen were conducted using VITA Easyshade®V (Serial No. 58089, VITA Zahnfabrik, Bad Säckingen, Germany).



Fig. 1. Acrylic resin teeth used in this study.

Table 1. Materials used in this study

Category	Products	Composition, Details	Manufacturer	Setting time
Single shade composite resin	Omnichroma	Filler: 79 wt% uniform sized supra-nano spherical filler (SiO ₂ -ZrO ₂ 260 nm) Base resin: UDMA, TEGDMA	Tokuyama, Tokyo, Japan	Light polymerization for 15 s
Resin-modified calcium hydroxide cement	Ultra-Blend™ plus	5% Calcium hydroxide, 59% Urethane dimethacrylate, 4% Tricalcium salt, Triethylene glycol dimethacrylate	Ultradent product Inc., Utah, USA	Light polymerization for 20 s
Dual cured resin-modified calcium silicate cement	TheraCal PT™	Silicate glass-mix cement (50 - 75%), Polyethylene glycol dimethacrylate (10 - 30%), Bis-GMA (5 - 10%), Barium zirconate (1 - 5%), Ytterbium fluoride	Bisco, Inc. Schaumburg, IL USA	Light polymerization for 20 s
Premixed MTA	Endocem® MTA premixed	Tricalcium silicate, Dodecacalcium hepta-aluminate, Dimethyl sulfoxide, Hydroxypropyl methylcellulose, Calcium sulfate, Zirconium oxide, Lithium carbonate, Silicon dioxide	Maruchi, Wonju, Korea	Initial: 4 - 5 min Final: 12 hours
	Well-root PT™	Calcium aluminosilicate compound, Zirconium oxide, Filler, Thickening agent	Vericom, Chuncheon, Korea	Initial: 7 min

UDMA: urethane dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; Bis-GMA: bisphenol A-glycidyl methacrylate.

2. Methods

1) Specimen preparation

Class III cavities (4.0 mm in height, 3.0 mm in width, and 2.0 mm in depth) were prepared on the mesial surface of 50 maxillary right central incisor resin teeth using a #311 flat-end cylinder diamond bur (Shofu, Kyoto, Japan) in a high-speed handpiece with water. The design of the cavity was determined considering the position of the pulp chamber and the thickness of the dentin, and the size of the cavity was standardized by using a digital caliper (Navimro, Seoul, Korea)[12]. The cavitated teeth were randomly assigned to each group (n = 10).

2) Filling of materials

In the experimental group, each pulp-capping material was filled to a thickness of 1 mm on the distal wall of the cavity (Fig. 2). To achieve a uniform thickness of pulp capping material restoration, a digital caliper was used within the rubber dam to mark a line using a pencil at a height of 1mm before the restoration procedure was performed. Paper points were used to remove excess material from the cavity of the resin tooth. The UB and TC were light-cured for 20 seconds using an LED light curing unit (B&LiteS, B&L Bio-tech, Ansan, Korea), EM

for 5 minutes, and PT for 7 minutes, according to the manufacturer's instructions[13].

The remaining areas of the cavity were restored using Single Bond Universal (3M ESPE™, St. Paul, MN, USA) adhesive and Omnichroma and light cured using an LED light curing unit (B&LiteS, B&L Biotech) for 20 seconds.

The control group was restored using Single Bond Universal (3M ESPE™, USA) adhesive and Omnichroma in the cavity without any pulp capping materials, and all specimens were polished for 20 seconds under water using the Enhance® finishing system (Dentsply/Caulk, Milford, DE, USA) (Fig. 3).

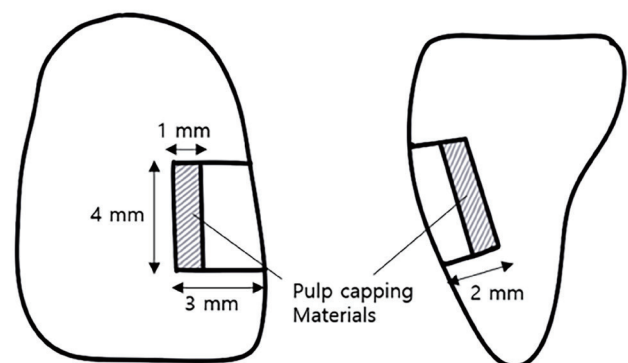


Fig. 2. Schematic illustrations of the preparation of a specimen.

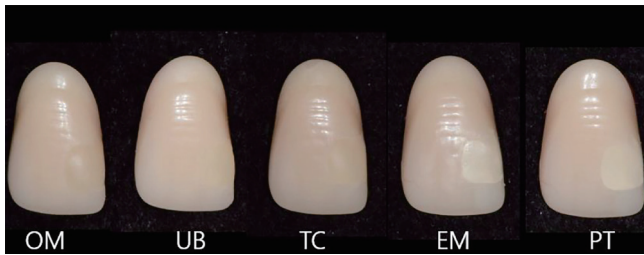


Fig. 3. Acrylic resin teeth were restored with Omnichroma and various pulp capping materials

OM: Omnichroma; UB: Ultra Blend™ plus; TC: Theracal PT™; EM: Endocem® MTA premixed; PT: Well root PT™.

3) Color measurement and evaluation

(1) Instrumental evaluation

Molds were prepared using rubber impressions (Suflex Putty; Hiossen, Eschborn, Germany) to ensure consistency and reproducibility of the measurements. The molds were made to measure the center and restorative areas of the tooth specimen and had a black background to create an environment similar to that of the oral cavity. The spectrophotometer was calibrated according to the manufacturer's instructions before each measurement. The measurements were performed three times for each specimen by a single operator, and the mean value was recorded for each site of the specimen (Fig. 4).

Color measurements were performed based on the CIE $L^*a^*b^*$ color space introduced by the International Commission on Illumination. Using the difference (ΔL^* , Δa^* , Δb^*) between the CIE $L^*a^*b^*$ value of the central part and the restored part of the specimen, the color difference

(ΔE_{ab}^*) was calculated and confirmed using the following formula: $\Delta E_{ab}^* = \{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}^{1/2}$. $\Delta E_{ab}^* \leq 3.3$ was set as the clinically acceptable color difference[8,14].

(2) Visual evaluation

A visual assessment of the color matching was performed according to ISO/TR 28642:2016, with nine dentists visually assessing the degree of color matching of the restoration to the color of the specimen. All specimens were evaluated on a gray background plate with an inclination of 45° at a distance of 35 cm under a standard light source D65 (natural light at noon on a clear day)[15]. The degree of color matching between the resin tooth and restoration was evaluated on a scale of 0 to 4 using the following criteria: 0, excellent match; 1, very good match; 2, not so good match (border zone mismatch); 3, obvious mismatch; and 4, huge (pronounced) mismatch[8,10].

3. Statistical analysis

Statistical analysis was performed by using IBM SPSS 21.0 (SPSS Inc., Chicago, IL, USA). Kolmogorov-Smirnov and Shapiro-Wilk normality tests were performed to test normality, and the Kruskal-Wallis test was used to compare the ΔE_{ab}^* values and color matching scores of each group. The Mann-Whitney U test with Bonferroni correction was used as a post-hoc test, and the significance level (α) was set at 0.005 (0.05 / 10).

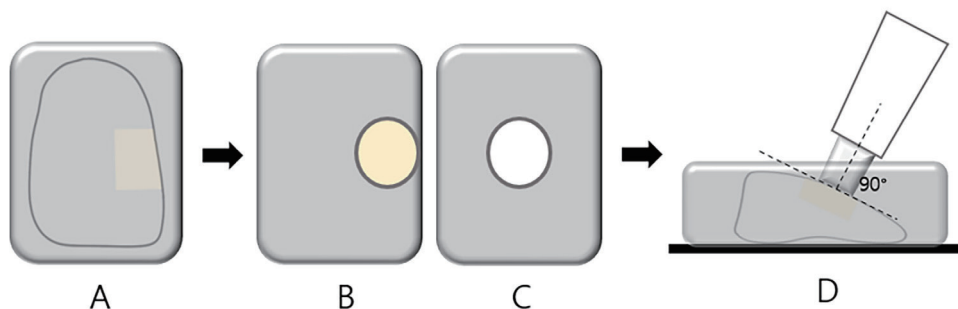


Fig. 4. Schematic illustration of the shade measurement with the spectrophotometer. (A) Vinyl polysiloxane is used to make shade guide molds. (B) A shade guide to measure the color of the restored specimen. (C) A Shade guide to measure the color of the center of the specimen. (D) The spectrophotometer is positioned perpendicular to the specimen to minimize errors.

Cronbach’s alpha test was performed to analyze the inter-rater reliability between the evaluators in visual evaluation, and the Pearson correlation test was performed to analyze the correlation between ΔE_{ab}^* values measured by spectrophotometer and color matching scores through visual evaluation.

Results

1. Instrumental evaluation

The results of the color measurements using the spectrophotometer are presented in Table 2 and Fig. 5. The mean value of the color difference (ΔE_{ab}^*) between the center and the restored site of the specimen in the con-

Table 2. Mean and standard deviation of ΔE_{ab}^*

Group (n = 10)	Mean \pm Standard deviation	<i>p</i> value
OM (Control)	3.20 \pm 0.43 ^a	
UB	3.39 \pm 0.94 ^a	0.739
TC	4.17 \pm 0.81 ^a	0.035
EM	7.06 \pm 1.10 ^b	< 0.0001
PT	7.87 \pm 1.22 ^b	< 0.0001

a, b, c: Different superscript letters of ΔE_{ab}^* indicate significant difference between groups according to the Mann-Whitney U test ($p < 0.005$). *p* values from the Mann-Whitney U test.

OM: Omnichroma; UB: Ultra-Blend™ plus; TC: Theracal PT™; EM: Endocem® MTA premixed; PT: Well-root PT™.

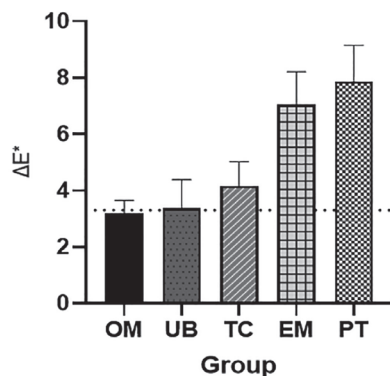


Fig. 5. The Mean and standard deviation of ΔE_{ab}^* values for each group. The dotted line represents a clinically acceptable discoloration of $\Delta E_{ab}^* \geq 3.3$.

OM: Omnichroma; UB: Ultra-Blend™ plus; TC: Theracal PT™; EM: Endocem® MTA premixed; PT: Well-root PT™.

trol group was 3.20 \pm 0.43, indicating a clinically acceptable color difference. The ΔE_{ab}^* was higher in the UB and TC groups than in the control group; however, this was not statistically significant ($p > 0.005$), whereas the EM and PT groups showed a color difference of 7.06 \pm 1.10 and 7.87 \pm 1.22, respectively, which was above the clinically acceptable levels and significantly different from the control group ($p < 0.005$).

2. Visual evaluation

The Cronbach’s alpha coefficient for reliability between the evaluators was 0.813, indicating high reliability. The color-matching scores for each group, as evaluated by the nine evaluators, are shown in Table 3 and Fig. 6. UB

Table 3. Mean and standard deviation of the color matching score

Group (n = 10)	Mean \pm Standard deviation	<i>p</i> value
OM (Control)	1.59 \pm 0.29 ^{AB}	
UB	1.12 \pm 0.43 ^A	0.023
TC	1.92 \pm 0.39 ^B	0.052
EM	2.90 \pm 0.56 ^C	< 0.0001
PT	3.17 \pm 0.18 ^C	< 0.0001

A, B, C: Different superscript letters of the color-matching score indicate a non-significant difference between groups using the Mann-Whitney U test ($p < 0.005$).

p values from the Mann-Whitney U test.

OM: Omnichroma; UB: Ultra-Blend™ plus; TC: Theracal PT™; EM: Endocem® MTA premixed; PT: Well-root PT™.

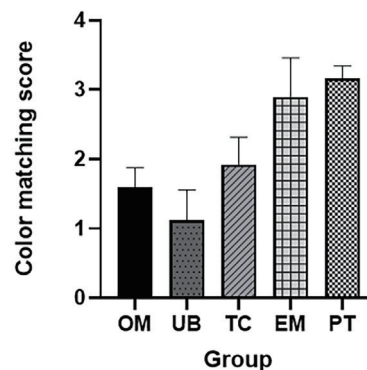


Fig. 6. The Mean and standard deviation of the color matching score for each group.

OM: Omnichroma; UB: Ultra-Blend™ plus; TC: Theracal PT™; EM: Endocem® MTA premixed; PT: Well-root PT™.

had the highest color-matching score (1.12 ± 0.43), followed by OM, TC, EM, and PT.

In addition, a Pearson correlation test was performed to analyze the correlation of the results between the two evaluation methods, and the ΔE_{ab}^* value measured using the spectrophotometer and the color matching score showed a high positive correlation ($r = 0.915$).

Discussion

Omnichroma, a recently developed single-shade composite resin, combines the color reflected from the surrounding teeth as ambient light passes through the resin, allowing it to blend naturally with the color of the teeth[6]. These properties reduce the time spent on shade selection and the need for layering techniques, making them more effective in pediatric dentistry, especially when short chair times are required[16]. However, owing to the nature of Omnichroma, color variations based on underlying materials may affect esthetics[17]. Therefore, in this study, we compared the color difference between restorations and adjacent teeth using various pulp capping materials in conjunction with Omnichroma in anterior restorations.

Two methods for evaluating the color of dental restorative materials are instrumental measurements and visual assessment[10,11,18]. Color differences between restorations and adjacent resin tooth specimens in this study were measured using VITA Easyshade®V. VITA Easyshade®V is a spectrophotometer that uses a spot measurement method, demonstrating higher accuracy than spectrophotometers measuring simultaneously the entire tooth surface. It features multiple spectrometers enclosed within a ring inside the light probe, allowing diffuse light measurements at two different distances. This enables accurate measurements even when the illuminated area of the tooth surface is smaller than that of the probe[19,20].

As in previous studies, the color evaluation method using a spectrophotometer involved measurements using the CIE $L^*a^*b^*$ system. In the CIE $L^*a^*b^*$ system, L^* represents the brightness from black to white, a^* indicates

the degree of redness to green-ness, and b^* represents the degree of yellowness to blueness. The color difference, ΔE_{ab}^* , can be calculated as $\Delta E_{ab}^* = \{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}^{1/2}$ [21]. According to previous studies, the clinically acceptable range of ΔE^* varies from 3.3 to 3.7. However, in this study, we utilized the widely adopted standard of 3.3, established by the U.S. Public Health Service, for our color difference assessment[22-24].

Color evaluation results using a spectrophotometer showed that the ΔE_{ab}^* value for the control group with the restoration solely done with Omnichroma was 3.20, demonstrating the lowest value and falling within the clinically acceptable range, consistent with previous Omnichroma color matching studies[8,11,22]. The UB and TC groups exhibited higher values of 3.39 and 4.15, respectively, than the control group; however, these differences were not statistically significant. In contrast, compared with the control group, the EM and PT groups showed significantly higher values of 7.06 and 7.87, respectively. These results were attributed to the color and translucency characteristics of the pulp capping material. The color and translucency of UB are similar to those of dentin[25], whereas TC, owing to the addition of ytterbium fluoride for increased radiopacity, exhibits a slight yellowish tint[26]. Conversely, EM and PT display an ivory-white color influenced by zirconium oxide addition, a substance added to increase radiopacity and reduce tooth discoloration[27,28]. Originally, bismuth oxide was added to Portland cement in materials of the MTA family to increase radiopacity. However, this caused gray discoloration in the teeth. In current developments, zirconium oxide, which induces less discoloration, is added instead[29]. Several studies suggest that this addition does not significantly affect the material's properties and results in relatively less discoloration of the teeth. However, zirconium oxide is inherently white, rendering the material itself opaque and white. Considering the properties of Omnichroma, which reflects the background color, the UB and TC groups, bearing a closer resemblance to the natural tooth color, may exhibit superior color harmony.

The UB group scored the highest on visual evaluation,

followed by the OM, TC, EM, and PT groups in descending order of excellence. Although the UB and TC groups did not show significant differences, the EM and PT groups exhibited significant differences compared with the OM group. In the mechanical evaluation, the OM group exhibited the smallest ΔE_{ab}^* value compared with all other groups. However, in the visual assessment, the UB group showed the highest color matching score because of the blending effect. The blending effect is a term used in esthetic restorative dentistry for the phenomenon where the color difference between the restoration material and the actual tooth appears more pronounced in isolation, but visually appears more esthetically pleasing and harmonious with the natural tooth color upon restoration within the tooth[30]. The blending effect is influenced by various factors, such as the inherent color and translucency of the material, the particle size of the restorative material, surface roughness, and the size of the filler particles. According to previous studies, the blending effect increases as the size of the filler particles decreases, the transparency increases, and the color difference of the material itself decreases[31,32]. While there have been no specific studies addressing the transparency of the UB material itself, the inference based on these various factors is that the UB group demonstrated a superior color matching score in the visual assessment compared with the OM group.

This study had several limitations. First, Omnicroma exhibits variations in color matching depending on the natural tooth color[10,11]. However, in this study, only a single color of resin teeth was used without comparing various colors. Future research should compare resin teeth of varying colors to provide a more comprehensive understanding. Second, because the color of restoration is associated with the thickness of the restorative material[33], additional research on the color harmony of Omnicroma based on thickness is recommended. Since this study utilized acrylic resin teeth, discoloration caused by the restorative material on natural teeth was not considered. Moreover, pulp capping materials can lead to discoloration of the coronal part of the tooth. Therefore, additional research that considers this aspect

is deemed necessary[3,34,35].

Conclusion

In this study, the color difference was compared between restorations and adjacent teeth using various pulp capping materials in combination with Omnicroma. In the instrumental measurements, all pulp capping materials exhibited high color differences compared to restoration with Omnicroma alone, reaching clinically unacceptable levels. However, when using Ultra-Blend™ plus and TheraCal PT™, no significant difference was observed compared with restoring with Omnicroma alone. However, in the visual assessment, the group using Ultra-Blend™ plus exhibited the best color matching, followed by the group restored with Omnicroma alone, the group using TheraCal PT™, the group using Endocem® MTA premixed, and finally the group using Well-root PT™.

This study suggests that esthetic outcomes may be compromised when using Omnicroma for restorations after pulp capping of anterior teeth compared to its standalone use. Additionally, if esthetics are a priority, Ultra-Blend™ plus or TheraCal PT™, which closely match enamel color, may offer better esthetic results compared to Endocem® MTA premixed and Well-root PT™.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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