

Color stability of indirect composite materials polymerized with different polymerization systems

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Abstract: The purpose of the current study was to evaluate the color stability of two indirect composite materials (Sinfony and Pearleste) polymerized with different laboratory polymerization systems. Disk specimens were prepared with their proprietary polymerization systems (Visio and Pearlcare systems) or with a metal halide light polymerization unit (Hyper LII) for 60, 120, and 180 s. After storage at 37°C for 24 h, the specimens were immersed in either purified water or tea. Color change between baseline evaluation and after 4 weeks was determined with a dental chroma meter (ShadeEye NCC) using black and white backgrounds. CIE 1976 L* a* b* values were determined, and they were converted into ΔE^*_{ab} values. The ΔE^*_{ab} value of the Sinfony material immersed in tea was the highest when the material was polymerized with the proprietary Visio system. The Pearleste material immersed in purified water and tea was not affected substantially by the polymerization systems. Among the 12 groups polymerized with the Hyper LII units, ΔE^*_{ab} values of 11 groups were significantly lower for the Pearleste material than for the Sinfony material. It can be concluded that the Pearleste material was stable against color change when the material was polymerized with either the Pearlcare system or with the Hyper LII unit. (J Oral Sci 51, 267-273, 2009)

Keywords: color; composite; heat; light; polymerization.

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Introduction

The application of indirect composite materials for tooth-colored restorations has increased substantially. This trend is probably due to improvement in the properties of composite materials (1-3). Despite the improvement in properties and clinical results, several factors which deserve attention have been reported. One of the problems associated with composite materials is unpredictable color stability (4). A number of testing methods and techniques for determination of optical properties of the material have been reported (5-14).

Color stability of composite materials is dependent on the conversion of matrix monomers (15,16), and is affected by both the type of polymerization system and the polymerization condition (17-25). Insufficient monomer conversion induces absorption of staining substances (26,27). A high-intensity laboratory light polymerization unit has been developed for the purpose of improving post-polymerization properties of indirect composite materials (28). Characteristics of the light source considerably affect the depth of cure, hardness, wear resistance, water sorption, and solubility of indirect composites (29-32).

Although color stability of composite restorative materials has been studied (6,9,18), only limited information is available about the resistance to color change of indirect composite materials, especially related to the compatibility of materials and laboratory polymerization units. The purpose of this study was to evaluate the color stability of two indirect composite materials polymerized with different laboratory polymerization systems.

Materials and Methods

Composite materials and polymerization systems

Two indirect composite materials were assessed (Table

Table 1 Indirect composite materials assessed

Material/Trade name	Manufacturer	Lot number	Composition
Sinfony E2	3M ESPE, Seefeld, Germany	2458161	Aliphatic monomer, Cycloaliphatic monomer, Alumina, Silica (0.5-0.7 μm)*
Pearleste E2	Tokuyama Dental Corp., Tokyo, Japan	205	Bis-MPEPP, TEGDMA, UDMA, Silica-zirconia (0.04 μm), Silica-titania (0.08 μm)

*Kakaboula et al. (33); Bis-MPEPP, 2,2-bis[(4-methacryloxy polyethoxy)phenyl]propane; TEGDMA, Triethyleneglycol dimethacrylate; UDMA, 1,6-bis(2-methacryloyl-oxyethoxy-carbonylamino)-2,4,4-trimethylhexane

Table 2 Polymerization systems employed

Polymerization unit	Manufacturer	Polymerization source	Polymerization mode
Visio-Alfa	3M ESPE	Halogen lamp* 100 W \times 1, 400-550 nm	15 s
Visio-Beta Vario	3M ESPE	Fluorescent tubes* 250 W \times 2, 400-550 nm	1 min under atmospheric pressure 14 min under reduced pressure
Pearlcure Light	Tokuyama Dental Corp.	High pressure mercury lamp 150 W \times 1, 380-550 nm	120 s
Pearlcure Heat	Tokuyama Dental Corp.	Heat oven	15 min under atmospheric pressure
Hyper LII	Toho Dental Products	Metal halide lamps** 150 W \times 2, 250-600 nm	60 s, 120 s, and 180 s

*Göhring et al. (34); **Matsumura et al. (28)

1). The Sinfony (3M ESPE, Seefeld, Germany) material is composed of 50-55 wt% aliphatic and cycloaliphatic monomers, and 45-50 wt% alumina and silica fillers (0.5-0.7 μm) (33). The Pearleste (Tokuyama Dental Corp., Tokyo, Japan) material is composed of three bifunctional methacrylates and 82 wt% fillers; silica-zirconia (0.04 μm) and silica-titania (0.08 μm).

Three polymerization systems were selected for evaluation of the material properties (Table 2). The Visio system consisted of two light polymerizing units; Visio-Alfa and Visio-Beta Vario (3M ESPE). The light source of the former was a halogen lamp, whereas that of the latter was fluorescent tubes (34). The polymerization mode of the Visio-Beta Vario unit was 1-min irradiation under atmospheric pressure followed by 14-min irradiation under

reduced pressure. The Pearlcare system consisted of two polymerization units; Pearlcare Light and Pearlcare Heat (Tokuyama Dental Corp.). The light source of the Pearlcare Light was a mercury lamp and that of Pearlcare Heat was a heat oven. The processing mode recommended by the manufacturer was light polymerization with the Pearlcare Light for 120 s, followed by heating with the Pearlcare Heat for 15 min under atmospheric pressure. The Hyper LII unit was equipped with two metal halide lamps (Toho Dental Products, Saitama, Japan) (28).

Preparation of specimens

The composite materials were filled into stainless steel molds (15 mm in diameter and 2 mm thick) on a cover glass plate (1.3 mm thickness, Micro Slide Glass, Matsunami

Glass Ind., Ltd., Osaka, Japan). After filling the composite, the surface was covered with the same plate. The specimen was then polymerized with their proprietary systems or with the Hyper LII unit for 60, 120, and 180 s as shown in Table 2. The top and bottom surfaces of each specimen were wet-ground with a series of silicon carbide papers (#800-2,000, WeterDry Tri-M-ite, 3M Corp., St. Paul, MN, USA), and then polished with a felt (TexMet 1500, Buehler Ltd., Lake Bluff, IL, USA) and alumina slurry (0.05 μm , BaikaloX 0.05CR, Baikowski International Corp., Charlotte, NC, USA). Final thickness of the specimen was adjusted to 1.0 mm. The thickness was checked by measuring with a digital caliper (Mitutoyo Corp., Kanagawa, Japan). All specimens were stored in an incubator at 37°C for 24 h.

Measurement of color and calculation of the color difference

After dry-state storage, all specimens were immersed in either purified water or tea. To prepare the tea solution, three teabags containing 15 g of tea (Day & Day Teabags, pH 4.75, Mitsui Norin Co., Ltd., Tokyo, Japan) were placed into 1,000 mL of boiling purified water and brewed for 5 min (27).

Color change after 4 weeks was measured with a dental chromameter (ShadeEye NCC, Shofu Inc., Kyoto, Japan) using black and white backgrounds (Konica Minolta Holdings Inc., Osaka, Japan). Mean color values of the white background were $L^* = 97.3$, $a^* = 0.1$, and $b^* = -1.3$, while those of the black background were $L^* = 15.8$, $a^* = 0.5$, $b^* = -3.3$.

The immersed specimens were rinsed with purified water and dried with absorbent paper before each color measurement. Color was measured according to CIE 1976 $L^*a^*b^*$ color space system relative to the standard illuminant D_{65} and observer functions (2-degree visual field), and calibrated at the start of each measurement using the white calibration tile supplied by the manufacturer. The aperture of the meter was placed on the polished surface of the specimen, measurements were repeated six times around the center of each specimen, and the mean values were calculated. Ten specimens were tested for each polymerization mode. Color difference (ΔE^*_{ab}) values, between pre- and post-immersion, were calculated for each specimen. The following equation was used to calculate the ΔE^*_{ab} of the specimens:

$$\Delta E^*_{ab} = \{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}^{1/2}$$

Statistical analysis

The results of ΔE^*_{ab} were primarily analyzed by Kolmogorov-Smirnov test for normality of distribution (SPSS 15.0, SPSS Inc., Chicago, IL, USA). When the

results of the Kolmogorov-Smirnov test did not show normality of distribution, Kruskal-Wallis test and Steel-Dwass comparison (KyPlot 4.0, KyensLab Inc., Tokyo, Japan) were performed with the value of statistical significance set at $\alpha = 0.05$. The difference in ΔE^*_{ab} of composite materials was analyzed with Mann-Whitney (M-W) U -test at $\alpha = 0.05$.

Results

Kruskal-Wallis tests run on the ΔE^*_{ab} values showed that the P -values were substantially less than 0.05. The results were analyzed with the Steel-Dwass multiple comparisons. The ΔE^*_{ab} median values are summarized in Tables 3 and 4. The ΔE^*_{ab} value determined with the black background ranged from 0.6 to 2.0 for the specimens stored in purified water, and varied from 1.0 to 3.3 for the specimens immersed in tea. The ΔE^*_{ab} value determined with the white background ranged from 0.4 to 2.6 for the specimens stored in purified water, and varied from a minimum 1.6 to a maximum of 5.3 for the specimens immersed in tea.

The ΔE^*_{ab} value of the Sinfony material immersed in purified water was the lowest when the material was polymerized with the proprietary system (categories a and l). However, the ranking changed considerably when the material was immersed in tea. Specifically, ΔE^*_{ab} value of the Sinfony material immersed in tea was the highest when the material was polymerized with the proprietary system (categories i and t).

Unlike the case of the Sinfony material, ΔE^*_{ab} value of the Pearleste material immersed in purified water was not affected substantially by the polymerization systems (categories d and e; o and p). Also, ΔE^*_{ab} value with white background of the Pearleste material immersed in tea was not significantly affected by the polymerization system (categories u and v). The ΔE^*_{ab} value with black background of the Pearleste material immersed in tea was high when the material was polymerized with the proprietary system (category k > j).

Among the 12 groups polymerized with the Hyper LII units, ΔE^*_{ab} values of 11 groups were significantly lower for the Pearleste material than for the Sinfony material. The L^* , a^* , and b^* values of Sinfony and Pearleste materials determined with white background are presented in Table 5. The b^* value of the Sinfony and Pearleste materials increased after immersion in tea, and the results indicate that the color was changed to yellowish. In addition, the b^* value of the Sinfony material was considerably high when the material was polymerized with the Hyper LII unit. The b^* value of the Pearleste material was not significantly affected by the polymerization system.

Table 3 ΔE^*_{ab} median values backed by black plate

Polymerization mode	Purified water			Tea		
	Sinfony	Pearleste	M-W <i>U</i> -test	Sinfony	Pearleste	M-W <i>U</i> -test
Proprietary system	0.8 (0.1) a	1.0 (0.3) e	Not Significant	3.3 (0.4) i	1.9 (0.2) k	Significant
Hyper LII 60 s	1.7 (0.2) b	0.6 (0.1) d	Significant	2.4 (0.1) h	1.2 (0.1) j	Significant
Hyper LII 120 s	1.7 (0.3) b	0.7 (0.2) d, e	Significant	1.6 (0.2) g	1.0 (0.2) j	Significant
Hyper LII 180 s	2.0 (0.2) c	0.9 (0.2) e	Significant	1.1 (0.1) f	1.1 (0.2) j	Not Significant

n = 8, Standard deviation in parentheses. Identical letters indicate that they are not statistically different (Steel-Dwass test, $P > 0.05$).
M-W *U*-test, The difference between the Sinfony and Pearleste (Significant; $P < 0.05$).

Table 4 ΔE^*_{ab} median values backed by white plate

Polymerization mode	Purified water			Tea		
	Sinfony	Pearleste	M-W <i>U</i> -test	Sinfony	Pearleste	M-W <i>U</i> -test
Proprietary system	1.6 (0.1) l	0.7 (0.2) p	Significant	5.3 (0.5) t	1.6 (0.3) u	Significant
Hyper LII 60 s	2.0 (0.2) m	0.5 (0.2) o, p	Significant	4.2 (0.2) s	2.1 (0.1) v	Significant
Hyper LII 120 s	2.5 (0.1) n	0.4 (0.2) o	Significant	3.0 (0.2) r	1.9 (0.2) u, v	Significant
Hyper LII 180 s	2.6 (0.2) n	0.6 (0.2) p	Significant	2.1 (0.2) q	1.6 (0.2) u	Significant

n = 8, Standard deviation in parentheses. Identical letters indicate that they are not statistically different (Steel-Dwass test, $P > 0.05$).
M-W *U*-test, The difference between the Sinfony and Pearleste (Significant; $P < 0.05$).

Discussion

This study evaluated the color stability of two indirect composite materials by means of different polymerization systems. The ΔE^*_{ab} value of the Sinfony material immersed in purified water was the lowest when the material was polymerized with the proprietary Visio system (categories a and l). The author speculates that degradation of the Sinfony material may have occurred due to heat generated by the high level of light energy of the Hyper LII unit. Specifically, the Sinfony material polymerized with the Hyper LII unit exhibited higher b^* value (4.5-6.2) as compared with that polymerized with the Visio system (2.6-2.7). The result indicates that the specimen light-exposed with the Hyper LII unit had changed to yellowish color before immersion in aqueous solution. It is therefore suggested that the light energy emitted from the Hyper LII unit was too strong for polymerization of the aliphatic

monomers contained in the Sinfony material.

The ranking of ΔE^*_{ab} changed when the composite materials were immersed in tea. The ΔE^*_{ab} value of the Sinfony material immersed in tea was the highest when the material was polymerized with the Visio system (categories i and t). This can be explained by the hypothesis that monomer conversion in the Sinfony material was lower when the material was polymerized with the Visio system than with the Hyper LII unit. The property test results concerning the Sinfony material using two polymerization systems support this speculation (35). Also, the hypothesis agrees with the previous experimental results that inadequate polymerization affected the post-curing properties of composite materials and the increased degree of conversion induced sufficient color stability (16).

The ΔE^*_{ab} value of the Pearleste material immersed in

Table 5 L*, a*, and b* values of Sinfony and Pearleste backed by white plate

Indirect composite	Polymerization mode	Media	Pre-immersion			Post-immersion		
			L*	a*	b*	L*	a*	b*
Sinfony	Visio system	Purified water	86.9	-1.7	2.7	87.2	-1.4	1.3
		Tea	87.2	-1.6	2.6	85.2	-0.9	7.6
	Hyper LII 60 s	Purified water	86.8	-2.2	5.5	87.8	-1.9	3.8
		Tea	87.0	-2.5	6.2	85.1	-1.5	9.7
	Hyper LII 120 s	Purified water	86.7	-2.1	4.5	87.8	-1.7	2.3
		Tea	86.9	-1.9	4.5	85.3	-1.1	6.7
	Hyper LII 180 s	Purified water	87.0	-2.0	4.9	87.9	-1.6	2.6
		Tea	87.7	-2.6	4.8	86.3	-1.7	6.2
Pearleste	Pearlcure system	Purified water	85.2	-4.4	21.0	85.5	-4.1	20.6
		Tea	84.4	-4.3	20.8	84.1	-3.5	21.9
	Hyper LII 60 s	Purified water	85.9	-4.2	19.0	86.2	-4.1	19.3
		Tea	86.3	-4.4	19.2	85.2	-3.7	20.8
	Hyper LII 120 s	Purified water	85.8	-4.1	18.6	85.9	-3.9	18.9
		Tea	85.2	-4.1	20.8	84.0	-3.1	21.5
	Hyper LII 180 s	Purified water	84.5	-3.7	19.8	85.0	-3.7	19.7
		Tea	86.0	-4.2	18.6	85.3	-3.6	20.0

n = 8, Numeric numbers in the table are Median.

purified water was not affected by the polymerization systems (categories d and e; o and p). Also, ΔE^*_{ab} value with white background of the Pearleste material immersed in tea was not significantly affected by the polymerization system (categories u and v). This is probably due to the fact that energy emitted from the Pearlcure system and the Hyper LII unit was sufficient to polymerize the Pearleste material properly.

Among the 12 groups polymerized with the Hyper LII units, the ΔE^*_{ab} values of 11 groups were significantly lower for the Pearleste material than for the Sinfony material. It is considered that ΔE^*_{ab} values lower than 3.0 facilitate color stability of the composite material (11). The results of the current study suggest that the Pearleste material polymerized with the Pearlcure system or the Hyper LII unit is considered to be an indirect composite material with excellent color stability.

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