

**Original**

## Changes in chroma of two indirect composite materials polymerized with different polymerization systems

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(Received 17 May and accepted 22 November 2012)

**Abstract:** This study evaluated chroma change in two composite materials (Sinfony and Pearleste) polymerized with two different systems. Disk specimens were prepared using a metal halide unit (Hyper LII) and an exposure time of 60 to 180 s. The proprietary polymerization systems (Visio and Pearlure systems) were used as the reference polymerization modes. After storage at 37°C for 24 h, CIE 1976 L\*a\*b\* values were measured by using a dental chroma meter (ShadeEye NCC) with a gray background. The specimens were then immersed in water or tea. Color change from baseline to 4 weeks was evaluated by measuring  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$ , after which  $\Delta E^*_{ab}$  values were calculated. The brightness of Sinfony specimens was reduced by tea immersion. The color of both materials shifted to yellow after tea immersion, although color change in Sinfony specimens was greater than that in Pearleste specimens. For both materials, color change was less after polymerization with the metal halide unit. In conclusion, Sinfony polymerized with the Hyper LII unit, and Pearleste polymerized with either system, were stable against discoloration due to tea immersion. (*J Oral Sci* 54, 349-354, 2012)

Keywords: chroma; composite; polymerization system.

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### Introduction

During the last decade, highly loaded composite materials have become increasingly used in fabricating restorations and fixed partial dentures, probably due to improvements in the mechanical properties (1-6) and wear resistance (7-9) of such materials. Although improvement in material properties has extended the service period of composite veneered restorations (10,11), a number of problems have been reported. One such problem is that restorations made of indirect composites have insufficient color stability, which is substantially influenced by the degree of monomer conversion (12). Color stability is also affected by the type of matrix monomers used, the polymerization system, and polymerization conditions (7,13-15).

A laboratory light polymerization unit equipped with a metal halide light source is now available (16), and the properties of a composite material polymerized with this unit were superior to those produced by the proprietary unit (16). Research has shown that the type of light source affects depth of cure (17), hardness, water sorption, solubility (5), and wear resistance (9) of indirect composite materials.

Color stability of direct composite restorative materials has been extensively studied using various aqueous solutions. However, there is limited information regarding resistance to discoloration in indirect composite materials (18-21), particularly with respect to the type of laboratory polymerization unit used. Nakazawa (22) evaluated the color stability of two composite materials placed on black and white backgrounds and found that one of the materials was more stable against color change after immersion in aqueous media. However, that study did not comprehensively evaluate chromatic change by

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Table 1 Materials assessed

Material/System	Trade name	Lot number	Information
Indirect composite	Sinfony E2*	2458161	Aliphatic monomer, Cycloaliphatic monomer, Alumina filler, Silica filler
Polymerization system	Visio-Alfa*		Halogen lamp (100 W×1; 400-550 nm); 15 s
	Visio-Beta Vario*		Fluorescent tubes (250 W×2; 400-550 nm); 15 min****
Indirect composite	Pearleste E2**	205	Bis-MPEPP, TEGDMA, UDMA, Silica-zirconia filler, Silica-titania filler
Polymerization system	Pearlcure Light**		High pressure mercury lamp (150 W×1; 380-550 nm); 2 min
	Pearlcure Heat**		Heat oven (150°C), 15 min
Polymerization unit	Hyper LII***		Metal halide lamps (150 W×2; 250-600 nm); 1, 2, and 3 min

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

\*3M ESPE, Seefeld, Germany; \*\*Tokuyama Dental Corp., Tokyo, Japan; \*\*\*Toho Dental Products, Saitama, Japan; \*\*\*\*1 min under atmospheric pressure and 14 min under reduced pressure

using a typical gray background. Therefore, the present study compared chroma change in two composite materials polymerized with their proprietary polymerization system or a metal halide unit.

## Materials and Methods

### Materials and polymerization systems

Two composite materials designed for indirect composite veneer were used (Table 1). The Sinfony (E2; 3M ESPE, Seefeld, Germany) material is composed of an aliphatic monomer and cycloaliphatic monomer (50-55 wt%), and alumina and silica fillers (0.5-0.7  $\mu\text{m}$ ; 45-50 wt%) (3). The Pearleste (E2; Tokuyama Dental Corp., Tokyo, Japan) material is composed of three bifunctional monomers (18 wt%)—2,2-bis[(4-methacryloxy polyethoxy)phenyl]propane (Bis-MPEPP), triethyleneglycol dimethacrylate (TEGDMA), 1,6-bis(2-methacryloyl-oxyethoxy-carbonylamino)-2,4,4-trimethylhexane (UDMA), and silica-zirconia (0.04  $\mu\text{m}$ ) and silica-titania (0.08  $\mu\text{m}$ ) fillers (82 wt%) (22).

Three polymerization systems were selected. The Visio system is a proprietary system for Sinfony and consists of two light polymerizing units: Visio-Alfa and Visio-Beta Vario (3M ESPE). The Visio-Alfa is equipped with a halogen lamp, whereas the Visio-Beta Vario uses fluorescent tubes (4). The Pearlcare system (Tokuyama Dental Corp.) is a proprietary system for Pearleste. Pearlcare Light uses a mercury lamp as a light source, and Pearlcare Heat is a heat oven. The Hyper LII (Toho Dental Products, Saitama, Japan) unit is equipped with two metal halide lamps (16).

### Specimen preparation

The composite material paste was filled into a stainless steel mold (15 mm in diameter, 2 mm in thickness) on a glass plate (1.3 mm in thickness, Micro Slide Glass,

Matsunami Glass Ind., Ltd., Osaka, Japan), and the surface was covered with the same plate. The specimen was then polymerized with the proprietary system or the Hyper LII unit. The top and bottom surfaces of each specimen were wet-ground with a series of silicon carbide abrasive papers (#800 to #2000, WetorDry Tri-M-ite, 3M Corp., St. Paul, MN, USA) and then polished with felt (TexMet 1500, Buehler Ltd., Lake Bluff, IL, USA) and alumina slurry (0.05  $\mu\text{m}$ , BaikaloX 0.05 CR, Baikowski International Corp., Charlotte, NC, USA). The thickness of the specimen was adjusted to 1.0 mm by using a digital caliper (Mitutoyo Corp., Kawasaki, Japan). All specimens were stored in an incubator at 37°C for 24 h in darkness.

### Analysis of color change

After the 24-h storage period, specimens were immersed in purified water or tea. To prepare the tea solution, three teabags (15 g; Day & Day Teabags, Mitsui Norin Co., Ltd., Tokyo, Japan) were placed into 1.0 L of boiling purified water and brewed for 5 min (23).

The color ( $L^*$ ,  $a^*$ , and  $b^*$  values) of the specimens at 24 h (1 day) and at 4 weeks (28 days) was measured with a dental chroma meter (ShadeEye NCC, Shofu Inc., Kyoto, Japan) against a gray background (Konica Minolta Holdings Inc., Osaka, Japan). The mean color values of the gray background were  $L^* = 55.4$ ,  $a^* = 0.4$ , and  $b^* = -2.0$ .

Before color measurement, the specimens were rinsed with purified water and wiped with absorbent paper. The color of the specimen was determined according to the CIE 1976  $L^*a^*b^*$  color space system (<http://www.cie.co.at/>) relative to the standard illuminant  $D_{65}$  and observer functions (2-degree visual field). Color value was calibrated at the start of each measurement, using a white calibration tile supplied by the manufacturer. The

Table 2  $\Delta L^*$  values for gray background, by composite material and immersion medium

Polymerization mode	Water						Tea							
	Sinfony			Pearleste			Sinfony			Pearleste				
	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR		
Proprietary system	0.0 (0.1)	0.0*	0.2	0.8 (0.5)	0.9***	0.9	S	-1.1 (0.2)	-1.1*	0.3	0.9 (0.2)	0.9*	0.4	S
Hyper LII 60 s	0.4 (0.3)	0.4**	0.5	0.5 (0.1)	0.5*	0.2	NS	-0.9 (0.2)	-1.0*	0.3	-0.6 (0.1)	-0.6**	0.1	S
Hyper LII 120 s	0.5 (0.4)	0.3**	0.7	0.4 (0.2)	0.4*	0.2	NS	-0.9 (0.3)	-0.8***	0.6	-0.5 (0.2)	-0.5***	0.4	S
Hyper LII 180 s	0.0 (0.3)	-0.1*	0.5	0.7 (0.2)	0.7**	0.3	S	-0.6 (0.3)	-0.6**	0.5	-0.3 (0.2)	-0.2***	0.4	S

IQR, interquartile range.

$n = 10$ . SD in parentheses. Values with an identical number of asterisks in a column are not statistically different (Steel–Dwass test,  $P > 0.05$ ). Difference between Sinfony and Pearleste (Mann–Whitney  $U$  test): S—significant ( $P < 0.05$ ), NS—not significant ( $P > 0.05$ ).

Table 3  $\Delta a^*$  values for gray background, by composite material and immersion medium

Polymerization mode	Water						Tea							
	Sinfony			Pearleste			Sinfony			Pearleste				
	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR		
Proprietary system	0.3 (0.1)	0.3*	0.1	0.2 (0.1)	0.2*	0.1	NS	0.3 (0.1)	0.3*	0.2	0.4 (0.1)	0.4*	0.1	S
Hyper LII 60 s	0.4 (0.1)	0.5**	0.1	0.0 (0.0)	0.0**	0.1	S	0.6 (0.1)	0.6**	0.1	0.3 (0.1)	0.3***	0.1	S
Hyper LII 120 s	0.3 (0.1)	0.3*	0.2	0.1 (0.1)	0.1**	0.1	S	0.5 (0.1)	0.5**	0.1	0.6 (0.1)	0.6**	0.1	NS
Hyper LII 180 s	0.4 (0.1)	0.4***	0.2	-0.1 (0.1)	-0.1***	0.2	S	0.5 (0.1)	0.6**	0.2	0.3 (0.1)	0.2***	0.2	S

IQR, interquartile range.

$n = 10$ . SD in parentheses. Values with an identical number of asterisks in a column are not statistically different (Steel–Dwass test,  $P > 0.05$ ). Difference between Sinfony and Pearleste (Mann–Whitney  $U$  test): S—significant ( $P < 0.05$ ), NS—not significant ( $P > 0.05$ ).

aperture of the chroma meter was placed on the polished surface of the specimen, and measurements were repeated six times around the center of each specimen, after which mean values were calculated. Ten specimens were tested for each polymerization mode. Pre- to post-immersion color change ( $\Delta E^*_{ab}$ ) was calculated for each specimen by using the following equation:  $\Delta E^*_{ab} = \{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}^{1/2}$ .

### Statistical analysis

$\Delta L^*$ ,  $\Delta a^*$ ,  $\Delta b^*$ , and  $\Delta E^*_{ab}$  were analyzed primarily by the Kolmogorov–Smirnov test to evaluate normality of distribution (IBM SPSS Statistics ver. 19.0, IBM Corp., Somers, NY, USA). When the results of that test did not show normality of distribution, the Kruskal–Wallis test and Steel–Dwass test (KyPlot 5.0, KyensLab Inc., Tokyo, Japan) were used, with the value for statistical significance set at  $\alpha = 0.05$ . Differences in  $\Delta L^*$ ,  $\Delta a^*$ ,  $\Delta b^*$ , and  $\Delta E^*_{ab}$  values between the two composite materials were analyzed with the Mann–Whitney  $U$  test at a significance level of  $\alpha = 0.05$ .

## Results

The Kolmogorov–Smirnov test revealed that several groups did not show normality. The Kruskal–Wallis tests of the experimental results showed that the  $P$  value for

the differences among  $\Delta L^*$ ,  $\Delta a^*$ ,  $\Delta b^*$ , and  $\Delta E^*_{ab}$  values was less than 0.05. The results were therefore analyzed with the Steel–Dwass test.

The values for the mean, SD, median, and interquartile range of  $\Delta L^*$ ,  $\Delta a^*$ ,  $\Delta b^*$ , and  $\Delta E^*_{ab}$  are shown in Tables 2 through 5. Table 2 shows mean and median  $\Delta L^*$  values. The median  $\Delta L^*$  for specimens immersed in water ranged from  $-0.1$  to  $0.4$  for Sinfony and from  $0.4$  to  $0.9$  for Pearleste. The median  $\Delta L^*$  for specimens immersed in tea varied from  $-1.1$  to  $-0.6$  for Sinfony and from  $-0.6$  to  $0.9$  for Pearleste. The median  $\Delta L^*$  for Pearleste was  $0.9$  when the material was polymerized with the proprietary system.  $\Delta L^*$  for Pearleste polymerized with the Hyper LII unit increased from  $0.4$  to  $0.7$  after water immersion and from  $-0.6$  to  $-0.2$  after tea immersion. A similar tendency was observed for Sinfony. The difference in  $\Delta L^*$  between the two composite materials was significant for six of eight comparisons.

Table 3 summarizes  $\Delta a^*$  values. The median  $\Delta a^*$  for specimens immersed in water ranged from  $0.3$  to  $0.5$  for Sinfony and from  $-0.1$  to  $0.2$  for Pearleste. The median  $\Delta a^*$  for specimens immersed in tea ranged from  $0.3$  to  $0.6$  for Sinfony and from  $0.2$  to  $0.6$  for Pearleste. The  $\Delta a^*$  values for Pearleste were  $0.2$  and  $0.4$  when the material was polymerized with the proprietary system. The  $\Delta a^*$  values ( $-0.1$  to  $0.2$ ) for Pearleste after water immersion

Table 4  $\Delta b^*$  values for gray background, by composite material and immersion medium

Polymerization mode	Water						Tea							
	Sinfony			Pearleste			Sinfony			Pearleste				
	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR		
Proprietary system	-0.9 (0.1)	-0.9*	0.1	0.0 (0.4)	0.0*	0.5	S	3.6 (0.4)	3.6*	0.7	1.3 (0.3)	1.3*	0.4	S
Hyper LII 60 s	-1.3 (0.3)	-1.2**	0.7	0.3 (0.1)	0.3**	0.1	S	2.5 (0.1)	2.5**	0.2	1.3 (0.1)	1.3*	0.2	S
Hyper LII 120 s	-1.6 (0.2)	-1.7**	0.5	0.1 (0.2)	0.1*	0.3	S	1.7 (0.2)	1.6***	0.4	0.9 (0.3)	1.0**	0.5	S
Hyper LII 180 s	-1.7 (0.1)	-1.7***	0.1	-0.1 (0.2)	-0.1*	0.3	S	1.1 (0.2)	1.0****	0.4	1.1 (0.3)	1.0***	0.5	NS

IQR, interquartile range.

$n = 10$ . SD in parentheses. Values with an identical number of asterisks in a column are not statistically different (Steel–Dwass test,  $P > 0.05$ ). Difference between Sinfony and Pearleste (Mann–Whitney  $U$  test): S—significant ( $P < 0.05$ ), NS—not significant ( $P > 0.05$ ).

Table 5  $\Delta E^*_{ab}$  values for gray background, by composite material and immersion medium

Polymerization mode	Water						Tea							
	Sinfony			Pearleste			Sinfony			Pearleste				
	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)	Median	IQR		
Proprietary system	1.0 (0.1)	1.0*	0.1	0.9 (0.5)	0.9*	0.6	NS	3.8 (0.3)	3.8*	0.7	1.6 (0.3)	1.6*	0.4	S
Hyper LII 60 s	1.5 (0.3)	1.4**	0.5	0.6 (0.1)	0.5***	0.3	S	2.7 (0.1)	2.7**	0.2	1.4 (0.1)	1.5*	0.1	S
Hyper LII 120 s	1.7 (0.1)	1.8****	0.2	0.4 (0.2)	0.4**	0.2	S	2.0 (0.1)	2.0***	0.2	1.2 (0.2)	1.3**	0.4	S
Hyper LII 180 s	1.8 (0.1)	1.8***	0.1	0.7 (0.1)	0.7*	0.2	S	1.4 (0.1)	1.4****	0.2	1.2 (0.2)	1.2**	0.3	S

IQR, interquartile range.

$n = 10$ . SD in parentheses. Values with an identical number of asterisks in a column are not statistically different (Steel–Dwass test,  $P > 0.05$ ). Difference between Sinfony and Pearleste (Mann–Whitney  $U$  test): S—significant ( $P < 0.05$ ), NS—not significant ( $P > 0.05$ ).

did not substantially vary. The difference in  $\Delta a^*$  between the two composite materials was significant for six of eight comparisons.

$\Delta b^*$  values are shown in Table 4. The median  $\Delta b^*$  for specimens immersed in water ranged from  $-1.7$  to  $-0.9$  for Sinfony and from  $-0.1$  to  $0.3$  for Pearleste. The median  $\Delta b^*$  for specimens immersed in tea ranged from  $1.0$  to  $3.6$  for Sinfony and from  $1.0$  to  $1.3$  for Pearleste. The  $\Delta b^*$  values for Sinfony and Pearleste were  $-0.9$  and  $0.0$  after water immersion and  $3.6$  and  $1.3$  after tea immersion, respectively, when the materials were polymerized with the proprietary system. The difference in  $\Delta b^*$  between the two composite materials was significant for all comparisons, except for specimens immersed in tea that were polymerized with the Hyper LII for 180 s.

$\Delta E^*_{ab}$  values are summarized in Table 5. The median  $\Delta E^*_{ab}$  for specimens immersed in water ranged from  $1.0$  to  $1.8$  for Sinfony and from  $0.4$  to  $0.9$  for Pearleste. The median  $\Delta E^*_{ab}$  for specimens immersed in tea varied from  $1.4$  to  $3.8$  for Sinfony and from  $1.2$  to  $1.6$  for Pearleste. The  $\Delta E^*_{ab}$  values for Sinfony and Pearleste were  $1.0$  and  $0.9$  after water immersion and  $3.8$  and  $1.6$  after tea immersion, respectively, when the materials were polymerized with the proprietary system. The  $\Delta E^*_{ab}$  for Sinfony immersed in tea was categorized into four groups (\* to \*\*\*\*) according to polymerization mode, whereas the

$\Delta E^*_{ab}$  of Pearleste was categorized into two groups (\* and \*\*). For both composite materials stored in tea,  $\Delta E^*_{ab}$  for the proprietary system was greater than that for the Hyper LII unit. The difference in  $\Delta E^*_{ab}$  between the two composite materials was significant for all comparisons, except specimens immersed in water that were polymerized with the proprietary system.

## Discussion

This study evaluated the color stability of two composite materials immersed in water or tea after polymerization with their proprietary polymerization system or a metal halide unit. For specimens polymerized with the proprietary system,  $L^*$  for the Sinfony was unchanged after immersion in water and lower after immersion in tea, whereas that for Pearleste was unchanged.  $L^*$  represents the brightness of materials. Thus, the increase in  $L^*$  after immersion of the Pearleste material in either water or tea was likely due to a change in transparency during the storage of the material. However, the polymerization efficiency of the Pearlcare system appears to be satisfactory because the brightness of Pearleste was not reduced by 28 days of tea immersion. For Sinfony stored in tea, the reduction in brightness was suppressed by using the Hyper LII unit with a longer exposure time, probably due to increased conversion of monomers in the Sinfony

material. Specifically, as compared with polymerization with the Hyper LII unit, matrix conversion in the Sinfony material was lower when the material was polymerized with the proprietary system. A previous study of color and other properties of composite materials supports the present findings (22,24).

In comprehensively evaluating chromatic change in composite materials polymerized with different systems,  $\Delta a^*$  and  $\Delta b^*$  are measured using a gray background color plate.  $\Delta a^*$  did not markedly vary with storage medium. According to the CIE 1976  $L^*a^*b^*$  color space system, a higher  $a^*$  indicates increased red, and a decrease in  $a^*$  represents increased green. The results of the current experiments suggest that the redness of Pearleste was slightly higher after immersion in tea, whereas, for the Sinfony material, red shift occurred regardless of storage media or polymerization system.

Unlike  $\Delta a^*$ ,  $\Delta b^*$  was substantially changed by tea immersion. In this color system, an increase in  $b^*$  indicates increased yellow, and a decrease in  $b^*$  represents increased blue. The  $b^*$  of both materials increased after immersion in tea for 28 days, possibly because yellowish color change was accelerated, and bluish color change was suppressed, by the original color of the tea solution. Yellowish color change in Sinfony material was substantially influenced by tea immersion. In addition, the degree of color change was affected by polymerization mode. The  $\Delta a^*$  and  $\Delta b^*$  values yielded by the different polymerization systems suggest that the color stability of Sinfony is insufficient when the material is polymerized with its proprietary system.

$\Delta E^*_{ab}$  represents the total color change of materials. The present results revealed no significant difference in  $\Delta E^*_{ab}$  between the two composite materials when they were polymerized with their proprietary system and stored in water. As indicated by the data in Tables 3 through 5, color change was due to yellowish discoloration in Sinfony and to a change in transparency in Pearleste, which suggests that Hyper LII is superior to the Visio system for polymerization and color stability in Sinfony, especially with regard to color stability after immersion in a colored medium like tea. A similar tendency was observed for the Pearleste material, although the differences in  $\Delta E^*_{ab}$  values under the four polymerization conditions were not remarkable. Behr et al. (25) reported that  $\Delta E^*_{ab}$  of less than 3.0 indicates color stability of composite materials. Although color change in materials is strongly influenced by storage medium (6), the results of the current study suggest that Sinfony polymerized with the Hyper LII unit and Pearleste polymerized with either of the investigated systems are color-stable after tea immersion.

## References

1. Jones RM, Goodacre CJ, Moore BK, Dykema RW (1989) A comparison of the physical properties of four prosthetic veneering materials. *J Prosthet Dent* 61, 38-44.
2. Tanoue N, Matsumura H, Atsuta M (1998) Properties of four composite veneering materials polymerized with different laboratory photo-curing units. *J Oral Rehabil* 25, 358-364.
3. Kakaboura A, Rahiotis C, Zinelis S, Al-Dhamadi YA, Silikas N, Watts DC (2003) In vitro characterization of two laboratory-processed resin composites. *Dent Mater* 19, 393-398.
4. Göhring TN, Gallo L, Lüthy H (2005) Effect of water storage, thermocycling, the incorporation and site of placement of glass-fibers on the flexural strength of veneering composite. *Dent Mater* 21, 761-772.
5. Satsukawa H, Koizumi H, Tanoue N, Nemoto M, Ogino T, Matsumura H (2005) Properties of an indirect composite material polymerized with two different laboratory polymerizing systems. *Dent Mater J* 24, 377-381.
6. Stawarczyk B, Egli R, Roos M, Ozcan M, Hämmerle CH (2011) The impact of in vitro aging on the mechanical and optical properties of indirect veneering composite resins. *J Prosthet Dent* 106, 386-398.
7. Wendt SL Jr (1987) The effect of heat used as secondary cure upon the physical properties of three composite resins. II. Wear, hardness, and color stability. *Quintessence Int* 18, 351-356.
8. Freiberg RS, Ferracane JL (1998) Evaluation of cure, properties and wear resistance of Artglass dental composite. *Am J Dent* 11, 214-218.
9. Hirata M, Koizumi H, Tanoue N, Ogino T, Murakami M, Matsumura H (2011) Influence of laboratory light sources on the wear characteristics of indirect composites. *Dent Mater J* 30, 127-135.
10. O'Neal SJ, Leinfelder KF, Barrett CE (1989) Clinical evaluation of Dentacolor as a posterior veneering agent. *J Esthet Dent* 1, 29-33.
11. Matsumura H, Nakamura M, Tanoue N, Atsuta M (2000) Clinical evaluation of an urethane tetramethacrylate-based composite material as a prosthetic veneering agent. *J Oral Rehabil* 27, 846-852.
12. Ruyter IE, Nilner K, Moller B (1987) Color stability of dental composite resin materials for crown and bridge veneers. *Dent Mater* 3, 246-251.
13. Hinoura K, Aoshima Y, Iwano K, Onose H, Moore

- BK (1993) Effect of die material hue and value on polymerization of indirect resin inlays. *Int J Prosthodont* 6, 255-258.
14. Koishi Y, Tanoue N, Atsuta M, Matsumura H (2002) Influence of visible-light exposure on colour stability of current dual-curable luting composites. *J Oral Rehabil* 29, 387-393.
  15. Kim SH, Lee YK (2008) Changes in color and color coordinates of an indirect resin composite during curing cycle. *J Dent* 36, 337-342.
  16. Matsumura H, Tanoue N, Atsuta M, Kitazawa S (1997) A metal halide light source for laboratory curing of prosthetic composite materials. *J Dent Res* 76, 688-693.
  17. Tanoue N, Matsumura H, Atsuta M (1998) Curing depth of a composite veneering material polymerized with seven different laboratory photo-curing units. *J Oral Rehabil* 25, 199-203.
  18. Peutzfeldt A, Asmussen E (1990) Color stability of three composite resins used in the inlay/onlay technique. *Scand J Dent Res* 98, 257-260.
  19. Douglas RD (2000) Color stability of new-generation indirect resins for prosthodontic application. *J Prosthet Dent* 83, 166-170.
  20. Stober T, Gilde H, Lenz P (2001) Color stability of highly filled composite resin materials for facings. *Dent Mater* 17, 87-94.
  21. Lee YK, Yu B, Lim HN, Lim JI (2011) Difference in the color stability of direct and indirect resin composites. *J Appl Oral Sci* 19, 154-160.
  22. Nakazawa M (2009) Color stability of indirect composite materials polymerized with different polymerization systems. *J Oral Sci* 51, 267-273.
  23. Tanoue N, Soeno K, Kawasaki K, Atsuta M (2004) Influence of acidulated phosphate fluoride solution on the color stability of indirect composites. *J Prosthet Dent* 92, 343-347.
  24. Imazato S, Tarumi H, Kobayashi K, Hiraguri H, Oda K, Tsuchitani Y (1995) Relationship between the degree of conversion and internal discoloration of light-activated composite. *Dent Mater J* 14, 23-30.
  25. Behr M, Rosentritt M, Faltermeier A, Handel G (2005) Electron beam irradiation of dental composites. *Dent Mater* 21, 804-810.