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Original Article

The effects of various finishing materials on the gloss and the color change of indirect prosthetic resin composites

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The effect of different polishing materials on the surface texture and the color change of indirect prosthetic resin composite materials exposed to a staining agent was studied. Six different resin composites were polished using the same procedures and were measured for the gloss. After exposed to a coffee solution, the changes were measured on the color properties. The six different types of resin composites were further divided into four groups of eight specimens each for the different surface polishing procedure. The gloss was measured by a gloss meter (TC-108D, Tokyo-Densyoku, Tokyo, Japan) with an angle of 45° and expressed in gloss units (GU). Before and after exposure to the staining agent, the color measurements of all specimens were recorded with a colorimeter (TC-1800MKII, Tokyo-Densyoku, Tokyo, Japan) using CIE L* a* b*. All specimens were stored in the coffee solution for 5 weeks at 37 °C. Most of the resin composites showed the highest gloss and staining resistances when the fine silicone diamond polishing point was used. The results of this study suggested that there are differences in the gloss and the color changes depending on the filler type and the composition of the polishing materials.

Key words: resin, polishing, gloss, color change

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Introduction

Currently, the improvements in the wear resistance and the mechanical properties in conjunction with the total acid-etch technique allowed clinicians to place more reliable posterior resin composite dental restorations[1]. The actual heavier consistency and the mechanical properties of these materials are produced by subtle modifications and concentration of the particle size of the reinforcing filler or other components[2].

An unacceptable color match is one of the major reasons for replacement of indirect resin composite restorations. The intrinsic factors including changes in the filler, matrix, silane coating or the extrinsic factors such as absorption of stains may cause color change of the materials. Another important factor for the color stability is the aging of resin composite under various physicochemical conditions, such as ultraviolet light exposure, thermal changes, and humidity[3-5]. The resin composition and the characteristics of the fillers play the major role in the color change of resin composites. The resin's affinity for stains is modulated by its conversion rate and its chemical characteristics, with the water absorption rate being of particular importance.

Spectrophotometry and colorimetry, applied both in vitro and in vivo environments, have made it possible to study the numerous parameters related to composite color stability. The color change can be evaluated with various instruments, since instrumental measurements eliminate the subjective interpretation of visual-color comparison. Spectrophotometers and colorimeters have been used to measure color changes in dental materials. One of the most commonly used methods to assess resin composite color changes is the reflectance spectrophotometry with the CIE L*a*b* color system[6-11]. The quantitative evaluation of color change (ΔE) with a colorimeter confers advantages such as repeatability, sensitivity, and objectivity, despite some limitations. In principle, if a material has a completely stable color, no color difference will be detected after its exposure to the testing environment ($\Delta E=0$). Various studies have reported different thresholds of color-difference values above which the color change is perceptible to the human eye. These values range from ΔE equal to 1[12], between 2 and 3[13], greater than or equal to 3.3[14], and greater than or equal to 3.7[15]. Values of ΔE between 0 and 2 were imperceptible, values of ΔE in the range of 2 to 3 were just perceptible, values from 3 to 8 were moderately perceptible, and values above 8 were markedly perceptible[8]. A ΔE value of 3.7 or less is considered to be clinically acceptable[15,16].

Proper finishing and polishing are important steps that enhance esthetics and long lasting quality of resin composite restorations. The surface roughness and surface integrity of the restorations can influence plaque accumulation, periodontal disease, recurrent decay and staining of the resin composite. The resin composite surface roughness is mainly dictated by the size, the hardness and the amount of filler, which influence the mechanical properties of the resin composite, and by the hardness and the grit size of the abrasive, and the flexibility, of the finishing material.

The purpose of this study was to investigate the effects of the different polishing materials on the gloss related with the color changes of the resin composite materials exposed to a staining agent.

Materials and methods

Six different resin composites were used in this study (Table 1).

The polishing materials used were basically silicone alumina polishing points, namely Silicone point P3, silicone polishing point with diamond particles Perladia #4000 and #5000 (Table 2). These points were made in same sizes as samples.

Thirty-two square specimens (20×20×2 mm) were prepared using a Teflon mold for each of the six different types of tested resin composite materials which were Pearleste(PE), Estenia C&B (ES), Gradia Forte (GF), Gradia (GR), Sinfony (SI) and Ceramage (CE). Specimens were light polymerized using Curing Light XL 3000 (3M ESPE, St. Paul, USA) with a light intensity of 400 mW/cm^2 for 20 seconds on both sides with the light tip approximately 1 mm away from the specimens and using Halide Master (Molten, Hiroshima, Japan) for 3 minutes on both sides. After light polymerized, PE, ES, SI and GF were polymerized using heat curing unit for 15 minutes. All specimens were wet-ground with 1500-grit silicone carbide polishing paper for 30 seconds by hand. The six different types of resin composite specimens were sub-divided into four groups of eight specimens each for the different surface polishing procedures. Group SiC#1500 specimens were polished with only 1500-grit silicone carbide polishing paper by hand. Group Al_2O_3 specimens were polished with 1500-grit silicone carbide polishing paper by hand and silicone point P3 with an electric hand piece at 7,500 rpm for 60 seconds. Group C#4000 specimens were polished with 1500-grit silicone carbide polishing paper by hand and polished with 4000-grit silicone diamond polishing points by an electric hand piece at 7,500 rpm for 60 seconds. Group C#5000 specimens were polished with 1500-grit silicone carbide polishing

Table 1. Dental resin composites tested in this study

Product	Monomer component	Filler shape	Filler type (amount)	Manufacturer	Shade	Code
PEARLESTE	bis-MPEPP,TEGDMA,UDMA	Submicron spherical	Inorganic filler (82 wt%)	Tokuyama Dental, Tokyo, Japan	E2	PE
ESTENIA C&B	bis-GMA,UTMA	Irregular	Inorganic filler (92 wt%)	Kuraray Medical Inc, Tokyo, Japan	E1	ES
GRADIA FORTE	UDMA	Irregular	Inorganic filler (73 wt%) Organic hybrid filler (3 wt%)	GC Inc, Tokyo, Japan	E3	GF
GRADIA	UDMA	Irregular	Inorganic filler (54 wt%) Organic hybrid filler (21 wt%)	GC Inc, Tokyo, Japan	E3	GR
SINFONY	Triacrylate	Irregular	Inorganic filler (50 wt%)	3M ESPE Inc, St. Paul, USA	E3	SI
CERAMAGE	UDMA,Urethane di-Acrylate	Progressive Fine-Structured	Organic hybrid filler (73 wt%)	SHOFU Inc, Kyoto, Japan	A3B	CE

Table 2. Polishing materials used in this study

Product	Polishing particle	Manufacturer	Code
Silicone point P3	Aluminum oxide	SHOFU Inc, Kyoto, Japan	Al_2O_3
PERLADIA #4000	Diamond 6 µm	Tokuyama Dental , Tokyo, Japan	C#4000
PERLADIA #5000	Diamond 4 µm	Tokuyama Dental , Tokyo, Japan	C#5000

paper by hand and polished with 5000-grit silicone diamond polishing points by an electric hand piece at 7,500 rpm for 60 seconds.

The surfaces of the all specimens were observed by naked eye and SEM.

Surface textures were examined by the measurement of gloss observation. The gloss was measured by a gloss meter (TC-108D, Tokyo-Densyoku, Tokyo, Japan) with an angle of 45° and expressed in gloss units (GU). A completely no reflective surface has 0 GU, and a polished white reflective index of 45° is defined as having gloss of 100 GU[17].

Before exposure to the staining agent, baseline color measurements of all specimens were recorded with a colorimeter (TC-1800MKII, Tokyo-Densyoku, Tokyo, Japan) using CIE (Commission Internationale de l'Eclairage) L*a*b*relative to a standard illuminant C against a white background. Measurements were repeated 3 times for each specimen, and the mean values of the L*, a*, and b*data were calculated. After the baseline color measurements were made, all specimens were stored in stationary coffee solution (Nescafe Classic; Nestle Suisse, Vevey, Switzerland) for 5 weeks at 37 °C. The coffee powder (3.6 g) was dissolved in 300 ml of boiling distilled water. After 5 weeks in the still coffee solution, the specimens were rinsed with distilled water for 1 minute and blotted dry with tissue paper before color measurement. The color change ΔE*between the 2 color measurements (after 5 weeks storage and baseline) in the 3-D L*a*b*color space was calculated as follow:

$$\Delta E^* = \left\| \left(L_1^* - L_2^*\right)^2 + \left(a_1^* - a_2^*\right)^2 + \left(b_1^* - b_2^*\right)^2 \right\|^{1/2}$$

A two-way analysis of variance method (ANOVA) using statistical software (SPSS for Windows, Version 12.0.1; SPSS, Ill, USA) was used to evaluate the effect on each specimen type and the surface finishing procedure on the gloss and the color change, including the possibility of interactions between the two factors. Tukey's HSD test was used as a post hoc multiple comparison. All statistical testing was performed at a 95 % level of confidence.

Results

The surfaces of the specimens polished with SiC#1500presented some scratches (by naked eye observation) and falling off the filler particles (by SEM views) compared with those polished with C#4000 or C#5000.

Gloss

Table 3 shows the means and standard deviations of the resin composites and polishing materials. Two-way ANOVA revealed that the type of resin composites and polishing materials had a significant effect ($p<0.05$). There was the interaction between resin composites and polishing materials ($p<0.05$). For most of the resin composites, the highest gloss values were recorded when C#5000 was used. For ES, no statistically significant differences were observed between C#4000 and C#5000. The lowest gloss values for most of the resin composites were found when SiC#1500 was used. For ES, no statistically significant differences were observed between SiC#1500 and C#4000. PE presented the highest gloss compared with other materials, when SiC#1500 was used.

Discoloration

Table 4 shows the means and standard deviations of the resin composites and polishing materials. Two-way ANOVA revealed that the type of resin composites and polishing materials had a significant effect ($p<0.05$). There was the interaction between resin composites and polishing materials ($p<0.05$). For PE, no statistically significant color differences were observed among any types of polishing point. For GR, the lower color dif-

Table 3. Gloss differences between the specimens related with polishing materials

Resin composites	Polishing materials											
	SiC#1500 Mean (SD)			Al_2O_3 Mean (SD)			C#4000 Mean (SD)			C#5000 Mean (SD)		
PE	68.2	(10.4)	gh	96.2	(2.7)	ab	66.0	(6.4)	h	99.4	(0.5)	a
ES	33.2	(4.4)	i	65.4	(7.4)	h	99.7	(0.2)	a	94.7	(3.1)	abc
GF	21.0	(5.8)	jkl	72.2	(2.1)	fgh	73.9	(2.0)	fgh	85.8	(2.7)	cde
GR	24.4	(6.5)	ijk	76.9	(4.1)	efg	65.0	(2.3)	h	87.7	(3.1)	bcd
SI	19.2	(3.3)	kl	78.8	(8.4)	def	91.3	(1.8)	abc	97.8	(6.4)	a
CE	13.9	(4.4)	l	70.8	(6.0)	fgh	29.5	(1.2)	ij	73.1	(8.2)	fgh

All values are mean (SD). The same letters demonstrate no significant differences among specimens.

Table 4. Color changes between the specimens related with polishing materials

Resin composites	Polishing materials											
	SiC#1500 Mean (SD)			Al_2O_3 Mean (SD)			C#4000 Mean (SD)			C#5000 Mean (SD)		
PE	5.3	(0.3)	bcd	5.0	(0.4)	abcd	4.9	(0.5)	abc	4.5	(0.3)	ab
ES	8.2	(0.4)	ij	6.0	(1.1)	def	6.7	(0.9)	efg	5.8	(0.4)	cde
GF	8.1	(0.7)	i	5.8	(0.8)	cde	5.1	(0.7)	abcd	4.1	(0.7)	a
GR	8.0	(0.5)	i	7.3	(0.3)	ghi	7.8	(0.3)	hi	5.1	(0.5)	abcd
SI	9.3	(0.6)	jk	7.6	(0.5)	ghi	7.7	(1.0)	ghi	5.8	(0.6)	cde
CE	9.2	(0.6)	k	6.9	(1.3)	fgh	7.6	(1.8)	ghi	6.8	(0.6)	efg

All values are mean (SD). The same letters demonstrate no significant differences among specimens.

ferences were recognized with C#5000. When ES was measured, the lower color differences were recorded when Al_2O_3, C#4000 and C#5000 were used. GF presented the lower color differences when C#4000 and C#5000 were used. For SI, the lowest color difference was observed in C#5000. The lower color differences for CE were recorded with Al_2O_3, C#4000, and C#5000.

In case of using SiC#1500, PE showed the lowest color change compared with ES, GF, GR, SI, and CE. When Al_2O_3 was used, PE, ES and GF produced the lower color changes. When C#4000 was used, PE and GF showed the lower color changes ($p<0.05$). When C#5000 was used, PE, GF and GR presented the lowest color differences (Table 4).

Discussion

Color change and stain of resin composite materials may be caused by intrinsic and extrinsic factors. The intrinsic factors involve the discoloration and stain of the resin material itself, such as the alteration of the resin matrix and of the interface of matrix and fillers, every component may take part in this phenomenon. Extrinsic factors cause the discoloration and staining as a result of contamination from exogenous agents.

Alumina and diamond particles contained in the polishing materials used in this study are harder than the filler of the restorative resin composites. However, diamond particles are harder than alumina particles. Therefore, in order to perform the best polishing, it is necessary to consider the shapes of the filler materials.

Gloss

The specimens polished with SiC#1500 showed the lowest gloss value for all of resin composites. For this reason, it is not enough to polish only with SiC#1500. It seems that PE keeps relatively high gloss value, when PE was polished with SiC#1500[17].

The resin composites showed the highest gloss value when C#5000 silicone diamond polishing point

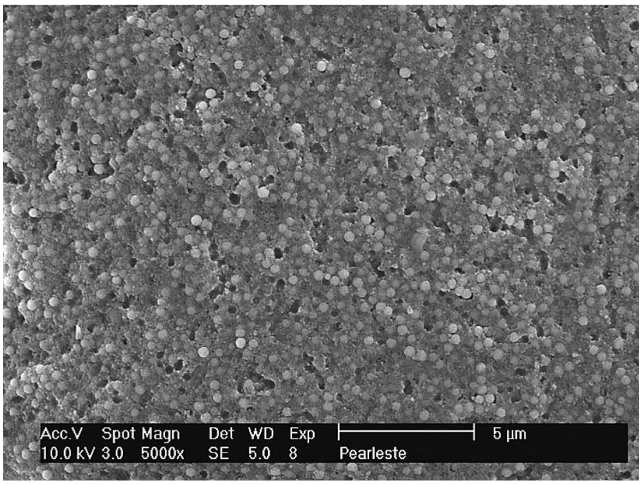

Fig. 1. SEM view of PE surface polished with SiC#1500 (×5000)

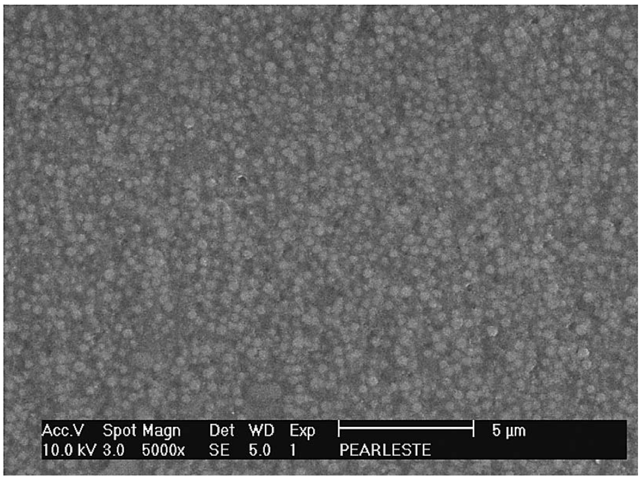

Fig. 2. SEM view of PE surface polished with C#5000 (×5000)

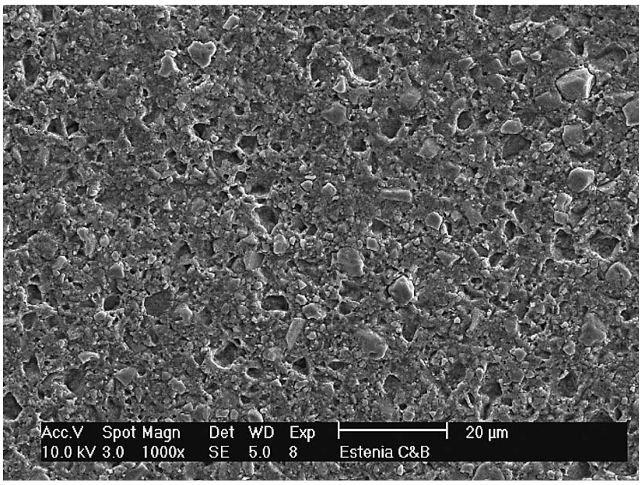

Fig. 3. SEM view of ES surface polished with SiC#1500 (×1000)

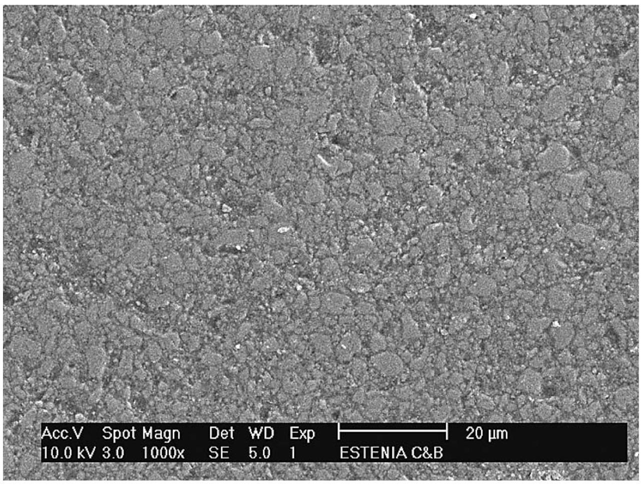

Fig. 4. SEM view of ES surface polished with C#5000 (×1000)

was used. When Al_2O_3 was used, PE showed significantly higher gloss value ($p<0.05$). Al_2O_3 consists mainly of alumina, so it has low abrasive performance for the filler compared with C#4000 and C#5000[18]. PE contains submicron spherical fillers. As submicron spherical fillers themselves have a smooth surface[19]. Meanwhile, the other materials showed lower gloss values because Al_2O_3 was difficult to polish the fillers.

Discoloration

The specimens polished with C#5000 showed the lowest color changes for all of restorative resin composites in this study. SiC#1500 showed highest color changes on all resin composite materials. The surfaces polished with SiC#1500 presented some scratches and falling off the filler particles, because the polishing with SiC#1500 did not work well for all types of materials. A strained surface is more susceptible to staining. The strain increases the activity of the atoms on the surface and facilitates accumulation of the dye. The use of water coolant or low pressure may prevent strain of the molecular arrangement of the resin matrix and inhibit the detachment of the filler particles from the heat-softened resin[20].

The staining property is connected with the amount of inorganic filler existing on the material surface. However, it is not correlated well with the weight percent of inorganic filler. Property of the resin matrix as well as the inorganic filler has a large effect on the staining[21,22].

A glossy surface was observed when ES was polished with C#4000. However, it apparently presented the highest dye concentration means, and the color change is not dependent on extrinsic factors such as the surface gloss alone. The color stability is directly related to the resin matrix of resin composites. 2,2bis4methacryloxypolyethoxyphenyl (Bis-MPEPP) seems to be more resistant for water absorption than diglycidylether methacrylate (Bis-GMA)[23]. PE presented low dye uptake means for most of the polishing agents tested. The resin component of PE consists of two major components: Bis-MPEPP and UDMA. These resins impart a greater hydrophobicity to the resin composite. The low staining susceptibility is related to a low water sorption rate due to the hydrophobic characteristics.

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