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Effects of polishing on surface roughness, gloss, and color of resin composites

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Abstract: This study evaluated the effects of polishing on surface roughness, gloss, and color of regular, opaque, and enamel shades for each of three resin composites. Two-mm-thick resin disks made with Estelite Σ Quick, Clearfil Majesty, and Beautifil II were final polished with 180-, 1000-, and 3000-grit silicon carbide paper. Surface roughness, gloss, and color were measured one week after curing. Estelite Σ Quick had significantly lower roughness values and significantly higher gloss values as compared with Clearfil Majesty and Beautifil II. The effects of surface roughness and gloss on color (L*a*b*) differed among resin composites and by shade. Correlation coefficients between surface roughness and L*a*b* color factors were generally high for Clearfil Majesty, partially high (i.e., between roughness and L*) for Beautifil II, and low for Estelite Σ Quick. Correlation coefficients between gloss and L*a*b* color parameters were generally high for Beautifil II and low for Estelite Σ Quick and Clearfil Majesty. However, for all resin composites, the values of the color differences between 3000-grit and 180-grit polishing groups for all shades were imperceptible by the naked eye. (J Oral Sci 53, 283-291, 2011)

Keywords: resin composite; polishing; surface roughness; gloss; color.

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Introduction

Tooth-colored resin composites have been widely used because of their excellent esthetic properties. The ultimate esthetic properties of tooth-colored restorative are greatly influenced by the final surface polish (1,2). The esthetic success of a restoration is directly related to its optical appearance. Surface roughness, surface gloss, and color are among the most important factors in the perceived visual effects of resin composite restorations (3). Correlations among these factors might differ by resin composite and shade; however, information on such correlations is limited (4). A previous study showed that the specular component mode of reflectance and polishing with different grit sizes of silicon carbide (SiC) paper had differing effects on color among the studied resin composites and shades (4).

In vivo studies of surface roughness (Ra) have shown that there was a substantial increase in bacteria retention above a threshold of 0.2 μm (5). In addition, roughness was positively correlated with accumulation of dental plaque and might also be related to differences in surface properties such as gloss retention and color stability (6,7).

The size and shape of resin composite fillers affect the surface morphology of resin composites subjected to finishing procedures (1,8,9). Polishing also changes gloss, and these two parameters were found to be inversely associated, i.e., as surface roughness increased, gloss decreased (10). Filler particle technology is considered to influence the optical properties and wear resistance of resin composite restorations (11). A reduction in the size of filler particles is expected to improve surface smoothness and gloss (12).

Recently, a new resin composite filled with supra-nano spherical filled resin composite (EQ, Estelite Σ Quick, Tokuyama Dental Co., Tokyo, Japan) was developed based on the sol–gel method that controls the diameter of fillers and changes the refractive index of the fillers (13). Data from the manufacturer show that this material obtains a high gloss in a short polishing time. In addition, a nano-hybrid resin composite with surface reaction type pre-reacted glass ionomer (S-PRG) filler was developed by applying PRG technology (B2, Beautifil II, Shofu Co., Kyoto, Japan). The PRG technology is based on forming a glass-ionomer phase only on the surface of a glass core layer by means of an acid-base reaction between special surface-fractured multifunctional fluoroboroaluminosilicate glass filler and polycarboxylic acid in the presence of water. Clearfil Majesty (CM, Kuraray Co., Tokyo, Japan) is a hybrid resin composite and includes prepolymerized organic fillers. To our knowledge, no information is available on the relationships among surface roughness, gloss, and color of different resin composites and different shades. Thus, the objective of this study was to evaluate the effects of polishing on surface roughness, gloss, and color of regular, opaque, and enamel shades of the three abovementioned resin composites.

Materials and Methods

The properties, type, and shades of the resin composites are shown in Table 1.

To make a standardized specimen, a 3-mm-thick mold with a 15-mm diameter hole was prepared. Resin composite was placed in the hole, and clear plastic film was placed on top. Then, the specimen was light-activated for 20 s at 3 different areas (total time, 60 s) using a quartz-tungsten halogen light-curing unit (Hyperlight, Morita Co., Kyoto, Japan). The composite disk was removed from the mold, after which the bottom of the disk was also light-activated for 60 s. The top sides of the resin disks were polished with 180-, 600-, 800-, 1000-, 2000-, and 3000-grit SiC papers, in that order, and the bottom sides of the resin disks were polished with 800-grit SiC paper under copious water cooling to a final thickness of 2 mm, as measured with a dial caliper (Mitsutoyo, Tokyo, Japan). Three polishing groups, corresponding to a final polishing with 180-, 1000-, and

Table 1 Characteristics of resin composites

Resin composite	Abbreviation	Composition	Type (Shade)	Filler loading
Estelite Σ Quick (Tokuyama Dental Co. Tokyo, Japan)	EQ	Matrix: bisphenol A diglycidyl methacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA) Filler: spherical silica-zirconia filler (100-300 nm; average: 200 nm)	supra-nano spherical filled (A2, OA2, CE)	71 vol% (82 wt%)
Clearfil Majesty (Kuraray Medical Co. Tokyo, Japan)	CM	Matrix: bis-GMA, hydrophobic aliphatic dimethacrylate, hydrophobic aromatic dimethacrylate Filler: silanated barium glass filler prepolymerized organic filler including nano filler (filler: 0.2- 100 μm; average: 0.7 μm)	hybrid (A2, OA2, XL)	66 vol% (78 wt%)
Beautifil II (Shofu Co. Kyoto, Japan)	B2	Matrix: bis-GMA, TEGDMA, urethane diacrylate (UDA) Filler: surface reaction-type prereacted glass-ionomer (S-PRG) and multifunctional (MF) glass fillers based on fluoroboroaluminosilicate glass (0.1 -4.0 μm; average: 0.8 μm)	nano-hybrid (A2, A2O, Inc)	68.6 vol% (83.3 wt%)

3000-grit SiC papers, were prepared for each shade. Thus, for each resin composite, a total of nine groups were classified by shade and polishing. Six disks were prepared for each group. The disks were stored in a 100% wet, light-blocked container at 23 ± 1°C.

One week after curing, color was measured with a spectrophotometer (CM-3600d, Konica Minolta, Tokyo, Japan) according to the Commission Internationale de l'Eclairage (CIE) L*a*b* color scale relative to the standard illuminant D_{65} in the reflectance mode over white and black backgrounds in the SCI (specular component included) mode, as previously described (14). In the CIE 1976 L*a*b* color scale, L* represents the psychometric lightness from black to white, and a* and b* are the psychometric chroma coordinates and indicate hue and chroma factors. The a* axis is red on the positive side and green on the negative side. The b* axis is yellow on the positive side and green on the negative side. A higher number indicates a stronger color factor. The diameter of the aperture was 7 mm for the reflectance measurement. Illuminating and viewing configurations were CIE diffuse/8° (15). Measurements were repeated three times for each specimen under each color measuring condition, and average values for the six specimens of the same group were calculated using the Spectra-Magic Version 2.11 (Konica Minolta) software package.

Color differences (ΔE*ab) between groups were calculated by using the equation of $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. Opacity was calculated by using the equation R(B) / R(W) × 100 (%). R(B) and R(W) represent the reflectance percentage measured with the black and white backgrounds, respectively.

The surface gloss of specimens in gloss units (GU) was measured with a digital precision gloss meter (GM-26D, Murakami Color Research Laboratory, Tokyo, Japan) with a square measurement area of 3 × 3 mm and 60° geometry. Measurements were repeated three times for each specimen, and average values were calculated.

The surface roughness (Ra, μm) of specimens was evaluated using a laser scanning microscope (VK-8500, Keyence, Osaka, Japan) with a square measurement area of 100 × 100 μm. Measurements were performed for three different areas on each specimen, and average values were calculated. Color micrographs (400×) were obtained for each specimen.

Data were analyzed by using two-way or three-way ANOVA and Fisher's protected least-significant-difference (PLSD) test with α = 0.05 for L*, a*, b*, opacity, gloss, and Ra. Correlations between surface roughness and color factor and between gloss and color factor were statistically analyzed using linear regression analysis with α = 0.05. All statistical analyses were performed using standard statistical software (StatView 5.0, SAS Institute Inc., Cary, NC, USA).

Results

Table 2 shows the effects of the final grit size of SiC polishing paper and composite shade on the surface roughness (Ra) of resin composites. In a comparison of Ra among different resin composites for each composite

Table 2 Effects of final grit size of SiC polishing paper and composite shade on surface roughness (Ra) of resin composites

Resin Composite	Polishing (grit size)	Regular Shade	Roughness (unit: μm)	Opaque Shade	Roughness (unit: μm)	Enamel Shade	Roughness (unit: μm)
EQ	#180	A2	1.4 (0.2) a, A, 2	OA2	1.9 (0.4) a, A, 1	CE	1.9 (0.2) a, A, 1
CM	#180	A2	6.2 (0.5) b, A, 1	OA2	6.1 (0.4) b, A, 1	XL	6.4 (0.7) c, A, 1
B2	#180	A2	6.0 (0.5) b, A, 1	A2O	6.0 (0.5) b, A, 1	Inc	5.6 (0.5) b, A, 2
EQ	#1000	A2	0.9 (0.2) a, B, 2	OA2	1.6 (0.2) a, B, 1	CE	0.7 (0.1) a, B, 2
CM	#1000	A2	4.6 (0.3) b, B, 1	OA2	4.6 (0.1) b, B, 2	XL	5.1 (0.3) c, B, 1, 2
B2	#1000	A2	4.7 (0.4) b, B, 1	A2O	4.8 (0.3) b, B, 1	Inc	4.7 (0.3) b, B, 1
EQ	#3000	A2	0.3 (0.1) a, C, 2	OA2	1.5 (0.3) a, B, 1	CE	0.3 (0.1) a, C, 2
CM	#3000	A2	5.0 (0.3) b, B, 1	OA2	4.9 (0.5) b, B, 1	XL	4.6 (0.7) b, B, 1
B2	#3000	A2	4.6 (0.3) b, B, 1	A2O	4.8 (0.5) b, B, 1	Inc	4.5 (0.6) b, B, 1

For each composite shade with identical grit polishing, different lower-case letters (a, b, c) represent statistically significant differences among resin composites ($P < 0.05$).

For each composite shade in the same resin composite, different upper-case letters (A, B, C) represent statistically significant differences among different grit polishing groups ($P < 0.05$).

For each resin composite with identical grit polishing, different numerals (1, 2) represent statistically significant differences among different composite shades ($P < 0.05$).

shade, with identical grit polishing, the Ra of EQ was significantly lower than those of CM and B2, and there was no significant difference in Ra between CM and B2, except for the enamel shade (XL/Inc) in the 180- and 1000-grit polishing groups. For enamel shades in the 180- and 1000-grit groups, the order of Ra for B2 was significantly lower than that for CM. In a comparison of Ra among different grit polishing, for each shade in the same resin composite, the Ra in the 180-grit polishing group was significantly higher than those in the 1000- and 3000-grit polishing groups. There was no significant difference of the Ra between the 1000- and 3000-grit groups, except for the regular (A2) and enamel (CE) shades of EQ. For the A2 and CE shades of EQ, the order of Ra was 180- > 1000- > 3000-grit group, and the differences among polishing groups were significant.

Table 3 shows the effect of final grit size of SiC polishing paper and composite shade on gloss in the resin composites. In a comparison of gloss among resin composites for each composite shade with identical grit polishing, the gloss of EQ was significantly higher than those of CM and B2, except for the opaque shade (OA2/A2O) in the 180-grit group. In the 180-grit group, there was no significant difference in gloss for the opaque shade among the different resin composites. For the enamel shade (CE/XL/Inc) in the 1000-grit group and all shades in the 3000-grit group, the order of gloss was E Q > CM > B2, and the differences among resin composites were significant. In a comparison of gloss among different grit polishing, for each shade in the same resin composite, the order of gloss was 3000 grit > 1000 grit > 180 grit; the differences among polishing groups were significant.

Table 4 shows the L*a*b* values and color differences (ΔL*, Δa*, Δb*, and ΔE*ab) between the 3000- and 1000-grit and between the 3000- and 180-grit polishing groups for each shade of each resin composite, measured on the white and black background. For EQ on the white background for all shades, the b* value of the 180-grit group was significantly lower than those of the 1000- and 3000-grit groups. On the black background for all shades, the L* value of the 3000-grit group was significantly lower than that of the 180-grit group, except for the CE shade. Regarding CM, on both the white and black backgrounds for all shades, the L* values of the 180-grit group were significantly higher than those of the 1000- and 3000-grit groups except for XL shade with white background. For XL shade with white background, there was no significant difference of the L* value between the 180- and 1000-grit polishing groups. For the A2 and OA2 shades, the b* value of the 180-grit group was significantly lower than those of the 1000- and 3000-grit groups. For the black background and all shades, the a* value of the 180-grit group was significantly higher than those of the 1000- and 3000-grit groups. However, on the white background, the a* value of the 180-grit group was significantly higher than those of the 1000- and 3000-grit groups only for the XL shade. For B2, the L* value of the 180-grit group was significantly higher than those of the 1000- and 3000-grit groups, on the white and black background, for all the shades. For all shades on both

Table 3 Effects of final grit size of SiC polishing paper and composite shade on gloss of resin composites

Resin Composite	Polishing (grit size)	Regular Shade	Gloss (unit: GU)		Opaque Shade	Gloss (unit: GU)		Enamel Shade	Gloss (unit: GU)	
EQ	#180	A2	15.9 (0.9)	a, A, 1	OA2	8.1 (0.6)	a, A, 2	CE	15.0 (0.4)	a, A, 1
CM	#180	A2	2.5 (0.2)	b, A, 1	OA2	3.2 (0.5)	a, A, 1	XL	3.2 (1.0)	b, A, 1
B2	#180	A2	2.4 (0.3)	b, A, 1	A2O	3.3 (0.2)	a, A, 1	Inc	2.8 (0.6)	b, A, 1
EQ	#1000	A2	36.0 (7.7)	a, B, 1	OA2	56.8 (5.6)	a, B, 1	CE	41.2 (14.2)	a, B, 1
CM	#1000	A2	5.6 (0.6)	b, B, 1	OA2	7.3 (0.6)	b, B, 1	XL	12.4 (1.7)	b, B, 2
B2	#1000	A2	5.6 (0.6)	b, B, 1	A2O	5.5 (0.9)	b, B, 1	Inc	5.8 (2.0)	c, B, 1
EQ	#3000	A2	69.8 (7.6)	a, C, 1	OA2	71.5 (2.3)	a, C, 1	CE	66.2 (3.2)	a, C, 1
CM	#3000	A2	50.0 (6.3)	b, C, 1	OA2	56.1 (5.2)	b, C, 2	XL	50.1 (7.4)	b, C, 1
B2	#3000	A2	21.8 (3.9)	c, C, 1	A2O	23.7 (1.9)	c, C, 1	Inc	30.2 (5.0)	c, C, 2

For each composite shade with identical grit polishing, different lower-case letters (a, b, c) represent statistically significant differences among resin composites ($P < 0.05$).

For each composite shade in the same resin composite, different upper-case letters (A, B, C) represent statistically significant differences among different grit polishing groups ($P < 0.05$).

For each resin composite with identical grit polishing, different numerals (1, 2) represent statistically significant differences among different composite shade ($P < 0.05$).

the white and black backgrounds, the a* value of the 3000-grit group was significantly higher than those of the 1000- and 180-grit groups.

For both the white and black backgrounds and all shades of all resin composites, the total color difference (ΔE*ab) was small, ranging from 0.13 to 1.34 for EQ, 0.13 to 2.09 for CM, and 0.13 to 0.98 for B2.

Table 5 shows the effect of final grit size of SiC

Table 4 L*a*b* values and color differences between 3000- and 1000-grit and between 3000- and 180-grit polishing groups for each shade of resin composite over white and black backgrounds

Resin	Shade	Polishing	<white background>							<black background>						
			L*	a*	b*	ΔL*	Δa*	Δb*	ΔE*ab	L*	a*	b*	ΔL*	Δa*	Δb*	ΔE*ab
EQ	A2	#3000	66.32 a	2.40 a	22.37 a					60.61 b	-0.93 a	14.70 a, b				
	A2	#1000	66.63 a	2.58 a	22.71 a	0.31	0.19	0.34	0.50	60.98 a, b	-0.84 a	15.02 a	0.37	0.09	0.32	0.50
	A2	#180	66.37 a	2.37 a	21.55 b	0.05	-0.03	-0.82	0.82	61.17 a	-0.83 a	14.39 b	0.55	0.10	-0.31	0.64
	OA2	#3000	69.77 a	2.34 a	17.27 a					66.25 b	-0.39 a	12.35 a				
	OA2	#1000	69.55 a	2.27 a	16.83 b	-0.23	-0.07	-0.43	0.49	66.36 a, b	-0.37 a	12.29 a	0.11	0.03	-0.06	0.13
	OA2	#180	69.70 a	2.17 a	15.94 c	-0.07	-0.17	-1.33	1.34	66.66 a	-0.36 a	11.61 b	0.41	0.03	-0.75	0.86
	CE	#3000	69.55 b	-2.96 a, b	12.66 a					59.76 b	-3.40 a	4.17 a				
	CE	#1000	70.13 a	-3.14 b	12.84 a	0.58	-0.18	0.18	0.63	60.42 a	-3.48 a	4.39 a	0.66	-0.08	0.22	0.70
	CE	#180	69.44 b	-3.02 a	12.10 b	-0.11	-0.07	-0.56	0.57	59.98 b	-3.41 a	3.72 b	0.22	-0.01	-0.45	0.50
CM	A2	#3000	68.56 b	0.89 a	13.14 a					62.94 c	-2.09 b	5.29 b				
	A2	#1000	68.85 b	0.89 a	12.75 a	0.29	-0.01	-0.40	0.49	63.29 b	-2.11 b	4.92 b	0.36	-0.01	-0.36	0.51
	A2	#180	69.82 a	0.92 a	11.48 b	1.26	0.03	-1.67	2.09	64.46 a	-2.00 a	3.96 a	1.53	0.09	1.33	2.03
	OA2	#3000	73.55 b	0.45 a	13.74 a					69.01 c	-2.40 b	7.13 b				
	OA2	#1000	73.80 b	0.44 a	13.73 a	0.25	0.00	-0.01	0.25	69.29 b	-2.44 b	7.11 b	0.29	-0.02	-0.02	0.29
	OA2	#180	74.52 a	0.54 a	12.97 b	0.98	0.09	-0.76	1.24	70.07 a	-2.24 a	6.46 a	1.07	0.17	-0.66	1.27
	XL	#3000	72.23 b	-3.05 b	10.47 a, b					65.49 b	-4.49 b	1.89 a				
	XL	#1000	72.56 a, b	-3.10 b	10.67 a	0.33	-0.05	0.20	0.39	65.63 b	-4.51 b	1.90 a	0.13	0.01	0.00	0.13
	XL	#180	72.90 a	-2.94 a	10.00 b	0.67	0.11	-0.47	0.83	66.47 a	-4.34 a	1.72 a	0.98	0.19	-0.18	1.01
B2	A2	#3000	71.73 b	2.73 a	13.03 b					66.60 b	-0.24 a	6.04 b				
	A2	#1000	71.80 b	2.47 b	13.23 a, b	0.07	-0.26	0.21	0.34	66.69 b	-0.43 b	6.29 a, b	0.09	-0.19	0.25	0.33
	A2	#180	72.21 a	2 .41 b	13.53 a	0.48	-0.31	0.50	0.76	67.13 a	-0.53 b	6.63 a	0.53	-0.29	0.59	0.84
	A2O	#3000	76.19 c	4.01 a	15.66 b					73.12 c	1.01 a	11.02 c				
	A2O	#1000	76.43 b	3.69 b	16.55 a	0.09	-0.27	-0.72	0.77	73.34 b	0.70 b	11.82 a	0.11	0.03	-0.06	0.13
	A2O	#180	76.60 a	3.77 b	16.08 a	0.46	-0.36	-0.36	0.69	73.53 a	0.77 b	11.38 b	-0.02	-0.17	-0.61	0.63
	Inc	#3000	69.82 b	-1.61 a	1.11 a					60.75 b	-2.15 a	-6.97 a				
	Inc	#1000	69.92 b	-1.88 b	0.39 c	0.24	-0.32	0.89	0.98	60.73 b	-2.32 b	-7.00 b	0.22	-0.31	0.81	0.89
	Inc	#180	70.29 a	-1.97 b	0.75 b	0.41	-0.24	0.42	0.63	61.33 a	-2.39 b	-7.58 c	0.41	-0.24	0.36	0.60

For L*, a*, and b* values for each composite shade of the same resin composite, different letters (a, b, c) represent statistically significant differences among different grit polishing groups ($P < 0.05$).

Table 5 Effect of final grit size of SiC polishing paper and composite shade on opacity of resin composites

Resin Composite	Polishing (grit size)	Regular Shade	Opacity (unit: %)	Opaque Shade	Opacity (unit: %)	Enamel Shade	Opacity (unit: %)
EQ	#180	A2	82.0 (0.4) a, A, 2	OA2	89.8 (0.2) b, A, 1	CE	70.2 (0.7) a, A, 3
CM	#180	A2	82.5 (0.4) a, A, 2	OA2	86.0 (0.3) a, A, 1	XL	79.9 (0.2) c, A, 3
B2	#180	A2	83.7 (0.2) b, A, 2	A2O	90.3 (0.1) c, A, 1	Inc	72.1 (0.2) b, A, 3
EQ	#1000	A2	80.7 (0.3) a, B, 2	OA2	89.3 (0.3) b, A, 1	CE	69.8 (0.4) a, A, 3
CM	#1000	A2	81.6 (0.3) b, A, 2	OA2	85.7 (0.1) a, A, B, 1	XL	78.3 (0.4) c, B, 3
B2	#1000	A2	83.6 (0.2) c, A, B, 2	A2O	90.3 (0.2) c, A, 1	Inc	71.3 (0.2) b, B, 3
EQ	#3000	A2	80.7 (0.7) a, B, 2	OA2	88.1 (0.3) b, B, 1	CE	69.5 (0.4) a, A, 3
CM	#3000	A2	81.5 (1.1) a, A, 2	OA2	85.2 (0.4) a, B, 1	XL	78.8 (0.5) c, B, 3
B2	#3000	A2	83.4 (0.3) b, B, 2	A2O	90.3 (0.1) c, A, 1	Inc	71.6 (0.4) b, B, 3

For each composite shade with identical grit polishing, different lower-case letters (a, b, c) represent statistically significant differences among resin composites ($P < 0.05$).

For each composite shade in the same resin composite, different upper-case letters (A, B, C) represent statistically significant differences among different grit polishing groups ($P < 0.05$).

For each resin composite with identical grit polishing, different numerals (1, 2) represent statistically significant differences among different composite shades ($P < 0.05$).

polishing paper and composite shade on the opacity of resin composites. In all polishing groups of all resin composites, the order of opacity for resin shades was opaque > regular > enamel, with significant differences among shades. In a comparison of opacity among different resin composites for each composite shade with identical grit polishing, the results differed by composite shade. For the regular shade (A2), in the 180- and 3000-grit polishing groups, the opacity of B2 was significantly higher than those of EQ and CM, but there was no significant difference in opacity between EQ and CM. For the opaque shade (OA2/A2O), the order of opacity was B2 > EQ > CM, and for the enamel shade (CE/XL/Inc), the order of opacity was CM > B2 > EQ, with significant differences among resin composites.

Table 6 shows the correlations between surface roughness and each color factor of L*a*b* and between gloss and each color factor of L*a*b* for each shade of each resin composite. Roughness was significantly correlated with b* of the CE shade of EQ; L* and b* of the A2 shade and L*, a*, and b* of the OA2 shade of CM; and L* of the A2 and Inc shades of B2. Gloss was significantly correlated with b* of the OA2 shade of EQ; L* of the OA2 shade of CM; and a* of the A2 shade, L* and a* of the OA2 shade, and a* and b* of the Inc shade of B2.

Table 6 Correlations between surface roughness and L*a*b* color parameters and between gloss and L*a*b* color parameters for each shade of the resin composites

Resin	Shade	Color factor	<Roughness vs. L*a*b*> Correlation coefficient	Correlation *P* value	<Gloss vs. L*a*b*> Correlation coefficient	Correlation *P* value
EQ	A2	L*	-0.015	0.9701	-0.222	0.5807
	A2	a*	-0.010	0.9796	-0.170	0.6741
	A2	b*	-0.440	0.2477	0.348	0.3737
	OA2	L*	0.553	0.1271	0.002	0.9966
	OA2	a*	0.266	0.5042	0.445	0.2407
	OA2	b*	-0.550	0.1296	0.929	< 0.0001
	CE	L*	-0.413	0.2823	0.117	0.8351
	CE	a*	0.428	0.2627	-0.085	0.1448
	CE	b*	-0.785	0.0096	0.534	0.1602
CM	A2	L*	0.775	0.0113	-0.281	0.4791
	A2	a*	0.280	0.4811	-0.368	0.3445
	A2	b*	-0.711	0.0295	0.543	0.1362
	OA2	L*	0.727	0.0239	-0.790	0.0087
	OA2	a*	0.826	0.0040	-0.551	0.1294
	OA2	b*	-0.876	0.0009	0.510	0.1684
	XL	L*	0.593	0.0950	-0.281	0.4799
	XL	a*	0.481	0.1989	-0.135	0.7392
	XL	b*	-0.615	0.0789	-0.042	0.9182
B2	A2	L*	0.873	0.001	-0.654	0.0555
	A2	a*	-0.514	0.1637	0.968	< 0.0001
	A2	b*	0.497	0.1819	-0.548	0.1317
	A2O	L*	0.615	0.0792	-0.912	0.0002
	A2O	a*	-0.213	0.5956	0.871	0.0011
	A2O	b*	-0.088	0.8294	-0.500	0.1786
	Inc	L*	0.778	0.0107	-0.651	0.0570
	Inc	a*	-0.621	0.0751	0.896	0.0004
	Inc	b*	0.002	0.9969	0.745	0.0185

Discussion

In clinical practice, transparent matrices such as a Mylar strip are preferred for forming resin composite and producing the smoothest resin composite surfaces with the highest gloss (1,2,16). However, as compared with other finishing treatments, the use of Mylar strips results in surfaces with lower hardness, which is evidence of less surface polymerization. Thus, polishing is required to prevent wear and discoloration on the resin-rich surface. In this study, as in a preliminary study, SiC papers of different grit sizes were used to prepare the polished surfaces.

In a previous study, (17) SiC papers of different grit sizes were used to polish five different types of resin composites, including Estelite Flow Quick (Tokuyama Dental Co.), Estelite Σ (Tokuyama Dental Co.), and Clearfil Majesty. The investigators noted that surface roughness became stable when polishing particles smaller than 13 μm (1200-grit in ISO 8486-1, 1996) were used. The findings of that study suggested that, to achieve satisfactory surface roughness and gloss, polishing should be completed with particles smaller than 9 μm (18). The particle sizes of popular polishing points from Shofu Co. are carborundum points (125 μm), regular diamond points (100 μm), white points (20 μm), silicone brown M2 points (35 μm), and silicone blue M3 points (6 μm). The particle sizes of the SiC papers used in this study were 3000 grit (5 μm), 1000 grit (15 μm), and 180 grit (>48 μm for 280 grit).

In the present study, the surface roughness values for the A2 and CE shades of EQ final polished with 3000-grit SiC paper were 0.32 and 0.30 μm, respectively (Table 2). These values are close to 0.2 μm, which was established as the threshold for bacterial adhesion (1). In addition to low surface roughness, the gloss of all shades of EQ, when final polished with 3000-grit SiC paper, was significantly higher than those of CM and B2 (Table 3). Thus, for the EQ resin composite, which is filled with numerous spherical nanoparticles, final polishing with 3000-grit SiC paper appears to yield close to satisfactory surfaces for shades A2 and CE. However, more careful polishing might be necessary for the high-opacity OA2 opaque shade. In contrast, the surface roughness of all shades of the hybrid or nano-hybrid resin composites CM and B2 ranged from 4.5 to 5.0 when final polished with 3000-grit SiC paper. Thus, to obtain optimally polished surfaces, additional polishing with finer particle polishers is required. Especially for B2, the gloss of all shades final polished with 3000-grit SiC paper was significantly lower than those of other resin composites (Table 3). Thus, we suspect that S-PRG-filled hybrid resin composites are more difficult to polish than spherical-filled resin composites. Although polishing with a finer polisher might reduce the surface roughness of B2, it had a lower gloss than other resin composites. Further study is required to identify the effect of gloss on esthetics and color matching of teeth.

Many studies have described the effect of the surface roughness of resin composites on discoloration after accelerated testing or soaking in dye solutions. These studies calculated ΔL* and/or ΔE*ab using values obtained before and after a discoloration test. Very limited studies reported the effects of surface roughness and/or gloss on the L*a*b* color parameters of resin composites (19). In a previous study (18), polished composites tended to appear lighter, whiter, and less glossy than a corresponding Mylar-covered surface. In the present study comparing L*, a*, and b* values on a white background, there were no significant differences for any shade among the polishing groups, except for b* of the OA2 shade of EQ and L* of the A2O shade of B2 (Table 4). For b* of the OA2 shade of EQ and the A2 and OA2 shades of CM, smaller SiC particle size (i.e., higher grit number) was associated with higher b* values (increased yellowness). This tendency was especially obvious for the OA2 shade of EQ (Table 4).

There is controversy regarding the threshold value of color differences (ΔE*ab) that can be perceived with the naked eye. Values of 1.1 for red-varying shades and 2.1 for yellow-varying shades have been reported (20); 3.7 is considered clinically acceptable (21), and 3.3 (22) is the value that 50% of observers considered unacceptable. In the present study, as compared with the 3000-grit polishing group, all the ΔE*ab values in the 1000- and 180-grit groups were less than 2.1 and difficult to distinguish with the naked eye for all shades of all resin composites (Table 4). However, high surface roughness can facilitate dental plaque accumulation and bacterial adhesion on resin (1), resulting in resin discoloration and dental caries. Thus, finer polishing is required in order to obtain optimally polished surfaces in resin restoration.

It has been generally accepted that as surface roughness increases, the degree of random reflection of light will also increase, which results in decreased gloss (23). In a previous study of resin composites that were polished with 1000- to 2500-grit SiC papers, there was a significant linear relationship between roughness and gloss (8). In the present study, the gloss ranking was 3000 grit > 1000 grit > 180 grit for all shades, and differences among groups were significant (Table 3).

A roughened surface increases random reflection at the surface, which leads to increased opacity. Thus, the opacity of translucent materials is very sensitive to surface roughness. In this study, the effect of shade on opacity was significant, and the effect of grit number of SiC polishing paper on opacity partially differed among resin composites and shades. However, lower grit numbers (i.e., higher surface roughness) tended to be associated with higher opacity values (Table 5).

The correlations between surface roughness and each of L*a*b* values and between gloss and each of L*a*b* values differed by composite and shade, and some significant correlations were observed (Table 6). Correlation coefficients between surface roughness and L*a*b* color parameters were mostly high for CM, partially high (between roughness and L*) for B2, and low for EQ. Correlation coefficients between gloss and L*a*b* color parameters were mostly high for B2 and low for EQ and CM. For CM, there were significant correlations between surface roughness and both the L* and b* of the A2 shade and L*, a*, and b* of the OA2 shade. For the same shades of CM, the ΔE*ab values between the 180- and 3000-grit groups measured on a white background were 2.09 and 1.24, respectively, and these values were higher than those of all other shades except the OA2 shade of EQ (Table 4). For B2, there were significant correlations between gloss and two color parameters of the L*a*b* values for the A2O and Inc shades; however, these results did not affect the color differences (Tables 4 and 6).

High gloss reduces the effect of a color difference, because the color of reflected light predominates over the color of the underlying resin composite (10). The main reason for the low correlations between surface roughness/gloss and the L*a*b* color parameters of EQ is that EQ has a low surface roughness and high gloss (Tables 2 and 3). In contrast, the surface roughness of CM and B2 is high, and gloss is low. Thus, there were partially high correlations between surface roughness/gloss and L*a*b* color parameters for CM and B2 (Tables 2 and 4). For B2 in particular, the gloss of all shades polished with 3000-grit SiC paper was significantly lower than those of EQ and CM (Table 3), which resulted in significant correlations. Differences in filler composition, type, and size, as well as filler loading and pigments of resin composites, might also influence correlations between surface roughness/gloss and L*a*b* color parameters.

A previous study reported that resin composites filled with spherical fillers easily attained higher gloss as compared with hybrid composites filled with irregularly shaped fillers (17). EQ is filled with spherical fillers, and gloss after polishing with 3000-grit SiC paper was significantly higher than that of hybrid resin composites filled with irregular fillers after polishing with 15000-grit SiC paper (17). Similar results were obtained in the present study (Tables 2 and 3). This feature of EQ is an advantage for children and disabled persons for whom a complicated polishing procedure is difficult.

Within the limitations of this study, it was shown that the effect of polishing on surface roughness and gloss differed by resin composite and shade. Limited significant correlations between L*a*b* color parameters and both surface roughness and gloss were obtained, and correlations differed among the resin composites and by shade.

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