



## Effect of Chemical and Mechanical Degradation on Surface Roughness, Topography, Gloss, and Polish Retention of Three Composites Polished with Five Polishing Systems

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### ABSTRACT

**Objective:** Finishing and polishing (F/P) of composites is a fundamental step influencing the clinical service of restorations. The aim of this study was to evaluate the effect of different F/P systems on surface roughness, gloss, and polish retention of composite resins.

**Materials and Methods:** One-hundred and five disc-shaped specimens (4×4 mm) were made from nanofilled, microhybrid, and microfilled composites (n=35). The specimens were divided into five subgroups (n=7) for F/P with Sof-Lex (4-step), Shofu (4-step), Cosmedent (3-step), Diacomp Composite-Pro (2-step), and Opti1Step systems. The surface roughness values (Ra and Rz) were measured before and after pH-cycling and simulated toothbrushing. Surface topography was assessed by using a scanning electron microscope (SEM) at three magnifications. For assessment of surface gloss, 45 rectangular specimens (10×8×2 mm) were fabricated from three composites (n=15) and randomly allocated to five subgroups (n=3). Surface gloss was measured before and after aging. The mean values were calculated and analyzed by two-way ANOVA, Tukey, and t-test. Level of significance was set at 0.05.

**Results:** The composite type had no significant effect on surface roughness (P>0.05); however, the type of F/P system significantly affected it (P<0.05). The pH-cycling and simulated toothbrushing had no significant effect on gloss or polish retention of the three composites (P>0.05).

**Conclusion:** Type of F/P system had a greater effect on surface roughness and gloss of composite resins than the type of composite.

**Keywords:** Composite Resins; Dental Polishing; Surface Properties; Materials Testing

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### INTRODUCTION

Despite tremendous improvements in dental materials and technologies, efficient finishing and polishing (F/P) of composite restorations to ensure long-term smoothness and gloss remains a challenging topic [1-3]. This is mainly because of the heterogeneous

microstructure of conventional composites, which are composed of organic matrix and inorganic filler particles with variable hardness and wear resistance [1,2].

The process of F/P of a restoration involves abrasive wear by use of abrasive particles [2,3]. The abrasive particles remove surface

irregularities and deep flaws and soften the scratches in a stepwise approach. After polishing, a smooth surface with enamel-like luster and no visible scratches is often achieved [1-3]. In this process, the abrasive particles and the composite resin (substrate) serve as a tribological system [2]. The efficiency of this system depends on the hardness and modulus of elasticity of the abrasive and substrate [2,3]. Some other important parameters including the size and shape of abrasive particles, rotational speed, pressure, and lubrication should also be taken into account [4-7]. If the abrasive particles are too hard and have a large grain size (coarse), the soft resin matrix may be removed faster than the fillers, and the filler particles may remain exposed and create projections on the surface or may be plucked out and cause microdefects [1-3]. Such surface irregularities can affect the reflected light from the composite surface and subsequently the surface gloss [8-10]. Since the human eye can well differentiate between the gloss of a restoration and the adjacent tooth structure, the restoration should match the adjacent tooth structure in terms of texture and gloss [11-13]. In addition, composite resins are subjected to functional and parafunctional loads and toothbrushing abrasion, and exposed to dental biofilm, tobacco smoke, and foods and beverages in the oral environment [14-18]. Toothbrushing, its duration and force, and the abrasiveness of dentifrices can all affect the surface roughness and gloss of composite restorations in the oral cavity [19-22]. Low pH of the oral environment caused by the activity of cariogenic microorganisms in dental biofilm and consumption of acidic foods and drinks, ionic composition of the saliva, and aging are among other factors that affect composite restorations [15,16]. Moreover, chemical interactions that occur in the oral environment may cause abrasion and chemical degradation of composite resins [15-18]. Such interactions can increase the surface roughness and decrease the surface gloss of composite restorations in the long-term. Therefore, toothbrushing abrasion should be accompanied by a chemical challenge such as pH-cycling to better simulate the oral

environment *in vitro* [16].

On the other hand, aside from proper initial polishing, periodic re-polishing may be required to enhance the luster of composite restorations [18]. Inherent smoothness and polishability of composite resins are influenced by a number of parameters including the resin matrix composition, filler content, shape, size, distribution, composition and weight percentage of fillers, the filler-matrix bond (coupling agent), and degree of polymerization [1,2]. After composite application and polymerization, some other factors may still affect the quality of the final polish such as the time lapse between light-curing and finishing (immediate/delayed), the F/P technique in terms of composition and type of instruments, the flexibility of backing and binder, the number of polishing steps, and dry or wet polishing [23-38]. Many researchers have investigated the effects of different F/P systems on the initial smoothness and gloss of composite resins [26-38]. However, their long-term gloss and polish retention are still matters of controversy. Therefore, the purpose of this study was to evaluate the effects of different F/P systems on the polish and gloss retention of different composite resins. The null hypothesis was that no significant difference would be found in surface roughness, gloss, and polish retention of composite resins regardless of their type or the polishing system used.

### MATERIALS AND METHODS

A total of 105 discs were fabricated from Filtek Z350 nanofilled, Filtek Z250 microhybrid, and Renamel microfilled composite resins (Table 1). Composite was applied into cylindrical polytetrafluoroethylene molds (4.0 mm diameter and 2.0 mm height) by a plastic instrument, and covered with a Mylar strip. The Mylar strip was pressed by a glass slab with 500 g force for 30 s to eliminate excess material and flatten the surface [31]. The specimens were then polymerized for 40 s from both sides using a LED curing unit (Demetron Kerr INC, Orange, CA, USA). After curing of 5 specimens, the light intensity was checked by a dental light meter (Model 100; Kerr Demetron, Dan burg, CT, USA).

**Table 1.** Description of materials

	<b>Composition</b>	<b>Manufacturer</b>
<b>Filtek Z350 XT (nanofilled composite)</b>	Filler: Silica and zirconia (clusters of 0.6-1.4 $\mu\text{m}$ and individual particles 5-20 nm) Filler content: 59.5% in vol. ,73.2% in wt. Matrix: BISGMA, BISEMA, UDMA, TEGDEMA	3M ESPE, St. Paul, MN, USA
<b>Filtek Z250 (nanohybrid composite)</b>	Filler type: Pyrogenic silicic acid (0.02-0.04 $\mu\text{m}$ ) zirconia/silica (0.01-3.5 $\mu\text{m}$ ) Filler content: 60% in vol. Matrix: Multifunctional methacrylate esters BISGMA, UDMA, BISEMA, TEGDEMA	3M ESPE, St. Paul, MN, USA
<b>Renamel (microfilled composite)</b>	Filler: Pyrogenic silicic acid (0.02-0.04 $\mu\text{m}$ ) Filler content: 60% in vol. Matrix: Multifunctional methacrylate esters	Cosmedent, Chicago, USA
<b>Shofu composite polishing system (4-step)</b>	1.Green stone: Silicon carbide abrasive 2.White stone: Aluminum oxide abrasive 3. Rubber: zirconium oxide abrasive, silicon dioxide matrix 4.Rubber: zirconium silicate abrasive, silicon dioxide matrix	Shofu, Kyoto, Japan
<b>Sof-Lex composite polishing system (4-step)</b>	Aluminum oxide particles: Coarse (50 $\mu\text{m}$ ) Medium (40 $\mu\text{m}$ ) Fine (24 $\mu\text{m}$ ) Ultra-fine (8 $\mu\text{m}$ )	3M, ESPE, St. Paul, MN, USA
<b>Cosmedent composite polishing system (3-step)</b>	Diamond particles, silicon dioxide matrix	Cosmedent, Chicago, USA
<b>Diacomp twist composite polishing system (2-step)</b>	Diamond particles, silicon dioxide matrix	EVE Ernst Vetter, Keltern, Germany
<b>Opti1Step composite polishing system (1-step)</b>	Diamond and Silicon carbide particles, silicon dioxide matrix	Kerr Hawe, Bioggio, Switzerland
<b>pH-cycling solution</b>	Demineralization solution: Calcium 2 mM, phosphate 2 mM, acetate 74 mM (pH=4.3) Remineralization solution: Calcium 1.5 mM, phosphate 0.9 mM, potassium chloride 150 Mm, (pH=7)	Razi, Tehran, Iran
<b>Crest 7 Complete tooth paste</b>	Sorbitol, water, hydrated silica, disodium pyrophosphate, sodium lauryl sulfate, sodium hydroxide, alcohol (0.7%), sodium saccharin, glycerin, carbomer, sodium benzoate, cetylpyridinium chloride, benzoic acid, mica, titanium dioxide, blue	Gross Greau, Riedstadt, Germany

The light intensity ranged from 650 to 700  $\text{mw}/\text{cm}^2$ . Finally, both sides were light-cured for an additional 20 s after removing the strip and glass slab. The specimens were then immersed in deionized water at 37°C for 7 days.

To standardize the specimens in terms of surface roughness, one side of each specimen was wet-polished using a universal polishing machine (Phoenix Beta Grinder Polisher; Buehler, Landkreis Esslingen, Germany) with 400-grit silicon carbide abrasive paper (SIC;

Struers A/S, Filial, Denmark) at 300 rpm with 15.7 N load for 15 s [35]. Thirty-five specimens were fabricated from each composite resin, and randomly allocated to 5 groups (n=7) based on the type of polishing procedure. A low-speed handpiece (operating at 10,000 rpm) was used under dry conditions for F/P of all specimens (W&H; Bur Moon, Austria) by the same operator (FF). In use of multi-step polishing systems, the specimens were rinsed and dried with air/water spray for 10 s between the steps. F/P was performed with intermittent mild hand pressure as follows:

**Sof-Lex discs (3M ESPE, St Paul, MN, USA):** The specimens were polished with Sof-Lex XT discs in four steps using coarse, medium, fine, and super-fine aluminum oxide discs each for 15 s in an orderly fashion.

**Shofu polishing kit (Shofu; Kyoto, Japan):** The specimens were polished with Shofu dental composite polishing system in four steps. Dura-green silicon carbide stone was first used followed by Dura-white aluminum oxide stone, and then fine and super-fine silicone rubbers were used that contain zirconium silicate particles. Each step lasted for 15 s.

**Cosmedent Top Finisher system (Cosmedent; Chicago, IL, USA):** The specimens were polished with Cosmedent Top Finisher system in three steps. Coarse, fine, and super-fine diamond rubbers were used in an orderly fashion, each for 15 s.

**Diacomp composite polishing system (EVE Ernst Vetter GmbH, Keltern, Germany):** The specimens were polished with Diacomp composite polishing system in two steps. Diamond pink (medium-grit) and gray (fine-grit) flexible spiral rubber discs were used in two steps, each for 15 s in an orderly fashion.

**Opti1Step Polisher (Kerr Hawe, Bioggio, Switzerland):** The specimens were polished with white Opti1Step diamond rubbers for 15 s. The primary mean surface roughness (Ra1) and the arithmetic mean height of surface profile (Rz1) values of specimens were measured using a profilometer (Hummel Tester T 8000; Hommel Werke, Waltrup, Germany) and reported in micrometers ( $\mu\text{m}$ ). Three values were recorded at a crosshead speed of 0.5 mm/second, and the mean value

was calculated (Ra1 and Rz1) [19]. The specimens were then immersed in 5 mL of demineralizing solution at 37°C for 6 h. After rinsing with deionized distilled water, the specimens were immersed in a remineralizing solution (artificial saliva) at 37°C for 18 h [15]. The acidic demineralizing solution contained 2 mM calcium and 2 mM phosphate in 74.0 mM buffering solution of acetate at a pH of 4.3. The remineralizing solution contained 1.5 mM calcium, 0.9 mM phosphate, and 150 mM potassium chloride in a buffering solution of 0.1 mM Tris (hydroxymethyl) aminomethane at a pH of 7.0 [15]. After rinsing with deionized distilled water, the specimens were mounted in a toothbrushing simulator (V8; Dorsa, Tehran, Iran), and immersed in containers filled with dentifrice slurry (Crest 7 Complete; Gross Greau, Riedstadt, Germany), prepared by dissolving 17 g of toothpaste in 50 mL of deionized water. The specimens were subjected to 10,000 cycles of 55-mm back-and-forth brushing strokes at a speed of 2 strokes per second. The applied load was 300 N, corresponding to 1 year of toothbrushing [15]. After cleaning in an ultrasonic bath, the surface roughness (Ra2, Rz2) was measured for the second time as explained earlier. One specimen with a surface roughness value close to the mean value was selected from each experimental group and underwent microscopic assessment under a scanning electron microscope (SEM; MV 2300; Camscan, Czech). SEM images were obtained at  $\times 300$ ,  $\times 700$ , and  $\times 3000$  magnifications to assess the surface topography of the specimens.

A total of 45 rectangular specimens (10 $\times$ 8 $\times$ 2 mm) were fabricated with the same method as explained earlier for surface gloss measurement.

Fifteen specimens fabricated from each composite were randomly assigned to 5 experimental subgroups for use of different F/P systems (n=3), and underwent the same F/P procedures as explained earlier. The surface gloss was measured by a glossmeter (Micro TRI; BYK-Gardner; Glom H, Kempen, Germany) calibrated on a black glass according to the manufacturer's instructions.

After primary measurement of gloss, the specimen was rotated by 180°, and the gloss was measured again. The mean value of gloss was then calculated.

The mean and standard deviation (SD) of surface roughness (Ra and Rz) and gloss before and after pH cycling and toothbrushing were calculated and analyzed using SPSS version 22 (SPSS Inc., IL, USA). The Kolmogorov-Smirnov test was applied to assess the distribution of the data. Two-way ANOVA was used to evaluate the effect of material type and type of polishing on surface roughness and gloss. Considering the significant interaction effect of material type

and type of polishing on surface roughness and gloss, the Tukey's HSD test was applied for pairwise comparisons of the groups. Also, t-test was used for pairwise comparisons of surface roughness and gloss before and after pH-cycling and toothbrushing. Level of significance was set at 0.05.

## RESULTS

Table 2 presents the mean and SD of surface roughness in the experimental groups. The type of composite had no significant effect on surface roughness before pH-cycling and toothbrushing (P=0.603 for Ra1 and P=0.942 for Rz1).

**Table 2.** Mean  $\pm$  SD of surface roughness (Ra and Rz values in  $\mu\text{m}$ ) in 15 experimental groups before (1) and after (2) pH-cycling and tooth brushing

	Renamel		Z350		Z250	
	1	2	1	2	1	2
<b>SL</b>						
<b>R<sub>a</sub></b>	0.62 $\pm$ 0.2	1.27 $\pm$ 0.49	0.45 $\pm$ 0.17	1.00 $\pm$ 0.43	0.92 $\pm$ 0.35	0.77 $\pm$ 0.23
<b>R<sub>Z</sub></b>	1.55 $\pm$ 0.58	3.15 $\pm$ 1.75	1.22 $\pm$ 0.74	3.70 $\pm$ 1.29	2.4 $\pm$ 0.73	2.47 $\pm$ 1.41
<b>Di</b>						
<b>R<sub>a</sub></b>	0.57 $\pm$ 0.22	0.52 $\pm$ 0.2	0.60 $\pm$ 0.24	0.95 $\pm$ 0.83	0.67 $\pm$ 0.12	0.60 $\pm$ 0.08
<b>R<sub>Z</sub></b>	1.02 $\pm$ 0.27	1.17 $\pm$ 0.62	1.50 $\pm$ 0.72	2.00 $\pm$ 1.61	1.70 $\pm$ 0.74	1.15 $\pm$ 0.17
<b>Co</b>						
<b>R<sub>a</sub></b>	0.47 $\pm$ 0.15	0.92 $\pm$ 0.4	0.46 $\pm$ 0.31	0.37 $\pm$ 0.3	0.50 $\pm$ 0.2	0.42 $\pm$ 0.09
<b>R<sub>Z</sub></b>	1.65 $\pm$ 0.73	2.47 $\pm$ 1.27	1.04 $\pm$ 0.33	1.02 $\pm$ 0.73	1.78 $\pm$ 0.5	2 $\pm$ 0.8
<b>Sh</b>						
<b>R<sub>a</sub></b>	0.70 $\pm$ 0.21	0.85 $\pm$ 0.61	0.80 $\pm$ 0.47	1.10 $\pm$ 0.67	0.8 $\pm$ 0	0.80 $\pm$ 0.29
<b>R<sub>Z</sub></b>	3.52 $\pm$ 1.61	3.57 $\pm$ 2.52	3.22 $\pm$ 1.2	5.50 $\pm$ 2.35	2.50 $\pm$ 1.12	2.50 $\pm$ 0.68
<b>Op</b>						
<b>R<sub>a</sub></b>	0.32 $\pm$ 0.12	0.30 $\pm$ 0.23	0.47 $\pm$ 0.37	0.45 $\pm$ 0.36	0.20 $\pm$ 0.11	0.20 $\pm$ 0.17
<b>R<sub>Z</sub></b>	1.37 $\pm$ 0.69	1.12 $\pm$ 0.84	2.27 $\pm$ 1.95	1.60 $\pm$ 1.22	1.20 $\pm$ 0.47	1.20 $\pm$ 1.15

Co: Cosmedent; Sh: Shofu; Op: Opti1Step; SL: Sof-Lex; Di: Diacomp

Different superscripted letters (Ra: lowercase and Rz: uppercase) in the same column show significant differences (P<0.001)

**Table 3.** Mean  $\pm$  SD surface gloss values (GU) in 15 experimental groups before (1) and after (2) pH-cycling and toothbrushing

	Renamel		Z350		Z250	
	1	2	1	2	1	2
<b>SL</b>	35.9 $\pm$ 5.21	0.27 $\pm$ 5.28	35.53 $\pm$ 3.16	21.66 $\pm$ 4.79	17.83 $\pm$ 4.77	22.73 $\pm$ 8.82
<b>Di</b>	21.76 $\pm$ 2.92	23 $\pm$ 7.18	51.4 $\pm$ 4.13	31.06 $\pm$ 4.92	34.26 $\pm$ 3.25	25.16 $\pm$ 1.05
<b>Co</b>	45.03 $\pm$ 1.93	20.4 $\pm$ 2.26	42.76	18 $\pm$ 2.1	27.3 $\pm$ 1.21	17.76 $\pm$ 0.4
<b>Sh</b>	27.86 $\pm$ 1.59	13.66 $\pm$ 1.67	39.6 $\pm$ 1.53	25.8 $\pm$ 4.14	16.76 $\pm$ 2.06	12.56 $\pm$ 4.8
<b>Op</b>	33.53 $\pm$ 2.6	17.53 $\pm$ 2.53	28.6 $\pm$ 2.12	24.53 $\pm$ 13.38	27.66 $\pm$ 5.7	22.63 $\pm$ 9.42

GU: Gloss unit; Co: Cosmedent; Sh: Shofu; Op: Opti1Step; SL: Sof-Lex; Di: Diacomp

However, the effect of F/P system on surface roughness was statistically significant ( $P < 0.002$  for Ra1 and  $P < 0.000$  for Rz1). The lowest mean Ra1 value was recorded in Opti1Step Polisher group ( $0.32 \pm 0.23 \mu\text{m}$ ), which was significantly lower than the value in Sof-Lex ( $P = 0.026$ ) and Shofu ( $P = 0.026$ ) groups, irrespective of composite type. Two-way ANOVA showed that after pH-cycling and toothbrushing, the type of composite did not have a significant effect on surface roughness ( $P = 0.354$  for Ra2 and  $P = 0.174$  for Rz2), but the type of F/P system had a significant effect on surface roughness ( $P < 0.002$  for Ra2 and  $P < 0.174$  for Rz2).

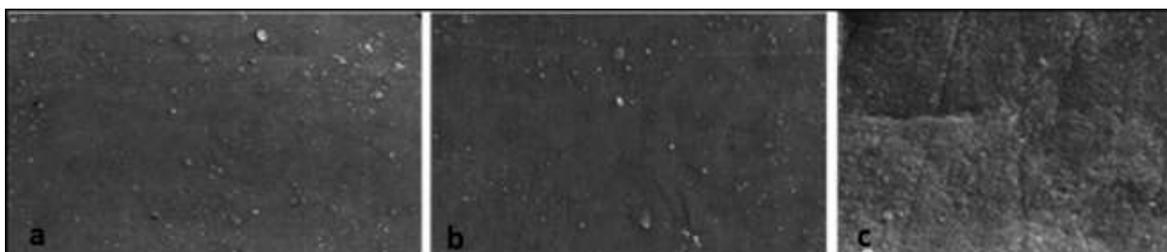
The lowest mean Ra value was noted in Opti1Step Polisher system ( $0.30 \pm 0.13 \mu\text{m}$ ), which was significantly lower than the value in Sof-Lex ( $P < 0.006$ ) and Shofu ( $P < 0.032$ ) groups, irrespective of composite type. Independent t-test revealed that there were no significant differences between the mean values of surface roughness before (Ra1, Rz1) or after (Ra2, Rz2) pH-cycling and toothbrushing ( $P > 0.05$ ). Table 3 shows the mean and SD of surface gloss values (G1, G2) in the experimental groups in gloss units (GU). The type of composite and F/P system had a significant effect on surface gloss before pH-cycling and toothbrushing ( $P < 0.000$ ). Renamel polished with Cosmedent system had the highest surface gloss value (45.033 GU), which was significantly higher than Sof-Lex ( $P < 0.028$ ), Diacomp ( $P < 0.000$ ), Opti1Step Polisher ( $P < 0.007$ ), and Shofu ( $P < 0.032$ ).

In Z350 composite, Diacomp resulted in the highest surface gloss value (42.766 GU), which was significantly higher than Sof-Lex ( $P < 0.000$ ), Cosmedent ( $P < 0.022$ ), Shofu ( $P < 0.003$ ), and Opti1Step Polisher ( $P < 0.000$ ). In Z250 composite, Diacomp yielded the highest surface gloss value (34.266 GU), which was significantly higher than Sof-Lex ( $P < 0.002$ ), and Shofu ( $P < 0.001$ ).

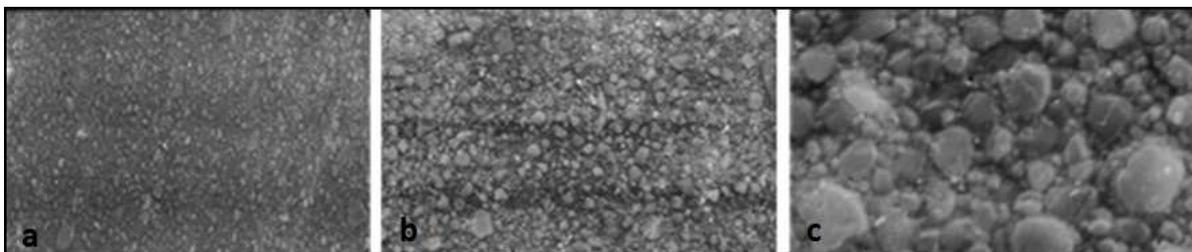
Two-way ANOVA revealed that after pH-cycling and toothbrushing, type of composite had no significant effect on surface gloss ( $P = 0.085$ ), but the type of F/P system significantly affected the surface gloss ( $P < 0.000$ ). In Renamel, polishing with the Sof-Lex system yielded the highest surface gloss value ( $27 \pm 5.282$  GU), which was significantly higher than the Shofu system ( $P < 0.018$ ).

The t-test revealed that there was no significant difference between the mean values of surface gloss before (G1), or after (G2) pH-cycling and toothbrushing ( $P > 0.05$ ). In SEM assessment of the surface of a Renamel specimen after polishing with Cosmedent system, a tenacious resinous smear layer was seen that formed during polishing, and in Z250 and Z350 specimens, removal of some rein matrix was seen (Figs. 1 and 2).

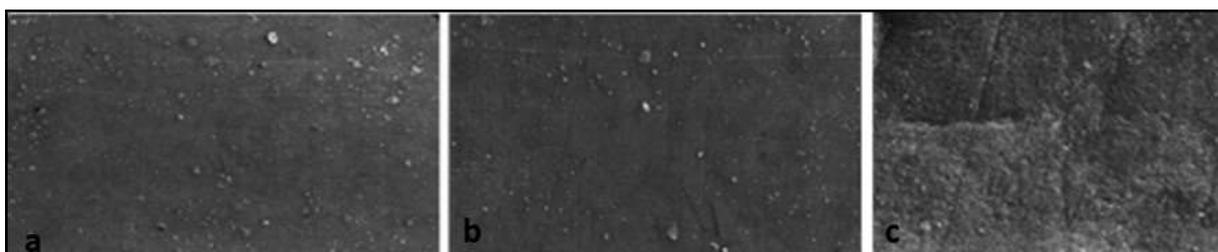
In SEM assessment of the surface of a Renamel specimen after polishing with Diacomp system, a tenacious resinous smear layer was seen that formed during polishing in all magnifications (Fig. 3a).



**Fig. 1.** Scanning electron micrograph of the surface of a Renamel specimen after polishing with Cosmedent system. (a) Original magnification  $\times 300$ . (b) Original magnification  $\times 700$ . (c) Original magnification  $\times 3000$ . In all magnifications, a tenacious resinous smear layer can be seen that formed during polishing



**Fig. 2.** Scanning electron micrograph of the surface of a Z250 specimen after polishing with Cosmedent system. (a) Original magnification  $\times 300$ . (b) Original magnification  $\times 700$ . (c) Original magnification  $\times 3000$ . In all magnifications, removal of some rein matrix is seen



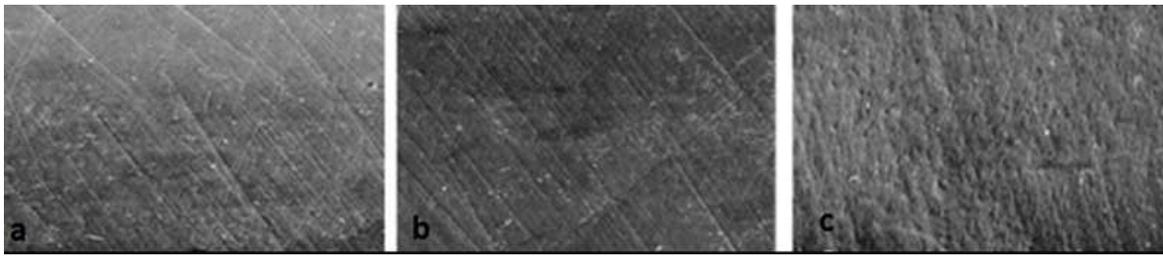
**Fig. 3.** Scanning electron micrograph of the surface of a Renamel specimen after polishing with Diacomp system. (a) Original magnification  $\times 300$ . (b) Original magnification  $\times 700$ . (c) Original magnification  $\times 3000$ . In all magnifications, a homogenous and tenacious resinous smear layer can be seen that formed during polishing. In  $\times 700$  magnification, some rubber remnants are seen

In higher magnifications, some rubber remnants and removal of some rein matrix were noted (Fig. 3b and 3c). In SEM assessment of the surface of Z250 and Z350 specimens after polishing with Diacomp system, removal of some resin matrix was seen in all magnifications. In SEM assessment of the surface of a Renamel specimen after polishing with Opti1Step system, a homogenous and tenacious resinous smear layer was seen that formed during polishing in all magnifications (Fig. 4).

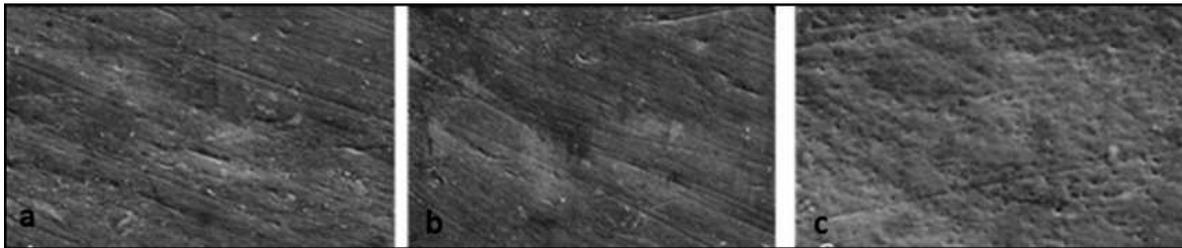
In SEM assessment of the surface of Z250 and Z350 specimens after polishing with Opti 1Step system, removal of some rein matrix and filler projections were seen in all magnifications. In SEM assessment of the surface of a Renamel specimen after polishing with Shofu system, a tenacious resinous smear layer that formed during polishing and some striations were seen in all magnifications (Fig. 5). In Z250 and Z350 specimens after polishing with Shofu system, some voids and removal of some rein matrix were noted at higher magnifications.



**Fig. 4.** Scanning electron micrograph of the surface of a Renamel specimen after polishing with Opti1Step system. (a) Original magnification  $\times 300$ . (b) Original magnification  $\times 700$ . (c) Original magnification  $\times 3000$ . In all magnifications, a homogenous and tenacious resinous smear layer can be seen that formed during polishing. At  $\times 700$  magnification, some rubber remnants are seen



**Fig. 5.** Scanning electron micrograph of the surface of a Renamel specimen after polishing with Sof-Lex system. (a) Original magnification  $\times 300$ . (b) Original magnification  $\times 700$ . (c) Original magnification  $\times 3000$ . In all magnifications, a tenacious resinous smear layer that formed during polishing and some striations can be seen



**Fig. 6.** Scanning electron micrograph of the surface of a Renamel specimen after polishing with Z250 system. (a) Original magnification  $\times 300$ . (b) Original magnification  $\times 700$ . (c) Original magnification  $\times 3000$ . Some multidirectional lines in all magnifications can be seen

It seems that green stone and white stone used in this system can remove the inorganic filler as well as the resin matrix. In SEM assessment of the surface of a Renamel specimen after polishing with Sof-Lex system, some multidirectional lines in all magnifications were noted (Fig. 6) and, at  $\times 3000$  magnification, some voids and filler projections were seen (Fig. 6c). In Z250 and Z350 specimens, some voids and removal of some resin matrix were seen after polishing with Sof-Lex system at higher magnifications.

## DISCUSSION

A number of factors may impair the esthetic appearance of composite restorations. Chemical degradation and mechanical abrasion are among the most important factors in this respect [15,25]. Therefore, in this study, the composite specimens were subjected to pH-cycling and toothbrushing to better simulate the oral environment [15,16,19-22]. Demineralizing solutions induce a severe acidic challenge similar to the process of demineralization and caries development following exposure to acidic

foods and beverages.

The adopted protocol for this purpose was similar to that used by Carvalho et al [16]. Evidence shows that toothbrushing with dentifrices affects the roughness and gloss of composite resins in a three-body abrasion mode [20,21]. It seems that the loose abrasive particles of dentifrices transfer energy and induce ploughing of particles from the substrate in micro- and nanometer scales [2]. A wide range of loads were applied to toothbrushes in previous in vitro studies (100 to 579 g) [21,22]. The load applied in this study (300 N) simulated a moderate brushing force [15]. The three composites evaluated in this study were chosen according to the general classification of resin-based materials based on filler particle size (microfilled, microhybrid, and nanofilled). By doing so, we also assessed the effect of composite type on surface roughness and gloss. Generally, the size of the largest inorganic filler particle is the most important determinant of the long-term surface smoothness of composite restorations, and the mean filler particle size is of little value in this respect [1-3].

Five commercially available F/P systems with different numbers of polishing steps were evaluated in this study. The polishing discs were used sequentially starting from larger (coarser) to smaller (finer) grits [1]. Also, a set of ultra-thin flexible discs (3M ESPE) coated with aluminum oxide particles were used as the gold standard for the purpose of comparison of F/P systems [1,2]. In all groups, standard polishing was first performed with 400-grit silicon carbide abrasive paper under running water to standardize the surface roughness. By doing so, occasional voids and bobbles on the surface were eliminated [34]. Surface profilometry is a quantitative method for evaluation of surface roughness [37-40]. However, the displayed roughness value does not correctly represent the actual topography of the composite surface in some cases. Therefore, SEM assessment was performed to obtain comprehensive results [39,40]. It has been confirmed that surface topography of restorative materials affects plaque accumulation, wear, and abrasivity of restorations [24,27].

Gloss is an important optical property of composite resins [11,12,14], which is directly related to the smoothness obtained after polishing [17]. High gloss decreases the effect of color difference between enamel and restorations, and such restorations can successfully mask the discolored underlying tooth structure [11-14]. In addition to factors that affect the surface roughness of composites, the reflection coefficient of fillers, the matrix viscosity, and the homogeneity of filler-matrix complex can affect the surface gloss of composites [9-12]. The results of this study showed that type of composite had no significant effect on surface roughness before/after pH-cycling and toothbrushing ( $P=0.603$  for Ra1 and  $P=0.942$  for Rz1). Although the size of particles ranged from 0.01 to 3.5  $\mu\text{m}$  in Z250 microhybrid composite, it showed similar behavior to microfilled (0.02 to 0.04  $\mu\text{m}$ ) and nanofilled (0.06 to 1.4  $\mu\text{m}$ ) composites. This may be due to the optimally high efficacy of F/P systems, that were capable of well removing the large inorganic fillers in microhybrid composite [22].

The type of F/P system had a significant effect on surface roughness before and after pH-cycling and toothbrushing in this study ( $P=0.002$  for Ra1 and  $P=0.000$  for Rz1, and  $P=0.000$  for Ra2 and  $P=0.174$  for Rz2). These results were in line with those of Rodrigues-Junior et al [4]. They demonstrated that surface roughness was affected by the type of F/P system, irrespective of composite type. Korkmaz et al. [34] did not find any significant difference between four composite types in terms of surface roughness, and Sof-Lex discs yielded the highest roughness value. However, Ereifej et al. [5] indicated that both composite type and F/P system affected the surface roughness. This controversy may be attributed to the use of different composite types in different studies. In the present study, the highest mean roughness value in all composites was achieved following the use of Shofu and Sof-Lex polishing systems. The silicon carbide impregnated green stones of the Shofu system are extremely sharp, hard, and brittle. They easily break and form new sharp particles [1,2]. It seems that deep scratches produced in the first step of polishing cannot be completely smoothed in subsequent polishing steps. Moreover, the Sof-Lex discs have rigid backing, which can result in ripping of the surface if high load is applied [7].

The highest mean Ra1 value was  $0.92 \pm 35 \mu\text{m}$ , and all composites showed acceptable Ra values following the use of all F/P systems. In topographic evaluation of Z250 specimens, the Shofu and Sof-Lex systems were more effective and produced smoother surfaces than other systems. After F/P with other systems, some filler projections were noted at all magnifications, sticking out of the surface of Z250 specimens. It seems that gouging of the softer part of the resin matrix occurred [1]. The Renamel microfilled composite showed the smoothest surface topography. It seems that all F/P systems produced a resin smear layer on the surface of this composite; however, after using the Shofu and Sof-Lex systems, some multidirectional scratches developed. A major shortcoming of microfilled composites is the weak bond between the

cured matrix and inorganic fillers, which causes abrasive wear via a chipping mechanism. On the other hand, during F/P, cracks may propagate around the loosely-bound organic fillers [1,3]. However, none of the five F/P systems used in this study created such defects in the Renamel composite. The lowest roughness value (Ra) in Renamel and Z350 composites was obtained following the use of Opti1Step Polisher. Opti1Step Polisher is a diamond-impregnated silicon polisher, which can be used for either finishing or polishing by altering the hand pressure [27,30]. The diamond particles used in Opti1Step Polisher have higher toughness and hardness than silicon carbide, aluminum oxide, and zirconium silicate particles used in Sof-Lex and Shofu systems [1,3]. In this study, Cosmedent three-step polishing system produced higher gloss in Renamel microfilled composite before pH-cycling and toothbrushing (45.033 GU). Renamel contains agglomerated particles embedded in 5-50 µm prepolymerized resin fillers [1]. The smaller difference between the wear resistance of filler and matrix in microfilled composites usually results in an acquired polished surface similar to their inherent polish [3]. The inherent polish is determined by the characteristics of the restorative material while the acquired polish is obtained after finishing and polishing [3]. Also, dry polishing of microfilled composite creates a resin smear layer on the surface of composite that can improve the surface gloss [3]. Berger et al. [6] showed that better results were obtained when the F/P system and the composite were from the same manufacturer. Z350 XT nanofilled composite also showed high gloss after F/P with Diacomp and Cosmedent systems. This composite contains non-agglomerated silica (20 nm) and zirconia (5-20 nm) particles. These clusters (60 nm to 0.04 µm) may loosely bind to each other and the resin matrix [1]. Reduction in gloss of Z350 composite after toothbrushing was less than that of Renamel. It seems that the chemical bond of nanofillers and nanoclusters to each other is strong enough to be worn instead of plucked off [1].

However, resin is susceptible to wear during tooth brushing; thus, proper cleaning procedures such as soft toothbrushing with a mildly abrasive dentifrice should be instructed to patients with esthetic composite veneers.

### CONCLUSION

The type of F/P system had a significant effect on surface roughness before and after pH-cycling and toothbrushing. The type of composite had no significant effect on surface roughness before or after pH-cycling and toothbrushing. The interaction effect of type of composite and type of F/P system was significant on surface gloss before pH-cycling and toothbrushing. The type of composite had no significant effect on surface gloss after pH-cycling and toothbrushing. The polished composites showed acceptable gloss and polish retention after pH-cycling and toothbrushing.

### ACKNOWLEDGMENTS

### CONFLICT OF INTEREST STATEMENT

None declared.

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