The Effect of Different Polishing Systems on Surface Roughness and Gloss of Various Resin Composites

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ABSTRACT

Purpose: The purpose of this in vitro study was to evaluate the surface finish and gloss of five direct resin composites polished with six polishing systems.

Materials and Methods: One hundred and fifty disk-shaped composite specimens (D = 10.0 mm, 2-mm-thick, $N = 30$ per material) were made. One side of each specimen was finished with a 16-fluted carbide finishing bur and then polished. Five specimens of each resin composite were randomly assigned to one of the six polishing systems. The surface roughness and gloss were measured with a surface profilometer and a glossmeter. The results were analyzed by two-way analysis of variance and Tukey's *t*-test ($p \leq 0.05$).

Results: There was no significant interaction between the composite and the polishing systems for surface roughness ($p = 0.059$). The order of surface roughness ranked according to composite was: Durafill < Esthet-X < Supreme < Z250 < Z100; and the ranking for the polishing system was: Pogo < Sof-Lex < Diacomp/Enamelize < Diacomp < ComposiPro brush < Jiffy. There was interaction of gloss values between the composites and the polishing systems ($p < 0.001$). The highest gloss value was recorded for Supreme + Pogo; the lowest was recorded for Z100 + Jiffy. Pogo showed the highest gloss values for all composites.

CLINICAL SIGNIFICANCE

The nanofill (Supreme) and minifill (Esthet-X) composites presented a surface roughness comparable to a microfill (Durafill), independent of the polishing system used, and a gloss comparable to a microfill, when polished with a one-step system (Pogo). As compared with the multiple-step systems, the smoothest surfaces and the highest gloss values were achieved using the one-step system (Pogo) for all the evaluated composites.

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INTRODUCTION

Over the years, several changes have been made in the fabrication of dental resin composites to obtain better color stability over time,[1] greater wear resistance,[2] and clinically acceptable surface smoothness of restorations.[3] To achieve the last goal, manufacturers predominantly have reduced the diameter of the filler particles. The microfill resin composites typically contain only nanometer-sized silica particles (40–50 nm). Because of the particle size, these composites can be polished to the highest luster and smoothest surface of all the composites. However, microfill composites are not as fracture-resistant as the other classes of composites.[4] Hybrid composites contain a blend of microscopic (averaging 1–5 µm) and submicroscopic (averaging 0.4–0.8 µm) glass and nanofiller particles (averaging 40–50 nm). The combination of filler particles allows the highest levels of filler loading among resin composites, and a corresponding improvement in physical properties.[4] By reducing the average size of the filler particles, manufacturers have been able to produce composites with a good mix of polishability and strength.

The small-particle hybrid composites can be divided into three categories: nanohybrid (5- to 100-nm nanofillers of silica or zirconia with some 0.1- to 1.0-µm glass and often prepolymerized resin blocks), minifill or microhybrid (0.1- to 1-µm glass with 40-nm silica), and midifill (1- to 5-µm glass with 40-nm silica). One of the advantages of the particle size reduction is the excellent surface finish that can be achieved.[5] Composites containing a high concentration of only nanosized fillers have also been introduced and are called "nanofills." These nanofill composites were developed to be used in all areas of the mouth, with high initial polish and superior polish retention (typical of microfills), as well as excellent mechanical properties suitable for high stress-bearing restoration (typical of a hybrid).[6] The manufacturers claim that these "new" composites have the strength of the hybrids and the polish of a microfill.

The search for the ideal polishing agent for dental composites is ongoing. Several polishing tools have been used over the years,[7] ranging from multiple-step systems using fine and superfine diamond burs, abrasive disks, diamond and silicon impregnated soft rubber cups, to one-step polishing systems containing diamond impregnated cups and silicon carbide brushes. Current one-step systems appear to be as effective as multiple-step systems for polishing dental composites.[7–11] With the ultimate goal of achieving a smooth surface of the composite restoration in fewer steps, the one-step polishing systems are appealing to the clinician. Because of the variety of composites and polishing systems available, they should be evaluated in order to verify which polishing system yields the best polish effect on a given composite. The *purpose* of this study was twofold: (1) to evaluate the surface finish and gloss of five direct resin composites: one microfill, one nanofill, and three minifill hybrid composites; and (2) to evaluate the polishing effect of different polishing systems, two one-step polishing methods and four different multiple-step polishing methods, on the various composites.

The null hypotheses were that there would be no difference in surface roughness or gloss between the polished resin composites or between the different polishing systems when used on the same composites.

MATERIALS AND METHODS

Five commercial resin composites (Table 1) and six polishing systems were evaluated in this study (Table 2). The average particle size of the polishing systems was estimated from scanning electron microscope (SEM) images (6400, JEOL, Peabody, MA, USA) (Figure 1A–K). One hundred and fifty disk-shaped specimens (D = 10.0 mm, 2-mm-thick, $N = 30$ per composite resin, and $N = 5$ per polishing system) were made by packing uncured composite (all A2 shade) into a polytetrafluoroethylene ring mold.

TABLE 1. DENTAL RESIN COMPOSITES TESTED.

Resin Composite	Type	Inorganic Filler Level (wt%)	Average Particle Size	Manufacturer	Lot #	Expiration Date
Filtek Z100	Minifill Hybrid	84.5	0.6–0.8 µm	3M ESPE Dental Products, St. Paul, MN, USA	20051119	2008-10
Filtek Z250	Minifill hybrid	82	0.6–0.8 µm	3M ESPE Dental Products	20051226	2008-11
Filtek Supreme Plus	Nanofill	78.5	20 or 70 nm	3M ESPE Dental Products	20051216	2008-11
Esthet-X	Minifill hybrid	77	0.85–0.9 µm	Dentsply Caulk, Milford, DE, USA	050829	2008-08
Durafill VS	Microfill	52	40 nm	Heraeus Kulzer Gruner, Hanau, Germany	010200	2009-01

TABLE 2. POLISHING SYSTEMS TESTED.

Polishing System	Approximate Average Particle Size (µm)*	Manufacturer	Lot #	Expiration Date
Pogo (diamond micropolisher disc)	10–15	Dentsply Caulk, Milford, DE, USA	050324	2008-03
ComposiPro one-step brush (silicon-carbide particles brush)	—	Brassler USA, Savannah, GA, USA	70506222	2006-12
ComposiPro Diacomp—Green (diamond impregnated knife)	20	Brassler USA	202331	2006-05
ComposiPro Diacomp—Gray (diamond impregnated knife)	5	Brassler USA	204321	2006-05
Jiffy—Green (silicon impregnated disc)	40	Ultradent, South Jordan, UT, USA	B232 V	Not provided
Jiffy—Yellow (silicon impregnated disc)	30	Ultradent	B23RW	Not provided
Jiffy—White (silicon impregnated disc)	5	Ultradent	B232 V	Not provided
Sof-Lex—Medium orange (aluminum oxide disc)	30 (electrostatically coated)	3M ESPE Dental Products, St. Paul, MN, USA	2385P	Not provided
Sof-Lex—Light orange (aluminum oxide disc)	30 (slurry coated)	3M ESPE Dental Products	2385P	Not provided
Sof-Lex—YellowSuperFine (aluminum oxide disc)	3	3M ESPE Dental Products	2385P	Not provided
Enamelize (aluminum oxide paste)	1.5	Cosmedent, Chicago, IL, USA	013423	2006-08

*From scanning electron microscope image analysis.

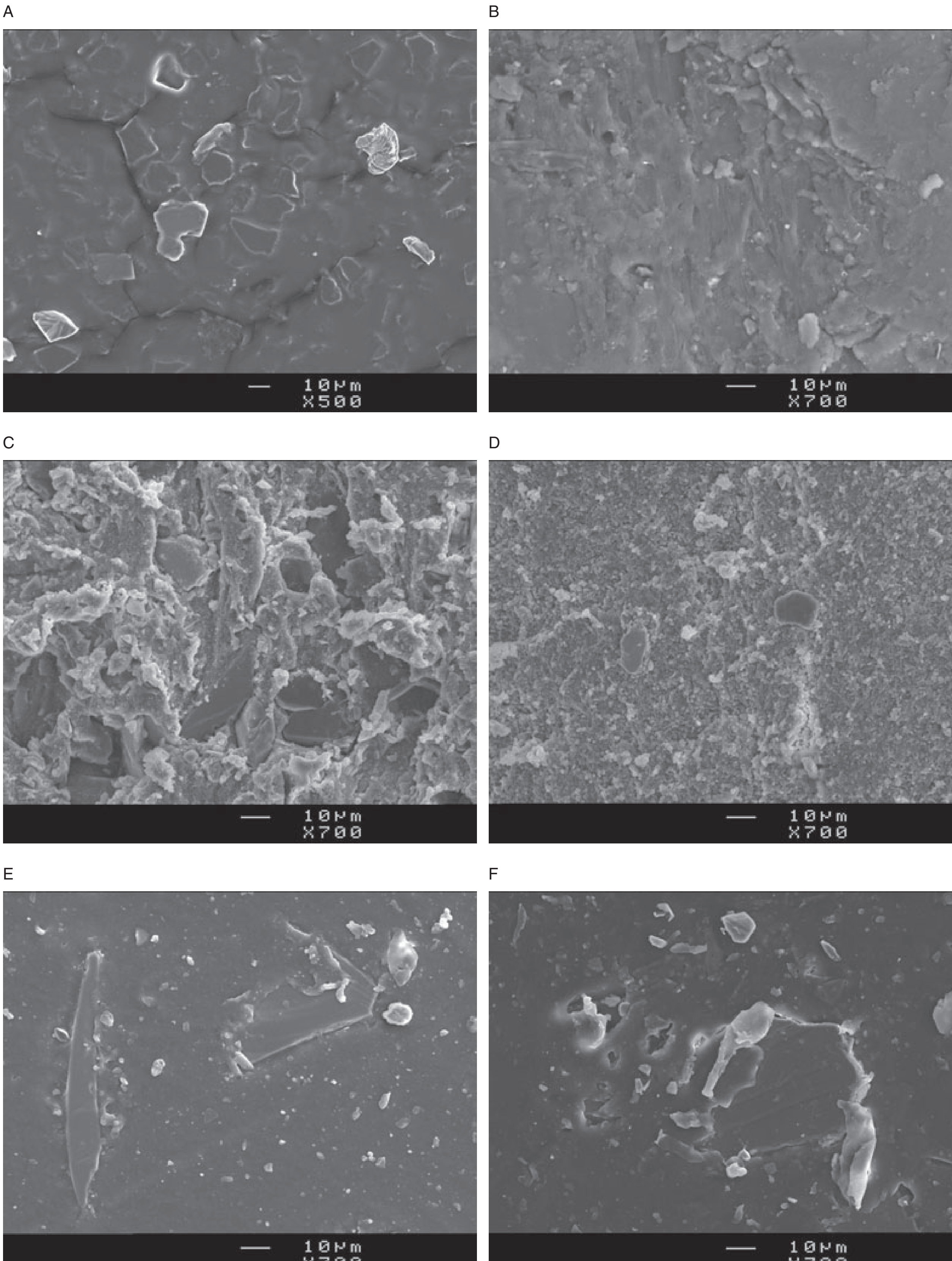
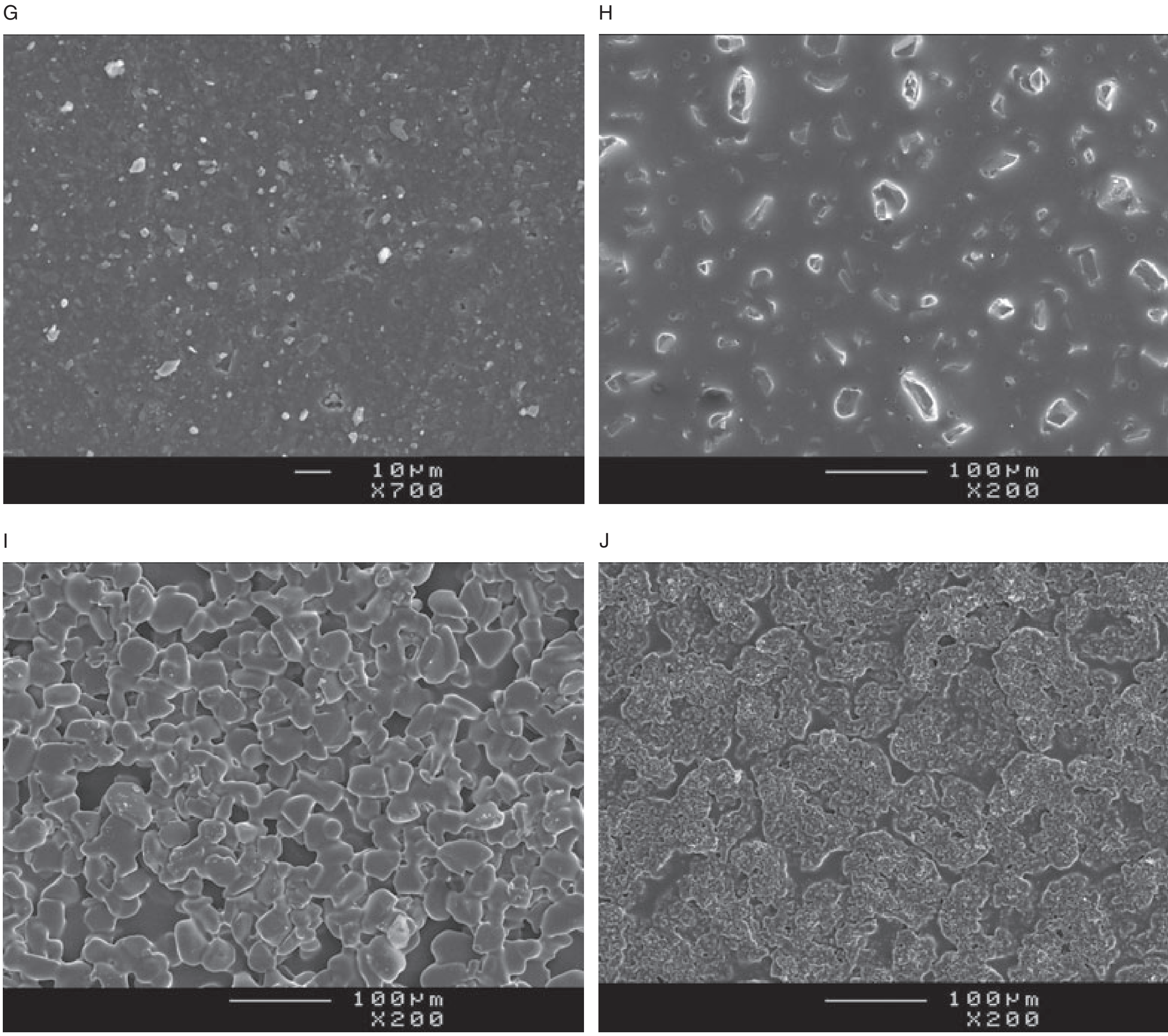


Figure 1. Scanning electron microscope images of the polishers evaluated. A, *Pogo.* B, *ComposiPro.* C, *Green Diacomp.* D, *Gray Diacomp.* E, *Green Jiffy.* F, *Yellow Jiffy.*



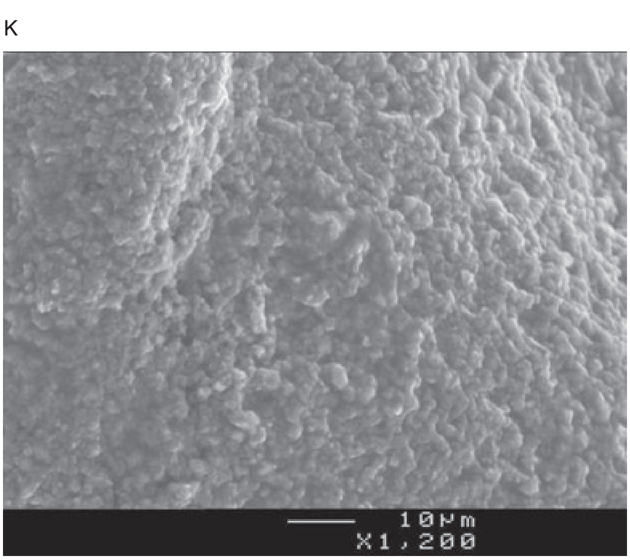


Figure 1. (Continued) G, *White Jiffy*. H, *Medium orange Sof-Lex*. I, *Light orange Sof-Lex*. J, *Yellow Sof-Lex*. K, *Enamalize paste*.

Mylar strips were placed over each surface of the uncured composite to prohibit oxygen inhibition. A 2-kg load was placed on the mold for 30 seconds to extrude the excess material. The specimens were then light-polymerized for 40 seconds using the LED Demetron 1 (Kerr Inc, Orange, CA, USA), except for Z250, which was cured for 20 seconds based on the manufacturer's recommendation. The energy of the polymerization light was monitored with a dental radiometer (Model 100, Kerr Demetron, Danbury, CT, USA) and ranged between 700 and 760 mW/cm^2. Immediately after the light-curing cycle, the specimens were taken from the mold and immersed in deionized water at 37°C for 7 days in the dark. Following the storage period, one side of each specimen was finished with a 16-fluted carbide finishing bur (Brassler, Savannah, GA, USA) to simulate a clinical finishing procedure. Five specimens of each resin composite were then randomly assigned to one of the six polishing systems. One person performed the polishing. Each polisher was used only once, and the same slow-speed handpiece (W&H, Burmoos, Austria) was used for all experiments. Polishing was performed as follows:

1. Pogo (one-step system)
   - Step 1: light pressure for 40 seconds, rinse and dry with water/air syringe for a total of 6 seconds
2. ComposiPro one-step brush (one-step system)
   - Step 1: light pressure for 40 seconds, rinse and dry with water/air syringe for a total of 6 seconds
3. ComposiPro Diacomp (two-step system)
   - Step 1 (fine grit): green disk with water, light pressure for 20 seconds, rinse and dry with water/air syringe for a total of 6 seconds
   - Step 2 (superfine grit): gray disk dry, light pressure for 20 seconds, rinse and dry with water/air syringe for a total of 6 seconds
4. ComposiPro Diacomp + Enamelize (Diac + Ena) (three-step system)
   - Step 1 (fine grit): green disk with water, light pressure for 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds
   - Step 2 (superfine grit): gray disk dry, light pressure for 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds
   - Step 3: Enamelize paste and Flexibuff disk (Cosmedent, Inc., Chicago, IL, USA), light pressure for 15 seconds, rinse and dry
5. Sof-Lex disks (three-step system)
   - Step 1 (medium grit): medium disk dry, 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds
   - Step 2 (fine grit): light orange disk dry, 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds
   - Step 3 (superfine grit): yellow disk dry, 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds
6. Jiffy polishers—silicon impregnated rubber discs (three-step system)
   - Step 1 (coarse grit): green disk with water spray, light pressure for 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds
   - Step 2 (medium grit): yellow disk dry, light pressure for 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds
   - Step 3 (fine grit): white disk dry, light pressure for 15 seconds, rinse and dry with water/air syringe for a total of 6 seconds

The average surface roughness (Ra, μm) was measured with a surface profilometer (Talysurf Plus, Tailor-Hobson, Leicester, UK), using a tracing length of 2 mm and a cutoff value of 0.25 mm to maximize filtration of surface waviness. Five tracings at different locations on each specimen were recorded. Gloss was measured using a small-area glossmeter (Novo-Curve, Rhopoint Instrumentation, East Sussex, UK), with a square measurement area of 2 × 2 mm and 60° geometry. Gloss measurements were expressed in gloss units (GU). A custom-made, 10-mm-thick, black polytetrafluoroethylene mold was placed over the specimen during measurements to enable accurate specimen positioning and eliminate the influence of the overhead light. The results were analyzed by two-way analysis of variance (ANOVA) and Tukey's t-test ($\alpha \leq 0.05$) (Sigmastat 3.11, Systat Software, Inc., San Jose, CA, USA).

RESULTS

Surface Roughness

The mean values and standard deviations of surface roughness (Ra, µm) for each resin composite are given in Figure 2. The two-way ANOVA showed significant surface roughness difference among the five composites and the six polishing systems ($p < 0.001$). There was no significant interaction between composite and polishing systems ($p = 0.059$). The order of composites (for all six polishing systems together) ranked from the lowest to the highest surface roughness was: Durafill < Esthet-X < Supreme < Z250 < Z100.

Pairwise multiple comparisons with Tukey's test showed Durafill to have the smoothest surface, but it was not significantly different from Filtek Supreme and Esthet-X. The least smooth surface occurred for Z100, which was not significantly different from Z250.

The mean values and standard deviations of surface roughness for each polishing system are given in Figure 3. The order by polishing system (for all five composites together) ranked from the lowest to the highest of surface roughness was: Pogo < Sof-Lex = Diacomp/Enamelize < Diacomp < CoposiPro brush < Jiffy.

According to all pairwise multiple comparison procedures, Pogo showed the smoothest surface and was not significantly different from Diacomp/Enamalize and Sof-Lex disks. Jiffy showed the greatest surface roughness, which was only significantly different from Pogo.

Gloss

The two-way ANOVA showed significant difference in gloss (GU) among the five composites and the six polishing systems, and a significant interaction between the composite and the polishing systems ($p < 0.001$). The mean values and standard deviation of gloss for the interaction between composite and polishing systems are given in Table 3 and Figure 4. In general, Durafill, Filtek Supreme, and Esthet-X showed higher gloss than Z100 and Z250. Pogo generally produced the highest gloss, while Jiffy produced the lowest gloss. Because of the interaction between the composite and the polishing system, it is necessary to compare the individual

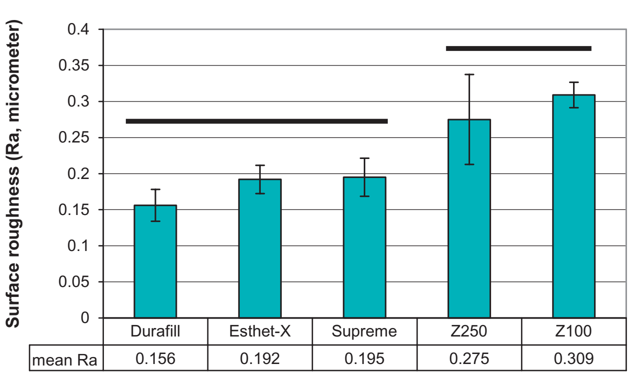


Figure 2. Surface roughness of the resin composites tested. Resin composites or polishing systems with the same black bar are not statistically different.

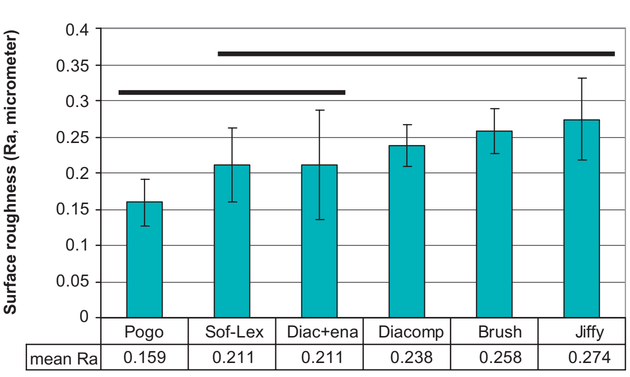


Figure 3. Surface roughness of the polishing systems tested. Resin composites or polishing systems with the same black bar are not statistically different.

TABLE 3. AVERAGE GLOSS VALUES (GU) AND STANDARD DEVIATIONS (±SD) FOR THE FIVE RESIN COMPOSITES AND SIX POLISHING SYSTEMS TESTED.

Resin	Polish					
	Pogo	Brush	Diac + Ena	Diacomp	Jiffy	Sof-Lex
Z100	59.5 ± 3.79$^{a/B,C}$	28.2 ± 3.15$^{b,c/B}$	51.2 ± 7.35$^{a/A}$	22.3 ± 8$^{b/B}$	19.9 ± 3.80$^{b/A}$	35.7 ± 5.33$^{c/C}$
Z250	64.05 ± 14.17$^{a/B,C}$	31.0 ± 9.21$^{c/B}$	20.2 ± 4.79$^{c/B}$	23.6 ± 6.97$^{c/B}$	26.6 ± 3.74$^{c/A}$	43.7 ± 2.51$^{b/B,C}$
Supreme	77.4 ± 4.44$^{a/A}$	36.5 ± 3.41$^{c/A,B}$	23.6 ± 2.88$^{d/B}$	26.6 ± 3.77$^{d/A,B}$	28.7 ± 1.73$^{d/A}$	55.6 ± 5.03$^{b/A}$
Durafill	71.0 ± 7.09$^{a/A,B}$	31.1 ± 3.98$^{c/B}$	48.5 ± 11.05$^{b/A}$	36.0 ± 6.20$^{c/A}$	28.4 ± 3.42$^{c/A}$	48.7 ± 7.96$^{b/A,B}$
Esthet-X	66.2 ± 11.07$^{a/B,C}$	42.8 ± 1.44$^{b/A}$	30.5 ± 6.29$^{c/B}$	20.1 ± 1.38$^{c/B}$	24.5 ± 3.48$^{c/A}$	47.3 ± 5.40$^{b/A,B}$

Values with the same superscript are not significantly different. The lowercase superscripts refer to the rows (polishing system within composite). Uppercase superscripts refer to the columns (composite within polishing system).

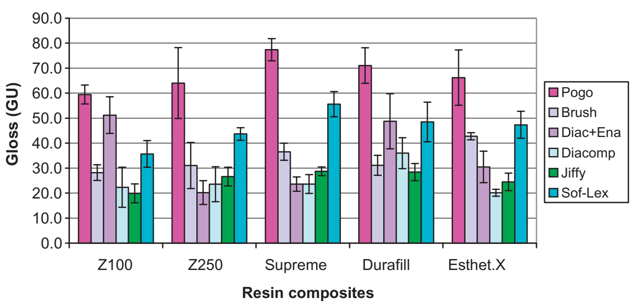


Figure 4. Gloss of resin composites and polishing systems tested.

means as opposed to making general statements from the statistical results.

Comparing the different polishing systems for each composite, the following results were obtained: Pogo produced the highest gloss for Z250, Supreme, Durafill, and Esthet-X, while Pogo and Diacomp/Enamelize produced the highest gloss for Z100. For every composite, Sof-Lex was intermediate between the polishers producing the highest and lowest gloss.

Comparing the different composites for each polishing system, the following results were obtained: Pogo produced the highest gloss on Supreme and Durafill; Brush produced the highest gloss on Esthet-X, Supreme, and Durafill; Diacomp/Enamelize produced the highest gloss on Z100 and Durafill; Diacomp produced the highest gloss on Durafill and Supreme; Jiffy produced the same level of gloss on all composites; while Sof-Lex produced the highest gloss for Supreme, Durafill, Esthet-X, and Z250.

DISCUSSION

The smoothest surface that can be produced on a dental composite is achieved with a matrix strip.[8,12–24] However, some functional adjustment is necessary on almost all clinical restorations. The presence of surface irregularities arising from poor finishing/polishing techniques and/or instruments can create clinical problems such as staining, plaque retention, gingival irritation, and recurrent decay, thus affecting the clinical performance of the restoration.[22–25] Surface roughness refers to the finer irregularities of the surface texture that usually result from the action of the production process or the material's characteristics.[26] A clinical study on titanium implant abutments revealed that a mean roughness of 0.2 µm is the critical threshold value for bacterial retention.[27] Another study reported that a change of surface roughness in the order of 0.3 µm can be detected by the tip of the patient's tongue.[28] According to this study Z100 and Z250 were the only composites that showed an average surface roughness above the 0.2-µm threshold. Hence, Pogo was the only polisher that provided the below 0.2-µm surface roughness threshold on the composites.

According to the surface roughness assessment, the microfill composite (Durafill) showed the smoothest surface, which corresponds to other results in the literature.[29] However, the surface roughness for the microfill was not significantly different from that of the nanofill (Filtek Supreme) and the minifill hybrid composite (Esthet-X). These findings are in accordance with a study that showed no significant difference in surface roughness between a microhybrid and microfilled composite.[5] Traditionally, it is believed that the ability to polish composites varies depending on their particle size,[29,30] and microfilled resin composites are more easily polished than hybrid types because of their smaller overall filler size. The fact that the nanofill composite showed similar surface roughness as the microfill was not unexpected, as the nanofill composite evaluated in this study contains only particles of a size below 100 nm, which are similar to the microfill composite. However, the larger particles present in the minifill composite, Esthet-X, would have led one to predict that its surface roughness would be greater than that of the microfill and nanofill; but this was not the case. Apparently, the particle size and distribution in Esthet-X allows it to be polished to a surface that is more consistent with the microfill and nanofill composite than the two other minifill hybrid materials, Z100 and Z250, most likely based on the size of the largest particles present in the material.

Current one-step systems appear to be as effective as multiple-step systems for polishing dental composites.[8] The one-step polishing system tested in this study, Pogo, generally produced the smoothest surfaces on all composites. This result is in accordance with previous studies.[7,9–11] Pogo was significantly different from the other one-step system, ComposiPro brush, and it was not significantly different from the three-step system, Sof-Lex, which showed the second-best result, or the other three-step system, Diacomp followed by Enamelize paste. The obvious advantage of the one-step system is the convenience and efficiency of producing a very smooth surface without having to switch to finer polishing items or having to wash and dry between each step to ensure removal of the larger abrasives from the previous step. Most investigators have concluded that flexible aluminum oxide disks are the best instruments for providing low roughness on composite surfaces.[9,31–33] This study showed similar or better performance regarding surface roughness between Sof-Lex disks and all of the other multiple-step systems evaluated.

Gloss is defined as “angular selectivity of reflectance, involving surface-reflected light, responsible for the degree to which reflected highlights or images of objects may be seen as superimposed on a surface.”[34] Gloss depends on material properties and on the particular process variables. In the plastic industry, gloss has been shown to be influenced by the size distribution, mechanical properties, and index of refraction of the fillers present in a plastic, as well as the viscosity and index of refraction of the matrix component.[35] Highly polished, plane black glass with a refractive index of 1.567 is defined as having a gloss of 100 GU at any measuring angle. A totally nonreflective surface has 0 GU.[36] In this study, there was a significant interaction among the composites and polishing systems evaluated in terms of gloss. The highest gloss values were recorded for the nanofill composite (Supreme) polished with the one-step system (Pogo), although this surface was not significantly different from that of the microfill composite (Durafill) and the minifill (Esthet-X) polished by Pogo. The one-step system, Pogo, had the highest gloss value for all composites evaluated. This finding is in accordance with a previous study.[10] It seems that this system works well for all different composites. Jiffy and Diacomp ranked the lowest in terms of gloss production.

The factors that might have influenced the surface roughness and gloss results might be particle size and type of abrasives used in the polishing system, as well as the time used for each polishing procedure. For example, Pogo is a diamond polisher with an average particle size of approximately 10 µm based on our qualitative evaluation by SEM. Diacomp is also a diamond polisher, with the finer-particle Diacomp having an average particle size of approximately 5 µm. In theory, the smaller particle-size polisher would be expected to yield smoother and glossier surfaces, but this was not shown in this study. It is possible that the manner in which the particles are bound within the matrix, as well as the composition of the matrix, is different for the different systems, and this affects their polishing efficiency. If the matrix wears at a more similar rate as the polishing particle, it is likely that the particle would be less likely to extrude significantly from the matrix; therefore, it would have less of a "gouging effect" on the composite. It is also important to point out that Pogo was used for 40 seconds in this study, which was equivalent to the amount of time that was used for the multistep systems. Perhaps if the Pogo disk was used only for 15 seconds, or if each disk of the multistep polishing systems were used for a longer period of time equivalent to the Pogo, the polishing efficiency of Pogo would have been found to be equivalent to the other systems. These possibilities would need to be tested in a future study.

The smallest average particle size of the one-step or the last step of the multiple-step polishing systems is found in the Enamalize paste. In theory, the Enamelize paste should have yielded the smoothest and the glossiest surface, with the brush producing the least smooth and glossy surface. However, this did not occur in this study. Perhaps an explanation for this lack of correlation between particle size in the abrasive and surface quality is reflected in the fact that the abrasives used in each system may also differ in terms of their composition and physical properties, such as hardness, which would be expected to affect polishing. Pogo and Diacomp contain diamond abrasives, while Jiffy and ComposiPro brush have silicon abrasives, and Sof-Lex and Enamelize have aluminum oxide abrasives.

CONCLUSION

Within the limitations of this study, the null hypotheses that there would be no difference in surface roughness or gloss between the polished resin composites or between the different polishing systems when used on the same composites were rejected. The microfill (Durafill), nanofill (Supreme), and minifill (Esthet-X) resin composites showed smoother and glossier surfaces than the minifill hybrid (Z100 and Z250). The nanofill and minifill composites presented surface roughness comparable to a microfill, independent of the polishing system used. The two minifill hybrid composites (Z100 and Z250) showed the roughest surfaces. The nanofill and minifill composites showed gloss that was comparable to a microfill when polished with a one-step system (Pogo) and two three-step systems (Sof-Lex and Jiffy). The one-step system (Pogo) produced better surface quality in terms of gloss and roughness than the multiple-step systems for all the composites evaluated.

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