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Surface Roughness and Gloss of Actual Composites as Polished With Different Polishing Systems

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Clinical Relevance

The choice of polishing system should take into consideration the type of composite used. For actual commercial composites, multistep systems produce lower surface roughness and higher gloss than the one-step system.

SUMMARY

Objective: This in vitro study evaluated the effect of polishing with different polishing systems on the surface roughness and gloss of commercial composites. Methods: One hundred disk-shaped specimens (10 mm in diameter × 2 mm thick) were made with Filtek P-90, Filtek Z350 XT, Opallis, and Grandio. The specimens were manually finished with #400 sandpaper and polished by a single operator using three multistep systems (Superfix, Diamond Pro, and Sof-lex), one two-step system (Polidores DFL), and one one-step system (Enhance), following the manufacturer's instructions. The average surface roughness (μm) was measured with a surface profilometer (TR 200 Surface Roughness Tester), and gloss was measured using a small-area glossmeter (Novo-Curve, Rhopoint Instrumentation, East Sussex, UK). Data were analyzed by two-way analysis of variance and Tukey's test (α=0.05). Results: Statistically significant differences in surface roughness were identified by varying the polishing systems ($p<0.0001$) and by the interaction between polishing system and composite ($p<0.0001$). Pairwise comparisons revealed higher surface roughness for Grandio when polished with Sof-Lex and Filtek Z250 and Opallis when polished with Enhance. Gloss was influenced by the composites ($p<0.0001$), the polishing systems ($p<0.0001$), and the interaction between them ($p<0.0001$). The one-step system, Enhance, produced the lowest gloss for all composites. Conclusions: Surface roughness and gloss were affected by composites and polishing systems. The inter-

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action between both also influenced these surface characteristics, meaning that a single polishing system will not behave similarly for all composites. The multistep systems produced higher gloss, while the one-step system produced the highest surface roughness and the lowest gloss of all.

INTRODUCTION

Dental composites have evolved throughout the years, undergoing modifications in composition and properties. The first composites were constituted by hard and large filler particles and were hard to polish. The refinement of the milling and grinding techniques resulted in the microhybrid composites, constituted of particles that vary from 0.4 to 1.0 μm in size and by nanoparticles (ranging from 1 to 100 nm). These composites are considered universal composites and are used for both anterior and posterior restorations.[1] Most recently, nanofill composites were introduced as another category of universal composite, constituted exclusively of nanoscale-sized filler particles.[2,3] Studies involving such composites have reported excellent polishability as well as superior polish retention.[2,4,5]

Recently, dental composites with new monomers have been introduced. One of them, the epoxy-based silorane system, aims to reduce the shrinkage stress resulting from the cure of traditional dimethacrylate-based composites.[6] The silorane-based composite has shown promising results of low shrinkage stress generation and water sorption and good mechanical properties.[6-8]

The surface quality of the restorations influences their clinical performance and affects aspects such as anatomic form, shade, gloss, and the surface roughness[9] with resulting bacterial accumulation. In fact, a threshold surface roughness of 0.2 μm or greater has been suggested as enhancing bacterial accumulation.[10,11] Also, the surface quality influences the speed of water diffusion into the bulk of the material and its subsequent degradation and affects the wear resistance resulting from toothbrushing or occlusal contact from mastication.[9]

Gloss plays a rather important role in esthetic dental restorations since differences in gloss between the restoration and the surrounding enamel are easily detected by the human eye, even when there is color match between the restoration and the tooth structure.[12] Also, a glossy enamel surface is maintained when submitted to mechanical wear, while the glossy surface of composites, which are typically lower initially, tend to further decrease under the same mechanical challenge over time.[12]

Several authors have suggested that the smoothest surface is achieved using a Mylar strip to cover the composite surface during curing.[5,13-18] However, the smooth surface produced by the contact with a Mylar strip results from the formation of a resin-rich superficial layer, less hard in comparison with the material in the bulk but near the surface, despite the inhibition of the contact of the composite surface with oxygen during polymerization by the strip.[14,19] This superficial layer would be more susceptible to changes of the restoration shade when in contact with staining food and beverages and therefore should always be removed by finishing and polishing procedures.[14,16]

Finishing refers to excess removal and gross contouring of the restoration and is usually performed using tungsten carbide finishing burs or diamonds. Polishing, on the other hand, refers to the reduction of surface roughness and removal of scratches generated by the finishing instruments.[16] Polishing also aims to prevent bacterial adhesion, which begins by the adhesion of a salivary pellicle layer on the surface of the tooth or restoration[20] and has been proven to be favored by rough surfaces.[11]

An immense variety of finishing and polishing systems is available in the dental market, involving multistep disks, fine and superfine diamond burs, abrasive disks, and diamond- and silicon-impregnated soft rubber cups.[5,21] Factors such as the flexibility of the back material in which the abrasive is embedded, the hardness of the abrasive, and its grit size all influence the ability of the polishing systems to produce a smooth surface.[13]

However, the polishing performance cannot be credited solely to the polishers. The interaction between polishing systems and composites on surface roughness has been shown to be significant in some studies,[15,17,22] indicating that the systems behave differently depending on the composite polished. This impairs one's ability to choose a single polishing system for all composites. In this sense, Berger and others[23] suggested the use of the polishing system from the same manufacturer as the composite as a safe option since these have produced good results in comparison with other polishers.

Nevertheless, discrepancies in literature reports and the continuous introduction of new polishing systems reveal the demand for new research on the topic. Therefore, the aim of our study was to evaluate

Table 1: *Composites Used in the Study*

Composite	Manufacturer	Shade	Organic Matrix	Filler	Light Curing Time (Seconds)	Batch Number
Filtek P90 (microhybrid)	3M/ESPE, St. Paul, MN, USA	A2	Silorane	Silica and zirconia—average size of 0.6 μm; 60% in vol., 82% in wt	20	N194550
Filtek Z350 XT (nanofill)	3M/ESPE	A2	BisGMA, BisEMA, UDMA, TEGDMA	Silica and zirconia (clusters of 0.6-1.4 μm—individual particle size of 5-20 nm); 59.5% in vol., 73.2% in wt[a]	20	N186543
Opallis (microhybrid)	FGM Produtos Odontológicos, Joinville, SC, Brazil	EA2	BisGMA, BisEMA, TEGDMA, UDMA	Silanized barium-aluminum-silicate glass and nanoparticles of silica dioxide (40 nm to 3 μm—average size of 0.5μm); 57%-58% in vol., 78.5%-79.8% in wt	20	031011
Grandio (nanohybrid)	Voco, Cuxhaven, Germany	A2		~84%-85% filler in wt[b]	20	1139078

[a] *Rodrigues Junior and others.*[24]
[b] *Beun and others.*[25]

the surface roughness and gloss produced by different polishing systems on different commercial composites, testing the null hypothesis that there would be no difference in surface roughness and gloss, regardless of the composite or polishing system used.

METHODS AND MATERIALS

One hundred disk-shaped specimens (10 mm in diameter × 2 mm thick) were made using the composites described in Table 1. The specimens were produced by packing the composite into a stainless-steel mold. A Mylar strip was placed over the surface of the uncured specimen and pressed against it with a glass plate in order to extrude the excess material. The specimens were light cured for the time recommended by the manufacturers (Table 1), using an LED light-curing unit (Ultraled, series no. 1010179, Dabi Atlante, Ribeirão Preto, SP, Brazil). The light irradiance was monitored with an LED radiometer (ECEL, series no. 000165, Ribeirão Preto) before usage and ranged between 653 and 663 mW/cm^2.

The specimens were removed from the mold immediately after light curing and were stored in distilled water at room temperature for 24 hours in the dark. After the storage period, one side of each specimen was finished on #400 carburundum paper. The specimens were then randomly allocated to each of the five polishing systems (Table 2).

Each polishing point was used only once with a low-speed hand piece (KaVo, Joinville, SC, Brazil). The polishing procedure was performed by a single operator, according to the manufacturer's instructions:

1. Diamond Pro (multistep system)
   - Step 1—Coarse grit: coarse disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 2—Medium grit: medium disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 3—Fine grit: fine disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 4—Superfine grit: superfine disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
2. Superfix (multistep system)
   - Step 1—Coarse grit: coarse disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 2—Medium grit: medium disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 3—Fine grit: fine disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 4—Superfine grit: superfine disk dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds

Table 2: *Polishing Systems*

Polishing System	Steps	Manufacturer	Composition	Approximate Average Particle Size (μm)[a]	Batch Number
Diamond Pro	4	FGM Produtos Odontológicos, Joinville, SC, Brazil	Polyester (PET), adhesive, abrasive, rubber silicone	Dark blue = 180 Medium blue = 100 Light blue = 25 White = 15	041111
Superfix	4	TDV Dental Ltda., Pomerode, SC, Brazil	Polyethylene terephthalate, aluminum oxide, synthetic rubber resin, polyvinyl chloride, metal, water-based pigments	Dark green = 200 Light green = 100 Yellow = 30 White = 20	0812/1011
Polidores DFL	2	DFL, Rio de Janeiro, RJ, Brazil		Yellow = 40 White = 12	—
Enhance	1	Dentsply, Petrópolis, RJ, Brazil	Tripolymer (methyl methacrylate-butadiene-styrene), silanized pirolitic sílica, uretane dimethacrylate, canforoquinone, N-methyl dietanolamine, aluminum oxide	30	—
Sof-Lex Pop On	3[b]	3M/ESPE, Sumaré, SP, Brazil	Polyester and aluminum oxide	Dark orange = 30 Light orange = 30 Yellow = 5	1123800210

[a] *From scanning electron microscope image analysis.*
[b] *The coarse grit of Sof-Lex Pop On was not used because it produced a coarse, uneven surface.*

3. Polidores DFL (two-step system)
   - Step 1—Coarse grit: coarse disk (yellow) dry for 20 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 2—Fine grit: fine disk (white) dry for 20 seconds, rinse and dry with water/air syringe for 6 seconds
4. Enhance (one-step system)
   - Step 1—Light pressure for 40 seconds, rinse and dry with water/air syringe for 6 seconds
5. Sof-Lex Pop On (multistep system):
   - Step 1—Medium grit: medium disk (orange) dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 2—Fine grit: fine disk (light orange) dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds
   - Step 3—Superfine grit: superfine disk (yellow) dry for 15 seconds, rinse and dry with water/air syringe for 6 seconds

The average surface roughness (Ra, μm) was measured with a surface profilometer (TR 200 Surface Roughness Tester, TIME Group, Pittsburgh, PA, USA) using a tracing length of 2 mm and a cutoff of 0.8 mm to maximize filtration of surface waviness. Three tracings were made on each specimen in a wheel spoke arrangement, and the average was calculated.

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-degree geometry. The glossmeter was calibrated each time against the supplied black, reflective standard. Gloss was expressed in gloss units. A jig was designed to place the specimen over the aperture in the same place each time, and four measurements were made by rotating the specimen 90 degrees around its center. The average of the four measurements was determined. Initial gloss measurements were made of the surface created with #400 paper, but these were always essentially zero. Surface roughness and maximum gloss data were tabulated and analyzed by two-way analysis of variance and Tukey's multiple comparison test (α=0.05).

The polishing systems were gold sputter coated for 45 seconds in a Denton Vacuum Desk II (Denton Vacuum Inc, Moorestown, NJ, USA) at a current of 45 mA and a vacuum of 50 mTorr. The specimens were observed with scanning electron microscopy (SEM) using secondary electron mode (Jeol, JSM-5910, Jeol Ltd, Tokyo, Japan). SEM micrographs at 200× and 500× were made of the polishing systems, and an estimate of the average particle size was obtained by comparing the size of several of the particles to the measurement bar in the SEM images.

RESULTS

The results of surface roughness of the composites polished with the different polishing systems are presented in Table 3. Two-way analysis of variance

Table 3: *Average Surface Roughness Values in μm and Standard Deviation (±SD) for the Composites and Polishing Systems Evaluated*

Composite	Polishing System				
	Diamond Pro	Superfix	Polidores DFL	Enhance	Sof-Lex
Grandio	0.229 ± 0.046 Aa	0.211 ± 0.035 Aa	0.387 ± 0.044 Aa	0.444 ± 0.260 Aa	0.693 ± 0.293 Ba
Filtek P90	0.422 ± 0.076 Aa	0.486 ± 0.217 Aa	0.412 ± 0.171 Aa	0.686 ± 0.243 Aa	0.347 ± 0.101 Aa
Filtek Z350	0.298 ± 0.068 Aa	0.306 ± 0.104 Aa	0.587 ± 0.236 Aa	0.705 ± 0.162 Ba	0.619 ± 0.131 Aa
Opallis	0.285 ± 0.146 Aa	0.268 ± 0.054 Aa	0.388 ± 0.113 Aa	0.759 ± 0.067 Ba	0.458 ± 0.097 Aa

Capital letters refer to statistical groupings in the row, and small letters refer to statistical groupings in the column. Different letters indicate statistical differences between groups (p<0.05).

revealed that there was no significant difference in surface roughness between the composites evaluated (p=0.077). On the other hand, statistically significant differences were found between polishing systems (p<0.0001) and from the interaction between composites and polishing systems (p=0.001). The surface roughness produced by the polishing systems for each composite was ranked as follows: for Grandio → Diamond Pro = Superfix = Polidores DFL = Enhance < Sof-Lex Pop On; for Filtek P90 → Diamond Pro = Superfix = Polidores DFL = Enhance = Sof-Lex Pop On; and for Filtek Z350 and Opallis → Diamond Pro = Superfix = Polidores DFL = Sof-Lex Pop On < Enhance (Figure 1). Pairwise multiple comparisons showed significantly higher surface roughness for Grandio when polished with the Sof-Lex Pop On system and of Filtek Z350 and Opallis when polished with the Enhance polishing system (Table 3).

The results of gloss are presented in Table 4. Two-way analysis of variance identified statistically significant differences in gloss between the composites (p<0.0001) and the polishing systems (p<0.0001) and from the interaction between composites and polishing systems (p<0.0001). The gloss produced by the polishing systems for each composite was ranked as follows: for Grandio and Filtek P90 → (Sof-Lex Pop On = Diamond Pro = Superfix) > (Polidores DFL = Enhance) and for Filtek Z350 and Opallis (Sof-Lex Pop On = Polidores DFL = Superfix) > (Diamond Pro = Enhance) (Table 4).

Figures 3 and 4 present the abrasive surface of the polishing systems used in the study. The estimated average of the abrasive particle size, based on the magnitude bar of the micrographs, is presented in Table 2. All the flexible abrasive disk systems used were constituted by aluminum oxide abrasive particles with different average size and shape, as revealed by the SEM micrographs (Figures 3A-H and 4A-C). Superfix and Diamond Pro presented irregular-shaped particles in the coarse disk ranging from 180 to 200 μm. The following grits of Diamond Pro presented round-shaped abrasive particles, similar to Sof-Lex though bigger. The medium, fine, and superfine disks of Superfix contained irregular filler particles, close to the average size of the disks of Diamond Pro. Micrographs of Enhance revealed a relatively flat surface covered by approximately 30-μm-sized abrasive particles (Figure 4D), while the

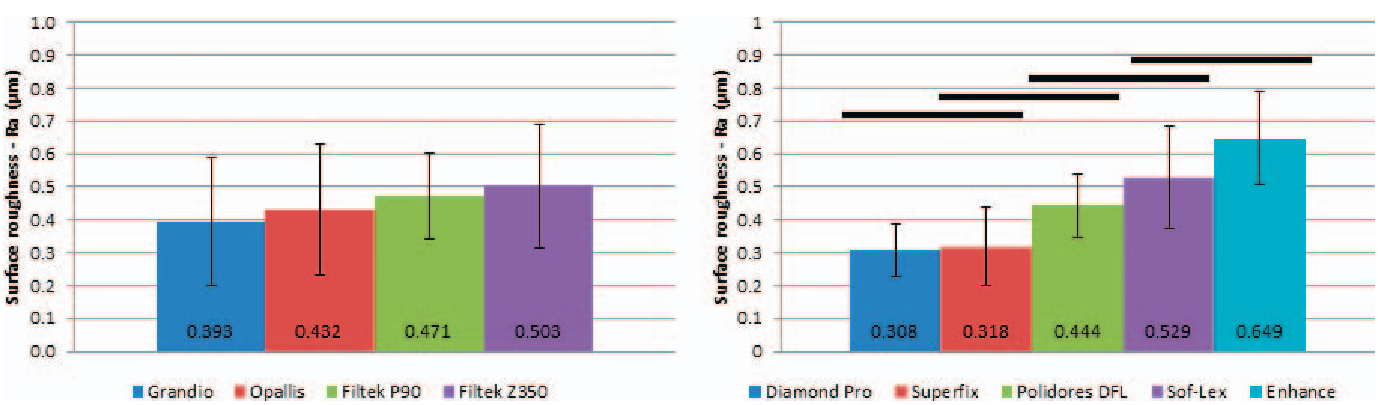

Figure 1. *Surface roughness did not differ significantly for the composites evaluated (left). Surface roughness produced by the different polishing systems varied (right). Black bars indicate that there is no statistically significant difference between groups.*

Table 4: *Average Gloss Values and Standard Deviation (±SD) for the Composites and Polishing Systems Evaluated*

Composite	Polishing System				
	Diamond Pro	Superfix	Polidores DFL	Enhance	Sof-Lex
Grandio	29.40 ± 6.8 Aa	42.66 ± 3.94 Ab	22.74 ± 5.49 Bb	22.74 ± 9.98 Ba	44.44 ± 3.43 Aa
Filtek P90	48.26 ± 10.91 Aa	47.46 ± 18.89 Ab	34.7 ± 11.20 Ba	33.36 ± 14.79 Ba	56.12 ± 3.49 Aa
Filtek Z350	31.32 ± 4.27 Ba	41.32 ± 4.82 Ab	52.4 ± 10.12 Aa	14.02 ± 4.82 Ba	59 ± 6.12 Aa
Opallis	36.20 ± 10.04 Ba	68.22 ± 3.26 Aa	48.08 ± 7.47 Aa	27.44 ± 4.18 Ba	50.36 ± 8.83 Aa

Capital letters refer to statistical groupings in the row, and small letters refer to statistical groupings in the column. Different letters indicate statistical differences between groups ($p<0.05$).

two-step Polidores DFL showed irregular particles of about 40 and 12 μm in the coarse and the fine disks, respectively (Figure 4E,F).

DISCUSSION

Most restorative procedures involving composites involve curing against a polyester or metallic strip that aids in the insertion of the composite layers. Regardless of the evidence that the surface in contact with the strip is usually smoother, gross contouring is required to better define the anatomy, and the scratch reduction and smoothening during initial polishing is required to achieve a highly polished, light-reflective, enamel-like surface.[21] An adequate surface polishing contributes to the restoration longevity by reducing the surface roughness, stain accumulation, and gingival inflammation and minimizing wear.[23] Also, polishing should produce high gloss in order to mimic the natural tooth structure in esthetic restorations, as increasingly demanded by patients.[26]

Proper polishing involves a complex combination of factors related to the restorative material, the restoration anatomy, the polishing system, and the operator's ability. Manual polishing was chosen in this study because it better simulates the clinical conditions. Jones and others[27], though, have shown that operator-dependent factors, such as force, speed, and application time, vary widely from one operator to another. Also, Heintze and others[28] revealed that surface roughness and gloss strongly rely on force and polishing time. Based on their results, composites achieve roughness values lower than the 0.2-μm threshold only after 60 seconds of polishing. Time was the only operator-dependent variable controlled in this study, achieved by using a digital chronometer held by a second person, and reached 60 seconds for only two polishing systems (Diamond Pro and Superfix). Even so, the roughness values in these groups were still higher than 0.2 μm, varying from 0.211 to 0.486 μm.

Jung and others[29] demonstrated the influence of the operator's experience on polishing. Studies conducted to simulate clinical polishing procedures rely on the operator's manual ability and might result in high variability. Other studies, in contrast, reveal no connection between the quality of the surface polishing and the operator's clinical

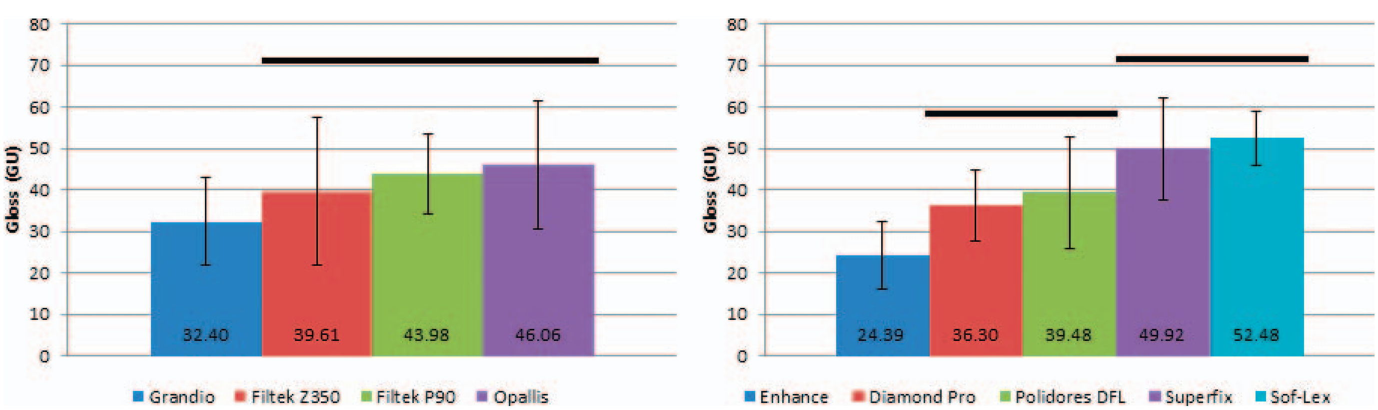

Figure 2. *Gloss of the composites evaluated (left). Gloss produced by the polishing systems studied (right). Black bars indicate that there is no statistically significant difference between groups.*

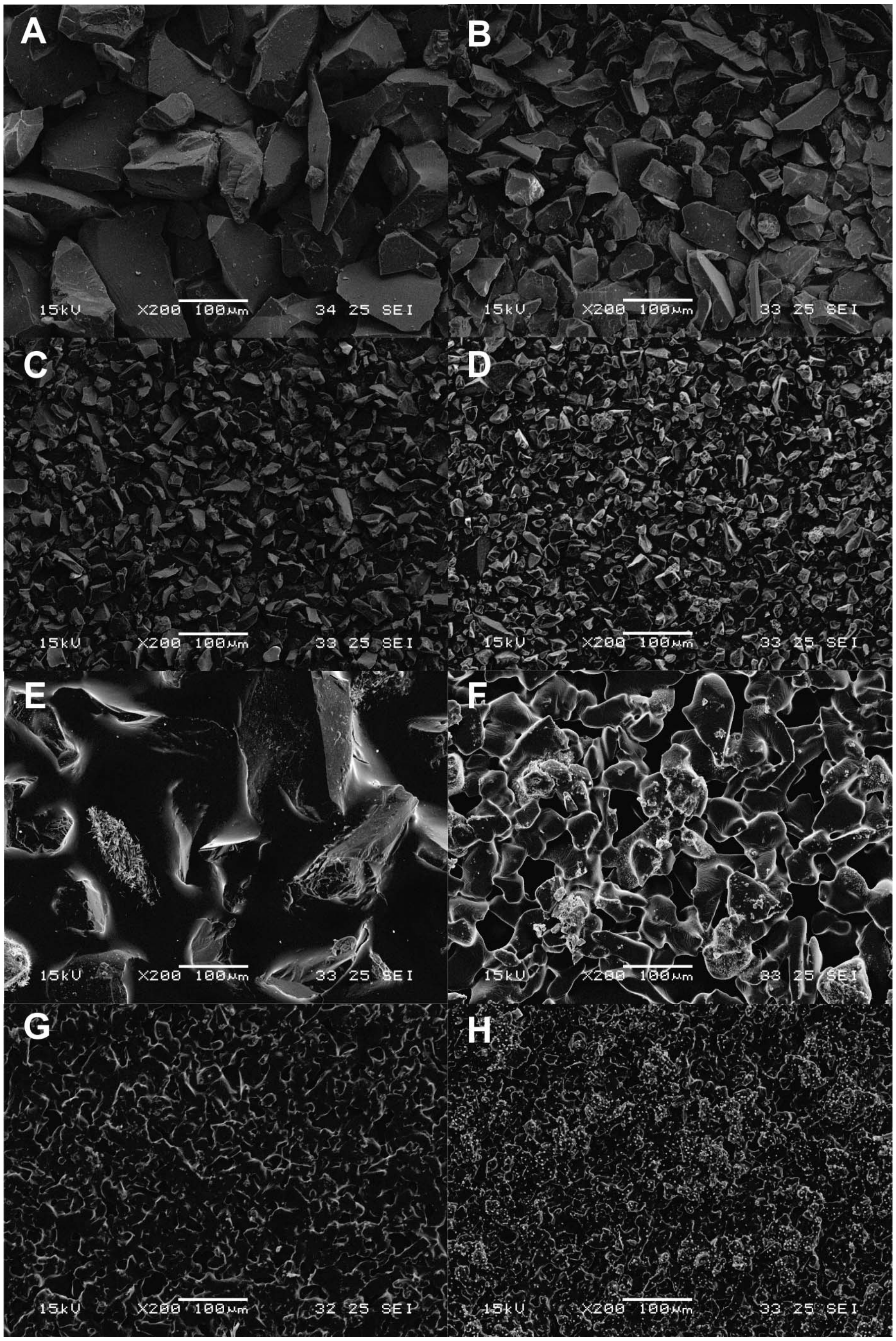

Figure 3. *Micrographs of the polishing systems (200×). (A): Superfix coarse. (B): Superfix medium. (C): Superfix fine. (D): Superfix superfine. (E): Diamond Pro coarse. (F): Diamond Pro medium. (G): Diamond Pro fine. (H): Diamond Pro superfine.*

experience. Zimmerli and others[30] observed no significant differences in Ra values produced by operators of different age and experience levels. However, it is worth noting that the less experienced operator had, at least, 6 years of experience in dental practice. In the present study, a single third-year graduate student performed all the polishing procedures, using the different polishing systems.

The operator's ability to handle the polishing procedure also depends on the flexibility of the backing material to which the abrasive is dispersed[13,15,16] since it represents a mechanism for compensating the force applied during polishing.[28] The one-step Enhance system and the two-step Polidores DFL system are rubber-based instruments, meaning that the abrasive particles are dispersed in a rubber-like elastic matrix, constituted

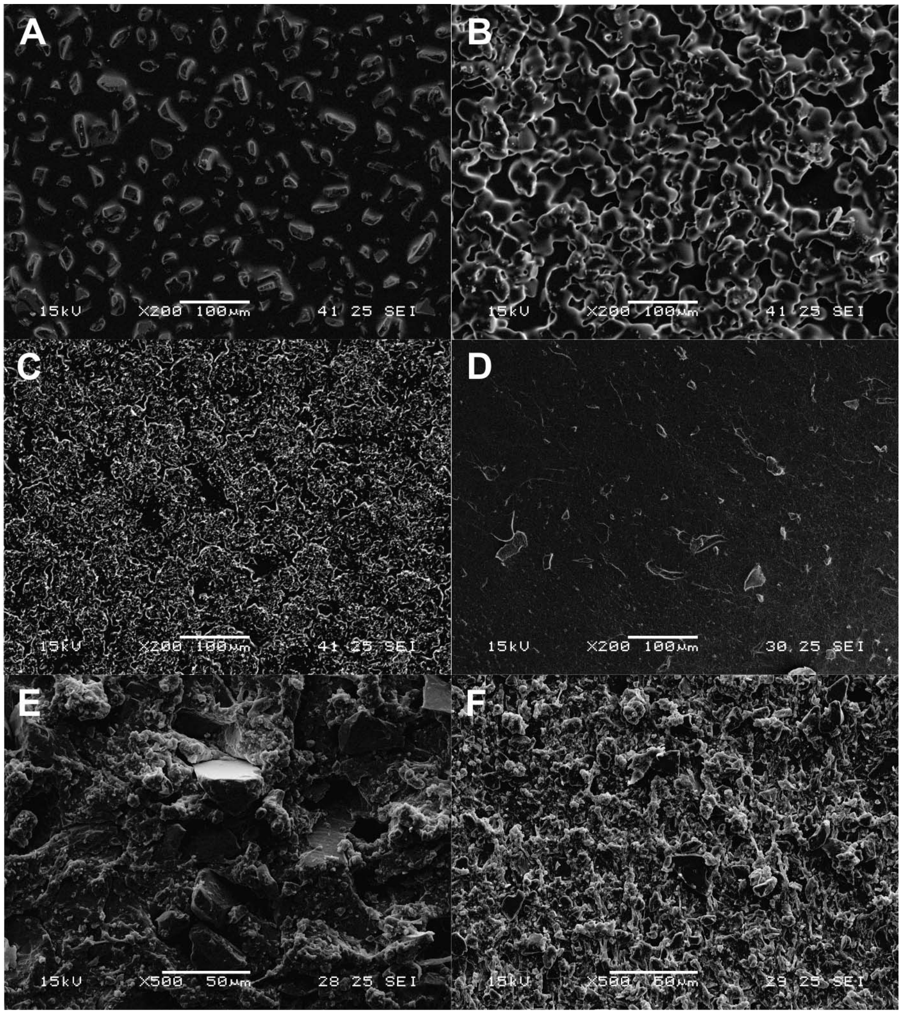

Figure 4. *Micrographs of the polishing systems (200× and 500×). (A): Sof-Lex medium. (B): Sof-Lex fine. (C): Sof-Lex superfine. (D): Enhance. (E): Polidores DFL coarse. (F): Polidores DFL fine.*

by a synthetic elastic polymer (Enhance) or silicon (Polidores DFL).[21] In this sense, these systems are stiffer and do not deflect with the applied force as easily as the flexible disks do.[28]

On the other hand, these systems are produced in variable shapes that include disks, cups, and points, helping to polish curved surfaces with the adequate anatomic contour of the tooth.[15] Those employed in this study were disk shaped, so the flat surface of the specimens could be uniformly polished regardless of the polishing system used. While the two-step system produced similar roughness results to the two multistep systems, the one-step system produced the highest surface roughness with Filtek Z350 and Opallis (Table 3; Figure 1). Both systems were used for 40 seconds, which was the least polishing time in the study. Therefore, it is likely that the difference between the one-step and the two-step systems might have been caused by a sequential decreasing particle size in the latter, leading to results similar to the multistep systems. For instance, the average particle size depicted in micrographs of the two-step system was about 40 μm for the coarse grit and 12 μm for the fine grit (Table 2). Other studies, though, have employed Enhance (30 μm average particle size) as a pretreatment for PoGo (about 10-15 μm average particle size, according to da Costa and others[5]), considering it, therefore, as a two-step system, and have obtained lower surface roughness than other polishing procedures[31] and even similar to the one produced by the Mylar strip, depending on the composite polished.[15]

There was no significant difference among the multistep flexible disk systems for most composites. The exception was the Sof-Lex Pop On system, which produced the highest surface roughness on Grandio (Table 3). This system differs from the other disk systems by having more flexible disks that have a metallic center through which they are attached to the mandrel and that demand tilting during polishing of a flat surface. However, the high flexibility of the disk might produce uneven surfaces when the applied force is high. This effect might have been higher for Grandio, which presented significantly higher surface roughness after polishing with this system (Table 3). Although in absolute terms Diamond Pro and Superfix produced lower surface roughness comparing to Sof-Lex Pop On, the difference was not significant, and the general surface roughness results with multistep systems reinforce the idea that sequential application of decreasing particle size disks is a desirable approach to produce a smooth surface in restorations.

Wear, according to Turssi and others,[32] could be defined as "the progressive loss of substance resulting from a mechanical interaction between two contacting surfaces, which are in relative motion." In this sense, the polishing procedure of dental restorations is an intentional, selective, and controlled wear of the restorative material surface, produced mostly through two-body abrasion,[21,32] aiming to attain a smooth, glossy surface. As such, polishing occurs as a function of a tribological process that involves structural aspects (eg, the materials in contact and contact geometry), interaction conditions (eg, the loads and the contact duration), and environmental conditions (eg, the surface chemistry, topography, and temperature).[32]

Aspects related to the composites that might affect polishing are the hardness of the filler relative to the abrasive, the filler content, shape, size and orientation, the filler hardness relative to the matrix, the degree of conversion of the matrix, and the stability of the silane coupling between the fillers and the resin matrix.[13,32] Among all these factors, the polishability and the surface roughness of composites has been shown as a function of the filler particle size,[1,5,33] with larger particles increasing surface roughness. Marghalani[33] also identified a significant influence of the filler shape on surface roughness, suggesting that irregular-shaped particles produce rougher surfaces. Based on our results, one could assume that compositional differences between the composites tested significantly influenced the surface roughness results (Table 3).

It has been shown that the mechanical behavior of composites is strongly dependent on the filler packing fraction, which in turn varies as a function of the average filler particle size.[34] The filler wt% of the composites was based on information provided by the manufacturers, except that for Filtek Z350 and Grandio, which was determined elsewhere through thermogravimetric analysis.[24,25] Grandio presented slightly lower filler wt% (84%) than that reported by the manufacturer (87%),[25] while Filtek Z350 presented up to 73% filler by weight.[24] According to Sabbagh and others,[35] these data discrepancies should be viewed with caution, as they might result from weighing the particles after the silane treatment. The filler percentage reported ranged from 73% to 84% to 85%, hence an 11% to 12% difference. Some studies have suggested that the microstructural arrangement of the filler plays an important role in the mechanical behavior of the composites regardless of the filler wt%.[36]

With the exception of the silorane-based composite Filtek P90, meant for posterior restorations, the other composites studied also contain nanosized filler particles that range from 20 to 40 nm and tend to fill the spaces in between the larger particles, therefore protecting to some extent the soft matrix from abrasion.[16] This particle size distribution could explain the lack of substantial difference in surface roughness for these composites and suggests a homogeneous behavior of these materials, closer to the microfill and nanofill composites, in spite of the presence of large particles.[5]

Based on the clustered arrangement of the nanofill particles in Filtek Z350, a wear mechanism has been suggested in which the clusters break off instead of plucking out the entire particle.[2,4,17] This mechanism is believed to be responsible for the polishability and polish retention of this composite.[2] Other composites containing nanosized filler particles, such as Opallis and Grandio, do not seem to present this mechanism. Janus and others[17] classify composites that contain both macro- and nanosized filler particles as nanofilled hybrid composites and reveal that these materials present voids from plucked-out filler particles after finishing. This would be consistent with the fact that the larger particles in Opallis and Grandio are cohesive particles and not clusters of smaller particles, as found in Z350, and therefore are not capable of breaking up but rather are plucked from the surface, leaving voids. Surface roughness of the silorane-based composite was comparable to the other dimethacrylate-based composites (Table 3; Figure 1). This was consistent with its similar filler composition to the other microhybrid composite, Opallis.

Gloss is an optical phenomenon defined by the amount of light rays that are reflected by a material surface at nearly the same angle as they hit the surface.[5,37] Based on this, one would expect gloss to present an inverse relationship with the surface roughness since the higher the surface roughness, the higher the degree of diffuse reflection of light, affecting gloss negatively.[19,26,34] This relationship, though, has not been so obvious in the literature.[26,28] Heintze and others[28] observed that the negative correlation between surface roughness and gloss varies during the polishing procedure and is not necessarily higher at the end of the procedure or similar for all composites.

Light reflectance is influenced by microstructural features of the material, namely, the mean size, shape, and index of refraction of the filler, and the viscosity and index of refraction of the matrix and the homogeneity of the filler-matrix complex.[5,12] According to Lefever and others,[12] the higher the filler size and the lower the homogeneity of the filler-matrix complex, the lower the light reflectivity of the composite material. Opallis and Filtek P90 presented average filler sizes of 0.5 and 0.6 μm, respectively, which were close to the size of the nanofill clusters in Filtek Z350. Grandio's filler phase, on the other hand, is constituted by irregular-shaped particles,[25] which has been shown to impair the production of a smooth, reflective surface compared with round-shaped filler particles.[34]

Gloss results revealed a significant interaction between composite and polishing system. Pairwise comparison revealed that there was no significant difference between Grandio and Filtek P90 when polished with Diamond Pro, Superfix, and Sof-Lex Pop On. A similar behavior was observed when Filtek Z350 and Opallis where polished with Superfix, Polidores DFL, and Sof-Lex Pop On. In absolute terms, the highest overall gloss was produced by Opallis when polished by Superfix; however, its gloss performance was lowered when polished with Diamond Pro and Enhance, reinforcing the trend of variability of the surface properties of actual composites with variation of the polishing systems. Among the multistep systems, Sof-Lex Pop On and Superfix were able to produce the highest gloss in all composites (Table 4). Low gloss values were produced by the one-step system Enhance for all composites (Table 4), which might be explained by the lowest polishing time used with this system.[28,37] Similar ranking was observed when Grandio and Filtek P90 were polished with Polidores DFL and Enhance and Filtek Z350 and Opallis were polished with Diamond Pro.

Differences in abrasive particle sizes, shapes, and distribution have been pointed out as influencing surface roughness and gloss[5] and could be observed through the micrographs (Figures 3 and 4). In absolute terms, the one-step system Enhance, which produced the highest roughness and the lowest gloss, presented the largest abrasive particles dispersed into a urethane elastic matrix.[21] Abrasives from the superfine disks of Diamond Pro and Superfix averaged 15 and 20 μm, respectively, while Sof-Lex showed the smallest abrasive particle (approximately 5 μm). One's expectation was that the smoother and glossier surfaces would be produced by the polisher with the smallest abrasive particle,[5] and Sof-Lex produced the glossiest surface, followed by Superfix, which also produced high gloss, similar to Sof-Lex, despite differences in abrasive grain size and shape (Figures 3 and 4). It has been stated that, besides size and shape of the abrasive, its binding to the matrix and the type and flexibility of the matrix might also influence the polishing efficiency.[5]

CONCLUSION

The null hypothesis was rejected since surface roughness and gloss were affected by the composites and polishing systems studied. In addition, a single polishing system did not produce equivalent surface characteristics for all composites. Although each polishing system produced similar roughness on the four composites evaluated, there were some differences in relation to surface gloss. The multistep systems produced the highest gloss on Grandio and Filtek P90 but not on Filtek Z350 and Opallis.

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Conflict of Interest

The Authors of this manuscript certify that they have no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

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