Surface Roughness and Staining Susceptibility of Composite Resins after Finishing and Polishing

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ABSTRACT

Purpose: The study aims to investigate the influence of filler size and finishing systems on the surface roughness and staining of three composite resins.

Methods: Three composites, classified according to their filler size, were selected: Filtek Supreme Plus/nanofill (3M ESPE, St. Paul, MN, USA), Esthet-X/minifill (Dentsply Caulk, Milford, DE, USA), and Renamel Microfill/microfill (Cosmedent Inc., Chicago, IL, USA). Composite specimens were made in stainless steel split molds and polished with Sof-Lex (3M ESPE), Enhance + PoGo (Dentsply Caulk), or FlexiDiscs + Enamelize (Cosmedent Inc.). Finishing systems were used according to the manufacturers' instructions and polished surfaces were evaluated with a profilometer and then immersed in 2% methylene blue for 24 hours. Specimens were then prepared for spectrophotometric analysis and results were statistically analyzed by two-way analysis of variance and Tukey's test.

Results: No significant differences in surface roughness among the composites were found when the surfaces were treated with Enhance + PoGo. In addition, no differences were observed when the Filtek Supreme Plus composite was submitted to surface staining evaluation. In general, the composites polished with the finishing systems from the same company demonstrated lower surface roughness and staining.

Conclusion: The results of this study recommend that composite resins could be finished and polished with finishing systems supplied by the composite's manufacturer. The surface roughness and staining of composite resins were not influenced solely by filler size.

CLINICAL SIGNIFICANCE

Dentists should finish and polish composite resin with the polishing agent supplied by the same manufacturer. The smallest filler size does not necessarily result in a low surface roughness and staining susceptibility.

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INTRODUCTION

The addition of filler to the resin matrix of restorative materials increases the strength, the toughness under strain, and the wear resistance of composites, all of which are fundamental to the durability of composite restorations.[1–4] The restorative composite resins are generally classified according to the size, content, and filler type, such as barium-aluminum-silicate, lithium boro-barium glass, ytterbium trifluoride, quartz, zirconia, and silicon dioxide. Fillers of greater than one micron in size are referred to as macrofills and fillers of less than one micron are referred to as microfills. New classifications of restorative composites include the nanoparticles and a mixture of different particle sizes known as a hybrid, microhybrid, or minifill.[5–7]

Fillers are irregular or spherical in shape, depending on the mode of manufacture.[1,8–10] Studies have shown that the filler size and shape can influence the surface roughness of dental composites.[11] The differences in surface topography among composite resins tested in such studies were attributed to differences in their interparticle spacing and their filler particle size. Thus, the composite resin fillers appear to play an intrinsic role in how well a composite finishes.[10,12,13]

This study evaluated the surface roughness and staining susceptibility after finishing and polishing procedures of the three composite resins containing different filler particle sizes. In addition, the composite surfaces were investigated by scanning electron microscope (SEM) observations. The hypothesis tested was that both surface roughness and staining susceptibility are influenced by increasing filler size.

MATERIALS AND METHODS

Three commercial resin composites were selected for this study, with different filler particle sizes: Filtek Supreme Plus nanofill composite (3M ESPE, St. Paul, MN, USA), Renamel Microfill composite (Cosmedent Inc., Chicago, IL, USA), and Esthet-X minifill composite (Dentsply Caulk, Milford, DE, USA). The respective finishing and polishing systems were also used: Sof-Lex Finishing and Polishing Discs (3M ESPE), FlexiDiscs and Enamelize Polishing Paste (Cosmedent Inc.), and Enhance Finishing & PoGo Polishing Systems (Dentsply Caulk). Compositions and lot numbers of the composite resins and finishing and polishing systems are listed in Tables 1 and 2, respectively.

Forty cylindrical specimens, 3-mm thick and 5-mm in diameter, of each resin composite were

TABLE 1. COMPOSITION OF THE COMPOSITE RESINS TESTED IN THIS STUDY.

Material	Composition	Filler volume (%)	Filler weight (%)	Particle size (µm)	Batch number
Filtek Supreme Plus	Bis-EMA, Bis-GMA, TEGDMA, nonagglomerated/non-aggregated 20 nm nanosilica filler, agglomerated zirconia/silica nanocluster	59.5	82	0.6–1.4	6AL
Renamel Microfill	Diurethane dimethacrylate, Butanediol dimethacrylate, Multifunctional methacrylate Ester, pyrogenic silicic acid filler	59	60	0.02–0.04	053819K
Esthet-X	Urethane modified Bis-GMA dimethacrylate, photoinitiators, stabilizers, barium boron fluoroalumino silicate glass, amorphous silica	60	77	0.04–1.0	0405191

TABLE 2. COMPOSITIONS OF FINISHING AND POLISHING AGENTS.

Finishing and polishing material	Type	Composition	Batch Number
Sof-Lex XT Polishing Discs	Discs	Coarse, medium fine, superfine aluminium oxide disc	70-2005-2387-9
FlexiDisc and Enamelize	Discs and paste	FlexiDisc: Aluminum oxide Enamelize: Paste of aluminum oxide	88409/061213
Enhance/PoGo	Discs	Enhance: Aluminum oxide PoGo: Fine diamond powder	534756/469541

prepared in stainless steel split molds. The composites were inserted into the mold incrementally using a composite placement instrument (Suprafill Plastic Filling, Duflex—SS White, Juiz de Fora, Minas Gerais, Brazil). Two layers were enough to fill the cavity and each increment was cured for 40 seconds with a visible light-curing unit Demetron Optilux 501 (Kerr Corp., Orange, CA, USA). The second layer was covered with a polyester Mylar strip (Dentsply Caulk), pressed with a glass slide (Glasstécnica Import Com. de Vidros Ltda., São Paulo, São Paulo, Brazil) and photo-cured.[14,15] All specimens were stored in distilled water at 37°C for 24 hours and the 40 specimens from each composite were randomly assigned to the four groups, corresponding to the control group and the three finishing/polishing systems. The control group comprised the specimens that were not submitted to finishing and polishing procedures and kept untreated. The specimens were finished and polished by a single investigator, according to the manufacturer's instructions. All composite resins were treated with the three polishing agents.

The paste and disc polishers were applied using a low-speed handpiece (Intramatic ES, Kavo do Brazil, Joinville, Santa Catarina, Brazil) for 30 seconds at a speed of 20,000 rpm. Sof-Lex Finishing and polishing discs (3M ESPE) were provided in four grits and used sequentially (from dark/coarse to light/superfine) with a mandrel to polish the surfaces. FlexiDiscs (Cosmedent Inc.) were also provided in four grits, with coarse to medium (blue), fine (yellow), and superfine (pink) grits, respectively. Flexible felt wheels (FlexiBuff, Cosmedent Inc.) were used after FlexiDiscs for the application of the Enamelize as a final polish. The Dentsply Caulk polishing system was comprised of the Enhance Finishing product, which is recommended to create a smooth defect-free surface, and PoGo, which was used with light pressure to polish the surface of composite.

After all specimens were polished, they were thoroughly rinsed with water and allowed to dry for 24 hours before measurement of the average surface roughness (Ra-µm). To measure the surface roughness of the specimens, a profilometer (Surfcorder SE 1700, Kosaka Corp., Tokyo, Japan) was used at a 0.05-mm/s speed, with a 2.5-mm length and 0.25-mm cutoff. Three measurements in different directions were recorded and the average surface roughness (Ra) was determined for each specimen. The Ra mean for each group was determined using the mean values of each specimen ($N = 10$).

After the profilometric examination, the spectrophotometric analysis was carried out with seven specimens per group, as three specimens per group were randomly assigned for use in SEM observations. The method used to quantify the dye uptake by the composite specimens was adapted from Reis and colleagues[13] and Cavalli and colleagues.[16] Seven specimens per group were immersed separately in 1 mL of 2% methylene blue solution at 37°C (315 SE, Fanem Ltda., São

TABLE 3. SURFACE ROUGHNESS AVERAGE (RA) IN μM (SD) PRODUCED BY THE FINISHING AND POLISHING INSTRUMENTS.

	FlexiDisc + Enamelize	Enhance + PoGo	Sof-Lex	Control group
Esthet-X	0.116 ± 0.014 Aab	0.09 ± 0.037 Aa	0.125 ± 0.03 Ab	0.093 ± 0.03 Aa
Filtek Supreme Plus	0.126 ± 0.045 Aa	0.084 ± 0.009 Ab	0.1 ± 0.038 ABab	0.093 ± 0.03 Ab
Renamel Microfill	0.084 ± 0.017 Ba	0.096 ± 0.018 Aa	0.082 ± 0.019 Ba	0.084 ± 0.01 Aa

Groups with different uppercase (column—comparison among composite resins within the same polishing agent) and lowercase letters (row—comparison among polishing agents within the same composite resin) are significantly different.

Paulo, São Paulo, Brazil). After 24 hours, specimens were rinsed with distilled water for 30 seconds, air-dried, and ground into powder with a stainless steel mortar and pestle (Marconi—Siemens, Piracicaba, São Paulo, Brazil). The resulting powder was placed separately into new tubes, which were filled with 4 mL of absolute alcohol (Qeel Quimica Especializada Erich Ltda., São Paulo, São Paulo, Brazil). After 24 hours, the solutions were centrifuged at 3,000 rpm for 3 minutes (Model 206BL, São Paulo, São Paulo, Brazil) and the supernatant was used to determine the absorbance in a spectrophotometer (DU 65, Beckman Instruments Inc., Fullerton, CA, USA). Standard solutions of methylene blue in 1 mL of absolute alcohol were prepared, containing 0 to 4 μg of dye/mL. Prior to determining the absorbance of experimental solutions at 668 ηm,[13,16] the correlation coefficient (r) between dye concentration and absorbance of the standard solutions was calculated and an *r*-value of 0.974 was obtained. To estimate the dye concentration in the experimental samples, a linear regression was obtained. The regression equation was expressed as: $y = 0.3315x - 0.8807$, where y is the absorbance and x is the dye concentration. The dye uptake of each specimen was expressed as μg dye/mL, where lower values indicate lower staining susceptibility ($N = 7$).

For statistical analysis, two-way analysis of variance was used to evaluate the data from profilometric and spectrophotometric experiments. To identify significant differences, a Tukey's test at a 0.05 level of significance was applied (SAS Institute Inc., Cary, NC, USA). Three specimens from each group were used for the SEM analysis (JSM 5600, Jeol Inc., Peabody, MA, USA). Specimens were sputter coated with gold to a thickness of approximately 50 Å in a vacuum evaporator (Balzers SCD 050, Balzers Union, Balzers, Liechtenstein) and photomicrographs of a representative area of the surfaces were taken at 500×.

RESULTS

The average surface roughness and the dye uptake for combinations of composite resins and polishing instruments are displayed in Tables 3 and 4, respectively. The representative photomicrographs of polished and untreated resins (control groups) are shown in Figures 1A, 2A, and 3A.

No statistically significant differences in surface roughness were observed among polishing agents for the Renamel Microfill composite ($p > 0.05$). Polishing with Enhance + PoGo and the control group produced similar surface roughness values among the composite resins ($p > 0.05$). The Filtek Supreme Plus composite presented surfaces that were more stain resistant than those of the Renamel Microfill and Esthet-X composites for all polishing systems, including the control group ($p < 0.05$). Renamel Microfill presented lower dye concentration means when

TABLE 4. MEAN (SD) DYE CONCENTRATIONS IN μG/ML IN COMPOSITE SAMPLES SUBJECTED TO VARIOUS SURFACE TREATMENTS.

	FlexiDisc + Enamelize	Enhance + PoGo	Sof-Lex	Control group
Esthet-X	0.217 ± 0.043 Ba	0.120 ± 0.023 Bb	0.139 ± 0.025 Bb	0.180 ± 0.053 Bab
Filtek Supreme Plus	0.06 ± 0.011 Aa	0.051 ± 0.019 Aa	0.037 ± 0.028 Aa	0.07 ± 0.017 Aa
Renamel Microfill	0.122 ± 0.018 Bb	0.231 ± 0.037 Ba	0.133 ± 0.023 Bb	0.180 ± 0.043 Bab

Groups with different uppercase letters (column—comparison among composite resins within the same polishing agent) and lowercase letters (row—comparison among polishing agents within the same composite resin) are significantly different.

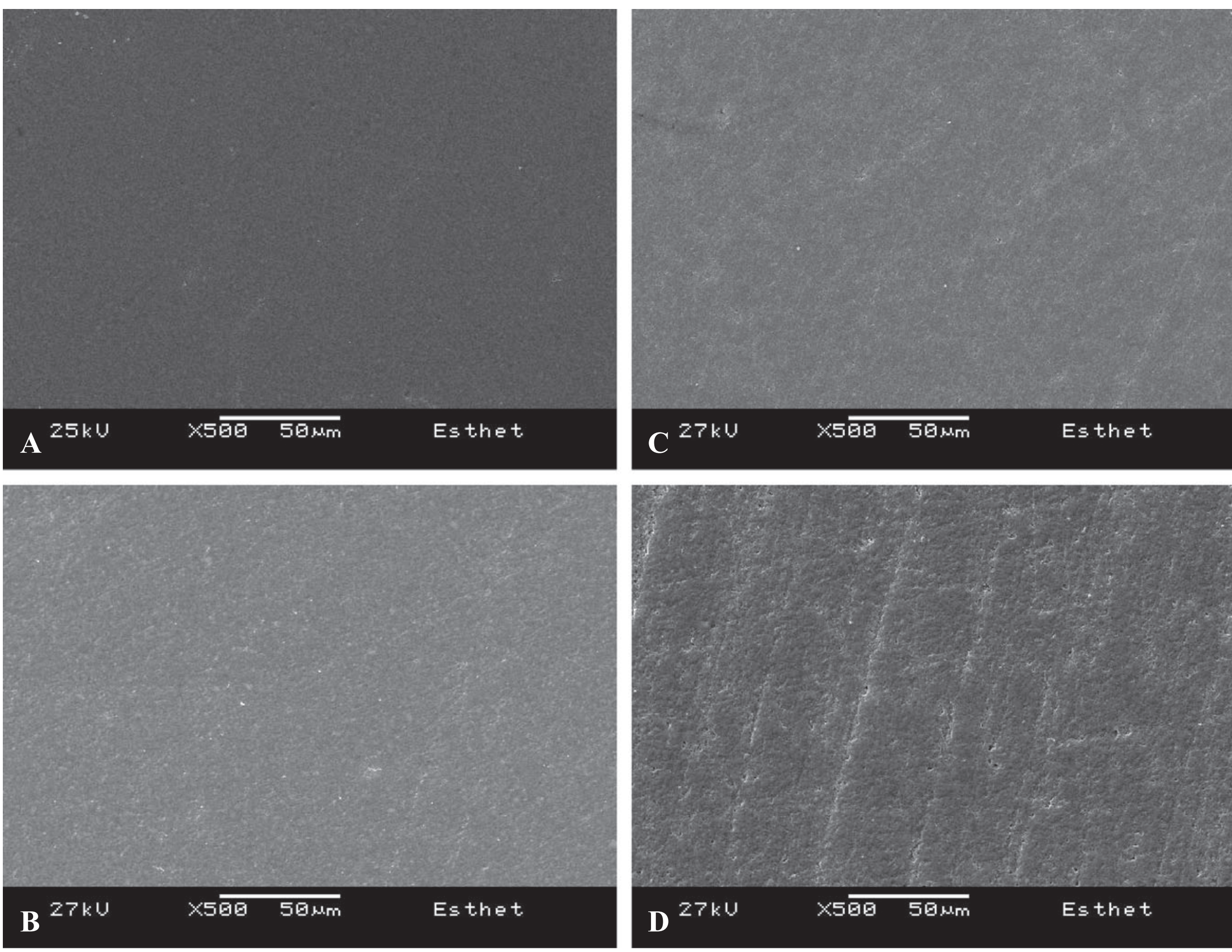

Figure 1. Scanning electron microscope photograph of Esthet X composite resin surface of the control group (A) *(Mylar strip-formed surface) and after finishing with FlexiDisc + Enamelize* (B), *Enhance + PoGo* (C), *and Sof-Lex* (D).

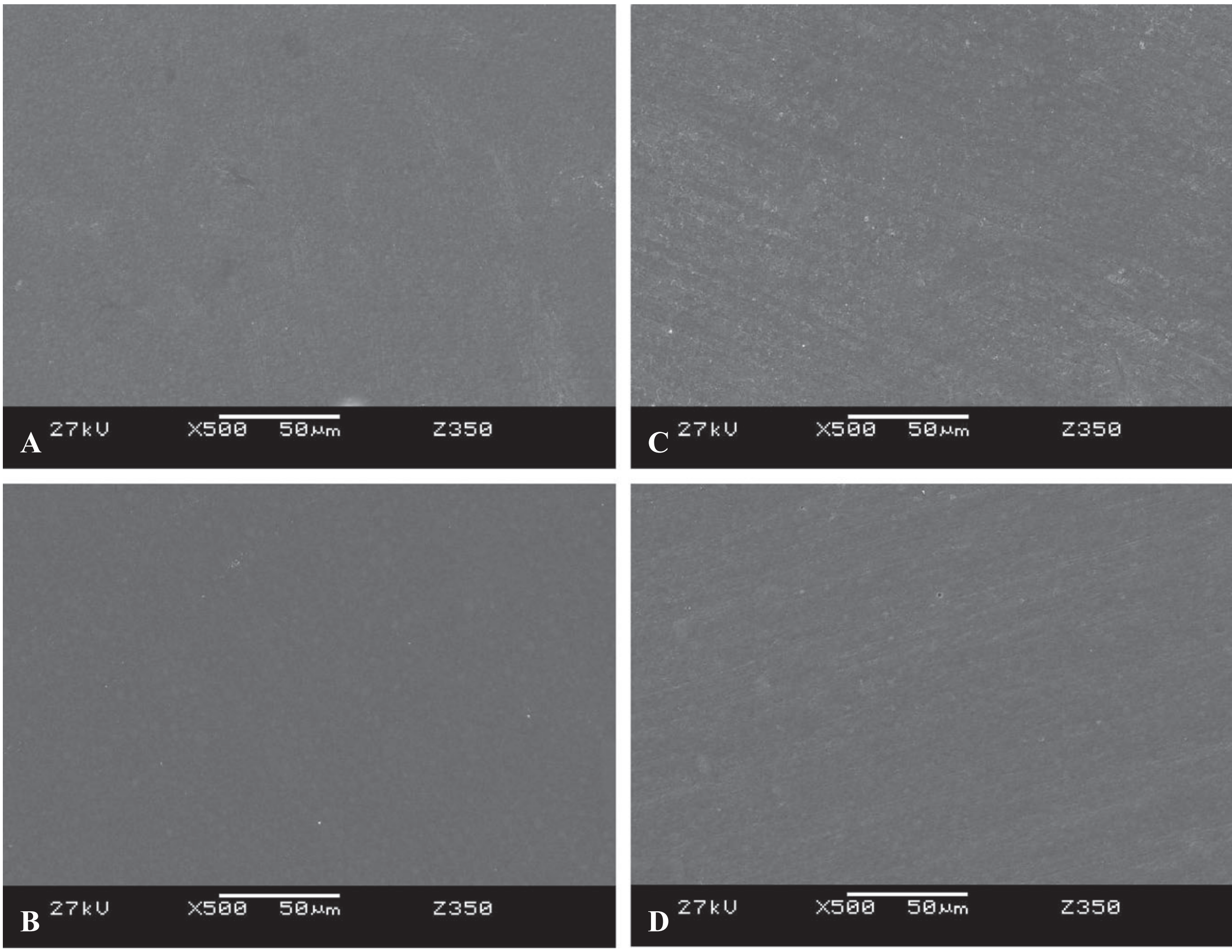

Figure 2. Scanning electron microscope photograph of Filtek Supreme composite resin surface of the control group (A) *(Mylar strip-formed surface) and after finishing with FlexiDisc + Enamelize* (B), *Enhance + PoGo* (C), *and Sof-Lex* (D).

treated with FlexiDisc + Enamelize and Sof-Lex than Enhance + PoGo ($p < 0.05$), whereas the Esthet-X composite presented a higher dye concentration when polished with FlexiDisc ($p < 0.05$). For all three composites, the control group presented similar dye concentration values to all polishing systems ($p > 0.05$).

DISCUSSION

The size of filler particles is an important parameter that has been used to characterize the restorative material for purposes of clinical applications, although most composite resins are designed for universal purposes.[9] As the polishability of composite resins is influenced by the filler type, shape, and content, some studies have shown that composites containing microfillers and spherical fillers are more efficiently polished than hybrid resins.[6,10–12] In this current study, the filler size ranged from 0.2 to 1.4 μm, and a clear relationship between filler size and composite surface roughness was not observed.

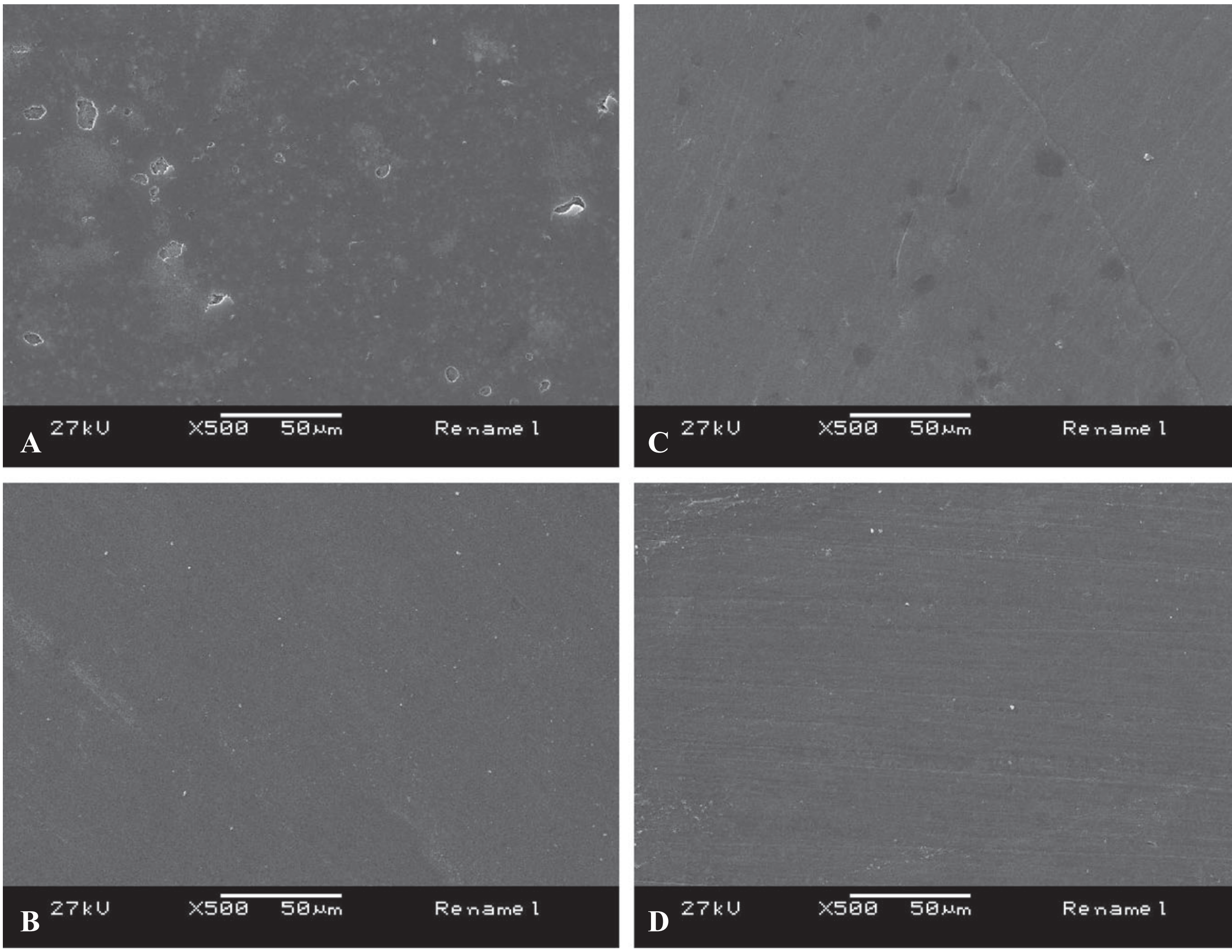

Figure 3. Scanning electron microscope photograph of Renamel Microfill composite resin surface of the control group (A) *(Mylar strip-formed surface) and after finishing with FlexiDisc + Enamelize* (B), *Enhance + PoGo* (C), *and Sof-Lex* (D).

During specimen preparation, a Mylar polyester matrix strip was used to produce standardized specimens. After light polymerization, the specimens that received no polishing served as control groups and were compared with treated groups with different polishing agents. Such samples, cured under Mylar strips, have also been used as controls in several studies[11,17,18,19] and, depending on polishing methods and materials, the surfaces of the composites resemble that of the Mylar strip, with no differences in average surface roughness between them.[20–22] In this study, the surface roughness of the composites cured under the Mylar strip was similar. For Esthet-X composite, the surface roughness of the control group was similar to those surfaces polished with FlexiDisc + Enamelize and Enhance + PoGo, whereas for Filtek Supreme Plus, the surfaces treated with Sof-Lex and Enhance + PoGo polishers produced similar surface roughness to that of the control.

Regarding the staining susceptibility after finishing and polishing procedures, the control groups from the three composite resins had similar dye uptake means to groups that were subjected to the polishing agents. Statistical differences in staining were observed only among the polished groups. In addition, there were significant differences among composites for the control groups. Esthet-X and Renamel Microfill presented higher dye concentration means than Filtek Supreme Plus when composites were cured under the Mylar strip.

Filtek Supreme Plus's staining susceptibility was also lower after using all finishing and polishing materials. These results are attributed to the monomeric composition of the resin matrix and the type of fillers. Low staining susceptibility is generally related to a low water absorption rate, and hydrophobic resins or low resin content in the composition of the restorative material.[23,24,25] Traditional dimethacrylates form cross-linked networks with unreacted pendant methacrylates that serve as plasticizers;[26] this plasticization imparts a more open structure to the polymers, which facilitate the absorption of dye.[27] In addition, the increase in dye concentration means has been attributed to the porosity of some glass particles of the filler.[13,28]

Some monomers, such as Bis-GMA, Bis-EMA, urethane dimethacrylate (UDMA) with small amounts of TEGDMA, are found in the composition of Filtek Supreme Plus. The UDMA seems to be more stain resistant than Bis-GMA[24], whereas the majority of TEGDMA, a somewhat hydrophilic monomer, has been replaced with a blend of UDMA and Bis-EMA.[26] There is a combination of a nonagglomerated/nonaggregated (20-nm nanosilica filler) and loosely bound agglomerated zirconia/silica nanocluster, which consists of agglomerates of primary zirconia/silica particles with the size of 5 to 20 nm fillers and a cluster particle size of 0.6 to 1.4 microns. Conversely, although this composite presents nanofillers, in this study, Filtek Supreme Plus did not present a lower surface roughness than other materials after polishing.

Most composites, such as Esthet-X, are hybrids, and manufacturers indicate their use for both anterior and posterior teeth. The Esthet-X composite is considered to have a microhybrid and minifill filler composition and contains inorganic bariumalumino fluoroborosilicate glass (ranging from 0.02 to 2.5 microns) with nano-sized silicon dioxide particles (range 10–20 nm). The size of the filler particles may be responsible for the differences in surface roughness between Esthet-X and Renamel Microfill polished with FlexiDiscs + Enamelize and Sof-Lex. The surface polished with FlexiDiscs presents some pitting, which may be because of the plucking of the filler during the polishing (Figure 1B), whereas Figure 1D shows scratches on the surface topography of the Esthet-X, polished with Sof-Lex, which can increase the surface roughness.

With regard to staining susceptibility, Esthet-X exhibited similar means of dye concentration to Renamel Microfill, but these were higher than that of Filtek Supreme Plus. Polished specimens of Renamel Microfill composite and its control group had no difference in staining susceptibility. Esthet-X and Renamel Microfill contain dental glasses as filler and conventional resin monomer, which are related to higher water sorption rate and less stain-resistant surfaces. The microfill composite (Renamel) presents an average particle size of 0.02 to 0.04 microns and exhibited lower or similar surface roughness to the other composites. A rough surface was noted when the specimens were polished with Enhance + PoGo, whereas a smooth surface was obtained when Renamel Microfill was treated with FlexiDiscs + Enamelize and Sof-Lex polishing agents.

The development of an optimal surface polish, in turn, can reduce the stain, biofilm accumulation, and gingival inflammation, minimizing the wear and improving the esthetics and the longevity of restorations.[29] Intrinsic factors such as resin monomers and concentration of filler also play an important role in the clinical behavior of these restorative materials. In cases of doubt, the polishing system from the same company as the composite resin should be used, as these showed good results in comparison with other polishers.[2] Additionally, manufacturers should remember that, depending on the hardness, size, and content of filler, the composites require specific finishing and polishing systems.

CONCLUSION

The surface roughness and staining susceptibility are not solely influenced by filler size of the composite resins tested.

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