Surface Roughness of Novel Resin Composites Polished with One-step Systems

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Clinical Relevance

One-step systems can polish resin composites containing nanoparticles with a reduced time application; however, their effectiveness depends on material properties.

SUMMARY

Objectives: This study: 1) analyzed the surface roughness of five novel resin composites that contain nanoparticles after polishing with three different one-step systems and 2) evaluated the effectiveness of these polishers and their possible surface damage using scanning electron microscope (SEM) analysis.

Methods: The resin composites evaluated in this study include CeramX, Filtek Supreme XT, Grandio, Premise and Tetric EvoCeram. A total of 100 discs (20/resin composites, 10x2 mm) were fabricated. Five specimens/resin composites cured under Mylar strips served as the control. The samples were polished for 30 seconds with PoGo, OptraPol and One Gloss discs at 15,000 rpm using a slow speed handpiece. The surfaces were tested for roughness (Ra) with a surface roughness tester and examined with SEM. One-way ANOVA was used for statistical analysis (*p*=0.05).

Results: For all the composites tested, differences between the polishing systems were found to be significant (*p*<0.05). For Filtek Supreme XT, Mylar and PoGo created equally smooth surfaces, while significantly rougher surfaces were obtained after OptraPol and One Gloss applications. For Grandio, Mylar and PoGo created equally smooth surfaces, while OptraPol and One Gloss produced equally rougher surfaces. Tetric EvoCeram exhibited the roughest surface with OptraPol, while no significant differences were found between Premise and Ceram X. According to SEM images, OptraPol and One Gloss scratched and plucked the particles away from the surface, while PoGo created a uniform finish, although the roughness values were not the same for each composite.

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Conclusion: Effectiveness of the polishers seems to be material dependent.

INTRODUCTION

The proper finishing and polishing of dental restoratives are critical clinical procedures that enhance the aesthetics and longevity of restorations. The surface texture of dental materials has a major influence on plaque accumulation, discoloration, wear and the aesthetical appearance of direct and indirect restorations.[1] Furthermore, a smooth surface adds to the patient's comfort, as a change in surface roughness of 0.3 µm can be detected by the tip of the tongue.[2]

Early studies have shown that the smoothest surface of a restoration is attained when the resin is polymerized against an appropriate matrix strip. When such a matrix is not used, polymerization of the outer layer is inhibited, resulting in a surface layer rich in organic binder, which has a stickier, softer consistency. Since such a finish cannot be maintained, further contouring and finishing are required. Finishing is the gross contouring of a restoration to obtain desired anatomy, while polishing refers to reduction of the roughness and removal of scratches created by finishing instruments. Finishing and polishing procedures require sequential use of instrumentation with gradually smaller grained abrasives in order to achieve the desired glossy surface.[3-4] For years, a set of highly flexible polyurethane-based finishing and polishing discs coated with aluminum oxide were widely used for polishing resin composite restorations.

More recently, diamond polishers and silicone synthetic rubbers have been introduced, which give hybrid composites a microfil shine and reduce the clinical time spent to finish the restoration. Manufacturers refer to them as "one-step" polishing systems, because they can be used to develop a high luster, and contouring, finishing and polishing procedures could be completed using a single instrument. This type of polishing concept meets the clinical demand for achieving a smooth surface within a minimum amount of time.[5] However, controversies exist regarding the *in vitro* performance of these systems.[6-7] A previous study demonstrated that the determining step in finishing and polishing restorations may have been the use of finishing burs, since the smoothest surfaces were achieved using carbide burs prior to using polishers.[8] It has been reported that a decrease in mean surface roughness could be achieved within five seconds of polishing in practically all restorative materials, and longer polishing times or the application of additional components did not result in a further decrease of the same magnitude.[9] Thus, when polishing composite restorations, one-step polishers assist in saving time.

Since the very first dental resin composites were developed, many efforts to improve their clinical performance have been undertaken.[10] Research has been done to develop new monomers for resin matrix,[11-13] and studies that focus on loading, particle size and silanation have been conducted on filler content.[14] The structure of resin matrix and the characteristics of filler particles have a direct impact on the surface smoothness of resin composites.[15]

One of the most important advances in the last few years is the application of nanotechnology to resin composites. Nanotechnology is based on the production of functional materials and structures in the range of 1 to 100 nanometers using various physical and chemical methods. These novel resin composites, which contain nanoparticles, have many advantages, including reduced polymerization shrinkage,[10] increased mechanical properties,[10,16-17] improved optical characteristics,[17] better gloss retention and diminished wear.[17-18]

One group of these materials, Filtek Supreme XT, contains zirconia-silica particles 5-20 nm fillers and 0.6-1.4 µm nanoclusters.[19] Another group, Grandio, introduced in early 2003, contains glass ceramic particles that contain 1 µm and silicium dioxide particles of 20-50 nm.[20] CeramX comprises organically modified ceramic nanoparticles and nanofillers that are combined with conventional glass fillers of ~1 µm.[21] Tetric EvoCeram also comprises features of nanotechnology. While the material contains only a small quantity of inorganic nanoparticles, nano additives, known as rheological modifiers, have been incorporated in a targeted fashion.[22] Another nano-hybrid resin composite, Premise, contains "trimodal" nanoparticles of 0.2-0.4 µm and pre-polymerized fillers.[23]

In recent years, efforts have been made to analyze the suitability of numerous systems available for the finishing and polishing of composites.[24-26] The effect of polishing systems on surface finish has been reported to be material dependent, and the effectiveness of one-step systems was mostly product dependent.[27] To date, a paucity of information is available on how to finish and polish novel nano-structured resin composites.

This investigation: 1) analyzed the surface roughness of five novel resin composites containing nanoparticles after polishing with three different one-step polishing systems and 2) evaluated the effectiveness of these one-step polishing systems and their possible surface damage by scanning electron microscope (SEM) analysis.

METHODS AND MATERIALS

Five novel resin composites containing nanoparticles were used in this study. The resin composites evaluated were Filtek Supreme XT (3M, St Paul, MN, USA), Grandio (Voco, Cuxhaven, Germany), CeramX (Dentsply DeTrey, Konstanz, Germany), Tetric Evo

Table 1: *Properties of the Resin Composites Tested*

Resin Composite	Composition	Type	Shade	Filler Content % (w/w) (v/v)	Lot #
Filtek Supreme XT (3M ESPE, St Paul, MN, USA)	**Matrix:** Bis-phenolA diglycidylmethacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA),urethane dimethacrylate (UDMA), bisphenol A polyethylene glycol diether dimethacylate **Filler:** silica nanofillers (5-75 nm) zirconia/silica nanoclusters (0.6-1.4 µm)	Nanofilled	A2B	78.5 59	5 AR
Grandio (Voco, Cuxhaven, Germany)	**Matrix:** Bis-GMA, dimethacrylate, urethane dimethacrylate (UDMA), triethylene glycol dimethacrylate (TEGDMA) **Filler:** silicium dioxide nanofillers (20-50 nm) glass ceramic microfillers (1 µm)	Nanohybrid	A2	87 71, 4	491813
CeramX (Dentsply DeTrey, Konstanz, Germany)	**Matrix:** Methacrylate modified polysiloxane, dimethacylate resin, fluorescent pigment, UV stabilizer, stabilizer, camphorquinone, ethyl-4 (dimethylamino) benzoate, iron oxide pigments, titanium oxide pigments, aluminum sulfo silicate pigments **Filler:** Barium-aluminum-borosilicate glass (1.1-1.5 µm) Methacrylate functionalized silicon dioxide nano filler (10 nm)	Nanohybrid	M2	76 57	0510000677
Tetric EvoCeram (Ivoclar Vivadent, Schaan, Liechtenstein)	**Matrix:** Dimethacrylates, additives, catalysts, stabilizers, pigments **Filler:** Barium glass, ytterbium trifluoride, mixed oxide, prepolymers	Nanohybrid	A2	82.5 68	H29941
Premise (KerrHawe, Bioggio, Switzerland)	**Matrix:** Ethoxylated bis-phenol-A-dimethacrylate, triethylene glycol dimethacrylate (TEGDMA), light-cure initiators and stabilizers **Filler:** Prepolymerized filler (PPF), 30 to 50 µm Barium glass, 0.4 µm, Silica nanoparticles, 0.02 µm	Trimodal nanofilled	A2 Dentin	84 69	05-114602

Table 2: *The Composition and Batch Numbers of the Polishing Systems Investigated*

Polishing System	Composition	Batch #
PoGo (Dentsply Caulk, Milford, DE ,USA)	Polymerized urethane dimethacylate resin, fine diamond powder, silicon oxide	030328
OptraPol (Ivoclar Vivadent, Schaan, Liechtenstein)	Caoutchouc, silicone carbide, aluminum oxide, titanium oxide, iron oxide	H32532
One Gloss (Shofu Inc, Kyoto, Japan)	Synthetic rubber (Polyvinylsiloxiane) abrasive grain (Al_2O_3) silicon oxide (SiO_2)	0605707 (IC 0183)

Ceram (Ivoclar-Vivadent AG, Schaan, Liechtenstein) and Premise (KerrHawe, Bioggio, Switzerland). Table 1 shows the properties of the materials tested. The polishing systems tested were Pogo (Dentsply Caulk, Milford, DE, USA), OptraPol (Ivoclar-Vivadent) and OneGloss (Shofu, Kyoto, Japan). Table 2 shows the components of the polishing systems tested.

Using a plexiglass mold (Plexiglass MC, Rohm and Haas, Philadelphia, PA, USA), 10x2 mm disc specimens were prepared. For each resin composite, 20 discs were fabricated, with a total of 100 discs obtained. The resin composites were placed in the mold using Optra Sculp (Ivoclar-Vivadent) modeling instruments, and the composites were covered with a Mylar strip. A glass slide 1-2 mm thick was placed over the strip before curing with a light activating source (Degulux/ Degussa, Frankfurt, Germany) to flatten the surfaces. The samples were then cured for 40 seconds through the Mylar strip and glass slide. After every five samples, the light output was checked using a photometric tester (Dentek, Inc, Buffalo, NY, USA) that exceeded 400 mW/cm^2. The curing light guide of the light-curing unit was moved on both sides of the specimen for an additional 20 seconds after removing the strips and glasses. The cured samples were then stored in 100% humidity at 37°C for 24 hours prior to the finishing procedures.

Five specimens per resin composite received no finishing treatment after being cured under Mylar strips; these specimens served as a control. After storage, the Mylar-created surfaces were evaluated with a surface roughness tester (Mitutoyo 178 SJ 400 Surftests 178-039, Japan) on a flat plane to obtain average surface roughness values that would serve as a baseline for the polishing systems. The remaining 75 samples were ground wet with 320 grit silicon carbide paper. This grit size was chosen based on an investigation by Chung,[28] which showed that pre-roughening with diamond burs resulted in an inhomogeneous surface texture and increased scattering of the results. Therefore, pre-roughening was standardized using a polishing machine with 320 grit SiC paper. A slow speed handpiece rotating at a maximum 15,000 rpm was used with a constant moving repetitive stroking action to prevent heat build-up and the formation of grooves. A new polishing disc was used for each specimen and was discarded after each use.

All the polishing systems tested were manufactured in different shapes, including cups, points or discs. In this study, disc shaped polishers were used in order to obtain direct contact with the surfaces of specimens. According to the manufacturers' instructions, the PoGo polisher gave the best results when used following Enhance (Dentsply Caulk) finishers; however, since there was no intermediate step for the other one-step systems, Enhance was avoided for standardizing the polishing procedures in this study.

The first group was polished with the flat, broad surface of a PoGo diamond micro-polisher disc that was first applied with light and intermittent pressure, then with decreased pressure to increase the surface lustre using a light buffing motion for 30 seconds. For the second group, an OptraPol disc was used with moderate pressure in conjunction with copious water spray for 30 seconds. The last group was polished with One Gloss discs, applying feather light pressure on the discs for 30 seconds.

The polished resin composite discs were washed, allowed to dry and kept in 100% humidity for 24 hours before measuring the average surface roughness values (Ra). The average surface roughness (Ra) of each specimen was measured five times with a cut-off value of 0.8 mm, a transverse length of 0.8 mm and a stylus speed of 0.1 mm/second near the center of each specimen using a surface roughness tester (Mitutoyo 178 SJ 400 Surftests 178-039, Japan). One representative specimen of each group was prepared for the scanning electron microscope (JEOL JSM 6060, Tokyo, Japan). The specimens were sputter coated with gold to a thickness of approximately 200 Å in a vacuum evaporator. Photographs of the representative areas of the polished surfaces were taken at 500x and 5000x magnifications.

RESULTS

Univariate analysis of variance with 4x5 factorial randomized design model was used for statistical analysis, with a significance level at 0.05. When there was interaction between the resin composites and polishing systems, one-way ANOVA was used. The homogeneity of

Table 3: *Mean Ra Values (µm), Standard Deviations and Standard Errors for the Various Materials and Polishing Systems Evaluated*

Restorative Materials	Polishing Systems	n	Mean Ra Values	Standard Deviation	Standard Error
Filtek Supreme XT	Mylar	10	0.152 µm	0.028	0.008
	PoGo	10	0.198 µm	0.045	0.015
	OptraPol	10	0.392 µm	0.048	0.015
	One Gloss	10	0.528 µm	0.078	0.024
Grandio	Mylar	10	0.122 µm	0.052	0.016
	PoGo	10	0.171 µm	0.041	0.013
	OptraPol	10	0.497 µm	0.114	0.036
	One Gloss	10	0.507 µm	0.093	0.029
Tetric Evo Ceram	Mylar	10	0.124 µm	0.021	0.006
	PoGo	10	0.223 µm	0.036	0.113
	OptraPol	10	0.696 µm	0.096	0.030
	One Gloss	10	0.584 µm	0.059	0.018
Premise	Mylar	10	0.106 µm	0.025	0.008
	PoGo	10	0.237 µm	0.044	0.014
	OptraPol	10	0.470 µm	0.068	0.021
	One Gloss	10	0.338 µm	0.037	0.011
Ceram-X	Mylar	10	0.118 µm	0.053	0.017
	PoGo	10	0.179 µm	0.046	0.014
	OptraPol	10	0.518 µm	0.057	0.018
	One Gloss	10	0.346 µm	0.049	0.015

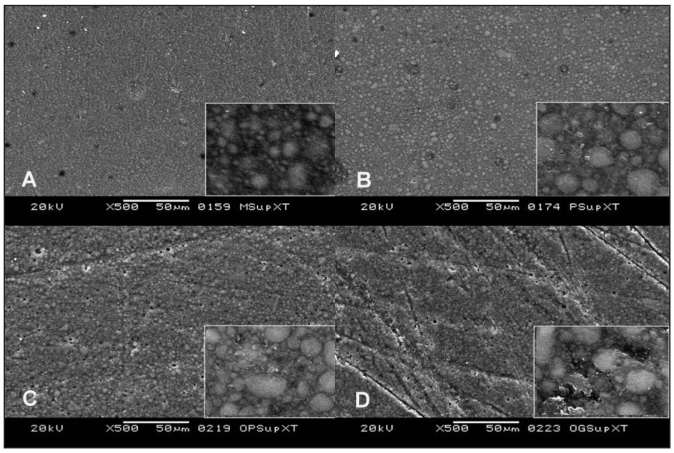

Figure 1. *Filtek Supreme XT surfaces polished with different one-step polishing systems (500x magnification; 5000x in the box). Figure 1A. Control surface (Mylar); B. Polished with PoGo; C. Polished with OptraPol; D. Polished with One Gloss.*

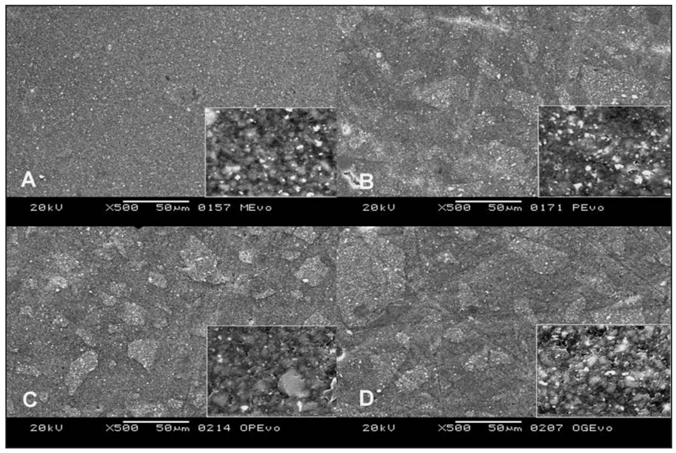

Figure 2. *Tetric EvoCeram surfaces polished with different one-step polishing systems (500x magnification; 5000x in the box). Figure 2A. Control surface (Mylar); B. Polished with PoGo; C. Polished with OptraPol; D. Polished with One Gloss.*

variances was checked with Levene statistic (p=0.05). The F-test and post-hoc Duncan tests were used when the variances were homogenous. When the variances were not homogenous, differences between the groups were checked using the Welch test and post-hoc Dunnett C test.

Table 3 summarizes the average surface roughness values and standard deviations. A Mylar strip was used as the control, and the surface roughness values for all polishing systems were compared to that of the Mylar test. Regarding the surface roughness of all composites tested, the differences between polishing systems were significant (p<0.05). For Filtek Supreme XT, Mylar and PoGo created equally smooth surfaces, while significantly rougher surfaces were obtained after applications of OptraPol and One Gloss (p<0.05).

Two main groups emerged according to the roughness values for Grandio. Mylar and PoGo created equally smooth surfaces, and OptraPol and One Gloss produced equally rougher surfaces (p<0.05).

For Tetric EvoCeram, Premise and CeramX, none of the polishing systems could produce smooth surfaces similar to Mylar (p<0.05). The differences among the procedures were all significant (p<0.05). PoGo created smoother surfaces than One Gloss and OptraPol.

For the resin composites that were tested, the authors of this study also evaluated the polishing performance of different one-step systems. For all materials, the smoothest surfaces were obtained with the PoGo polisher. PoGo could equally create smooth surfaces for Grandio, CeramX and Filtek Supreme XT. Tetric EvoCeram exhibited the roughest surface with OptraPol, while no significant differences were found among Premise, Grandio and CeramX (p<0.05). One Gloss could better polish Premise and CeramX. The other materials exhibited similarly rougher surface texture. In terms of SEM images, OptraPol and One Gloss created scratches on the surfaces of the resin composites and plucked the particles away, while a uniform finish could be obtained with PoGo, although the roughness values were not the same for each composite (Figures 1-5).

DISCUSSION

In aesthetic dentistry, restorative materials should duplicate the appearance of a natural tooth. A resin composite restoration can be imperceptible to the naked eye when its surface closely resembles the surrounding enamel surface. Thus, polished restorations should demonstrate an enamel-like surface texture and gloss. The appearance of the restoration is affected by the degree of surface gloss after polishing[29] and is based on reflected light from the restoration. With increased surface roughness, the degree of light reflection increases, resulting in decreased gloss. The clinical significance of surface roughness is related to the aesthetic appearance of the restoration (discoloration and wear), the biological consequences regarding periodontal health and the development of secondary caries due to increased plaque accumulation. With regard to the impact of surface roughness on gingival health, clinical studies have shown that rough surfaces increase plaque formation and reduce the cleaning efficiency of oral hygiene procedures.[30]

The surface micromorphology of resin composites after finishing and polishing has been shown to be influenced by the size, hardness and amount of filler particles.[28] Harder filler particles are left protruding from the surface during polishing, as the softer resin matrix is preferentially removed in hybrid composites. Filler particles should be situated as close together as possible in order to protect the resin matrix from abrasives. Hence, the application of nanotechnology to com-

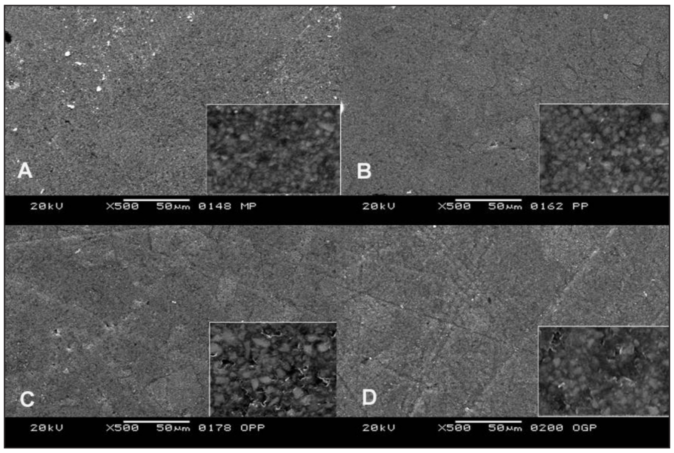

Figure 3. *Premise surfaces polished with different one-step polishing systems (500x magnification; 5000x in the box). Figure 3A. Control surface (Mylar); B. Polished with PoGo; C. Polished with OptraPol; D. Polished with One Gloss.*

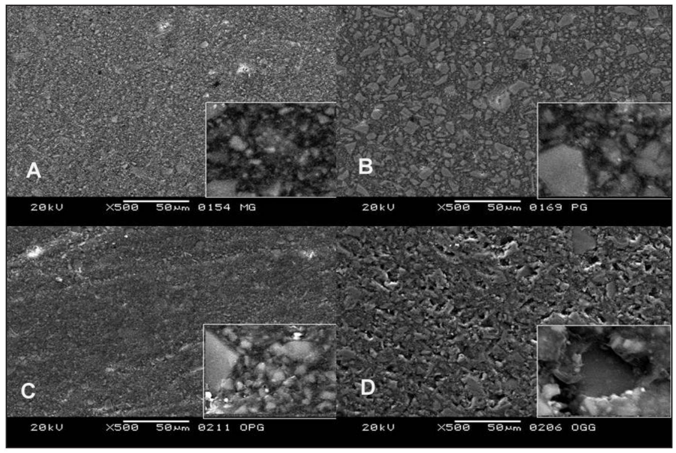

Figure 4. *Grandio surfaces polished with different one-step polishing systems (500x magnification; 5000x in the box). Figure 4A. Control surface (Mylar); B. Polished with PoGo; C. Polished with OptraPol; D. Polished with One Gloss.*

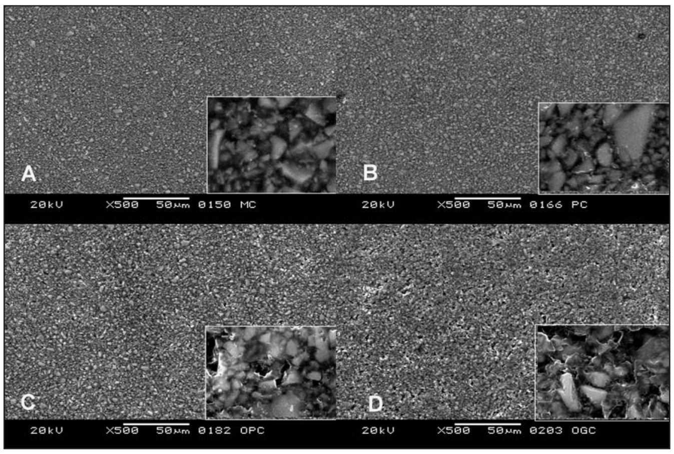

Figure 5. *CeramX surfaces polished with different one-step polishing systems (500x magnification; 5000x in the box). Figure 5A. Control surface (Mylar); B. Polished with PoGo; C. Polished with OptraPol; D. Polished with One Gloss.*

posite research is of great benefit. Due to reduced dimension of the particles and wider distribution, an increased filler load can be achieved, which results in reducing polymerization shrinkage and increasing mechanical properties.[10] The resin composites tested in this study comprise features of nanotechnology with their high filler load.

The efficiency of abrasive systems is related to flexibility of the backing material in which the abrasive is embedded, hardness of the abrasive, geometry of the instrument and how the instruments are used.[24] For a composite finishing system to be effective, the abrasive particles must be relatively harder than the filler materials. If not, the polishing agent will only remove the soft resin matrix and leave the filler particles protruding from the surface.[31] Türkün and Türkün[25] compared the effects of Sof-Lex discs, Enhance and PoGo polishers on the surface roughness of microhybrid resin composites; they reported that PoGo produced smooth surfaces similar to those obtained with Mylar strips. Also, in this study, PoGo polisher produced equally smooth surfaces for Filtek Supreme XT and Grandio to those of Mylar. In terms of the roughness values of the other resin composites tested, there were statistically significant differences between the surfaces created with Mylar and PoGo; however, among the other one-step polishers, the smoothest surfaces were obtained with the PoGo system. This might be attributed to the fact that the flexible micro-polisher disc contained fine diamond particles. Furthermore, the visual observations of the polished samples with PoGo demonstrated an enamel-like glossy surface, while the other one-step systems created a dull appearance. A clinical trial has shown that the majority of patients could detect differences of about 0.3 µm in mean roughness.[2] Although PoGo was not used in combination with the Enhance system, as recommended by the manufacturers, PoGo could create imperceptible surfaces with roughness values lower than 0.3 µm, while One Gloss and OptraPol created rougher surfaces. Yap and others[5] investigated the surface texture of a resin composite (Z100, 3M/ESPE) and compomer (F2000, 3M/ESPE) restorative after treatment with different one-step polishing/finishing systems; they also reported that One Gloss produced rougher surfaces than PoGo and the other systems tested (Sof-Lex Brush, 3M; CompoSite, Shofu; Super Snap, Shofu). Based on their results, it was concluded that the effectiveness of these systems was product-dependent.

Many studies on the polishing of resin composites have been introduced, and the most commonly used parameter to describe surface roughness is Ra.[32-34] Surface roughness is a function of the microstructure created by the series of physical processes used to modify the surface and is related to the scale of the measurement. The inherent surface roughness of a restoration must be equal to or lower than the surface roughness of enamel-to-enamel occlusal contact areas (Ra=0.64 µm).[35] When comparing the roughness values of optimally polished surfaces, most studies analyze the surface roughness of materials pressed against transparent matrices, such as Mylar strips. Thus, very smooth surfaces can be created, which should be representative of the clinical situation when matrices are used. Although the surface obtained by using the Mylar strip is perfectly smooth, it is rich in resin organic binder. Therefore, removal of the outermost resin by finishing and polishing procedures would tend to produce a harder, more wear resistant, and, hence, a more aesthetically stable surface.

Profilometers have been used for years to measure surface roughness in *in vitro* investigations. They provide limited two-dimensional information, but an arithmetic average roughness can be calculated and used to represent various material/polishing surface combinations that assist clinicians in their treatment decisions.[36] However, the complex structure of a surface cannot be fully characterized by the use of only surface roughness measurements. More valid predictions of clinical performance can be made when the surface roughness measurements are combined with a SEM analysis that permits an evaluation on the destructive potential of a finishing tool.[36-37] In this study, surface roughness measurements were used for relative comparisons. Additionally, changes in the surface texture were examined with SEM.

In this study, SEM images revealed that OptraPol and One Gloss, by plucking particles away and creating scratches, damaged the surfaces of all the resin composites tested. It was observed that profilometric measurements were largely confirmed by SEM analysis.

The highest mean Ra value was 0.69 for all the one-step polishing systems and materials tested in this study. According to Shintani and others,[38] there were no appreciable differences in plaque accumulation between surfaces polished by the different methods, which resulted in Ra values within the 0.7-1 µm range. Chung[28] reported that restorations appeared optically smooth when their surface roughness was smaller than 1 µm.

An important factor is the intrinsic roughness of a composite material, which is determined by the size, shape and quantity of the filler particles. Among the resin composites tested in this study, only Filtek Supreme XT, containing both nanofillers and nanoclusters, is considered to be a true nanofill composite. Nanocluster filler particles consist of loosely bound agglomerates of nano-sized filler particles. During polishing, these particles, not the clusters themselves, can be worn away, rather than plucking out the larger second particle from the resin itself. Eventually, the surfaces have smaller defects and better polish retention, unlike the rough texture with pits or craters observed in hybrid composites. According to the SEM images of Filtek Supreme XT and Premise, no particle dislodging, was observed, while the large glass fillers (1-1.5 µm) of Grandio and CeramX were plucked away, leaving voids or craters behind after being polished with OptraPol and One Gloss. Tetric EvoCeram also displayed a rougher surface after the application of OptraPol and One Gloss, although it did not contain large glass fillers as did Grandio and CeramX. According to the results of a previous study, Tetric EvoCeram showed a considerably higher reduction in surface roughness after having being polished with Astropol HP (High Polishing) (Ivoclar-Vivadent) rather than after having been polished with Astropol P (Polishing) component.[9] This may be due to the fact that the effectiveness of the polishing systems was material dependent.

CONCLUSIONS

Novel resin composites that contain nanoparticles combine superior esthetics, long-time polish retention and other optimized physical properties. The polishing effect of PoGo was worse than Mylar but still better than other polishing systems. Considering the reduced steps, application time, elimination of cross-infection risks and achievement of Mylar-strip-like surfaces, PoGo diamond micro-polisher can be used for polishing these novel materials.

The question, to what degree a surface must be finished, cannot be answered sufficiently at the moment. Results suggest that, in order to achieve long-lasting esthetics in resin composite restorations, special attention should be paid to obtaining optimal resin polymerization and a perfect surface finish by polishing. Additional studies are needed to determine which of the new finishing and polishing techniques is best suited to clinical situations where access is limited and restoration surfaces are concave.

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