The effect of polishing systems on surface roughness of nanohybrid and microhybrid resin composites

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ABSTRACT: Purpose: To compare the effect of polishing systems on surface roughness of nanohybrid and microhybrid resin composites. **Methods:** Two types of restorative resin composites and two one-step polishing systems were used in this study (IPS Empress Direct as the nanohybrid resin composite and Filtek P90 as the microhybrid). A total of 120 discs were fabricated (n=120). The specimens were divided into six groups of n=20 each. For polishing systems, PoGo One-Step Diamond Micro-Polisher and OptraPol Next Generation were selected. The before and after mean Ra values were recorded using a surface profilometer. Results were statistically analyzed with the Kruskal-Wallis H and the Mann-Whitney U tests. A P-value of ≤ 0.05 was considered statistically significant. **Results:** PoGo polishing system recorded the lowest surface roughness, in case of both nano and microhybrid composites, with mean Ra values of 0.060 µm and 0.108 µm, respectively. PoGo also produced maximum reduction in the surface roughness in the nanohybrid group with 56.83%. OptraPol recorded a comparatively similar mean Ra value of 0.067 µm for the nanohybrid composites but recorded the least reduction in surface roughness with 48.41% for the microhybrid group. (*Am J Dent* 2019;32:47-52).

CLINICAL SIGNIFICANCE: One-step diamond polishing systems combined with nanohybrid resin composites exhibit increased surface smoothness compared to microhybrids.

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Introduction

The increase in demand for restorations and the parallel criterion for quality finishing-polishing, has given a rise to the number of commercially available products available to dentists.

Researchers and operators are in disaccord as to which system and material combination results in the ideal appearance and luster to the natural tooth.[1] All system/material combinations have advantages and disadvantages with respect to efficiency and the degree of achieving surface smoothness.[2]

One factor that influences the polishability of the restorations is the individual properties of the polishing systems, i.e., abrasive type, speed, angle, size, etc.[3] Secondly, the complexity and formulation of the resin composite materials affect the final outcome of the restoration. These variances include type of inorganic filler, filler size, inter-particle spacing, abrasion susceptibility, filler loading and hardness.[2,3] To understand this compound relationship, both the polishing systems and the resin composites need to be explored individually and as pairs.

The process of finishing and polishing is achieved by contouring, removing scratches and reducing the surface roughness of the restoration. The end result is a highly smooth, light-reflective, enamel-like surface that duplicates the appearance of the natural tooth.[4,5] In literature, the terms finishing and polishing are often referred to as "finishing-polishing" or "finishing/polishing" since the two procedures are inter-related and often difficult to separate.[6]

The finishing-polishing systems are fabricated with a variety of materials. Some commonly used solutions include diamond or carbide burs, silicone-carbide-coated or aluminum oxide-coated abrasive discs and wheels, diamond-impregnated rubber or abrasive-embedded resin polishing cups and points, abrasive strips, bonded abrasives, and polishing pastes or powders.[3,7,8] Finishing-polishing systems are also categorized by the number of sequential steps required to achieve a final esthetic surface. Manufacturers have labeled these products as one-step (PoGo, OptraPol), two-step (Sof-Lex, Super Snap), multi-step (VersaFlex, Astropol) systems, etc. Among these systems, the one-step polishing systems have received a wider acceptance among dentists as contouring, finishing and polishing can be completed using a single instrument and in a minimum amount of time. One-step diamond polishers and silicone synthetic rubbers are especially preferred to achieve a natural sheen and high luster on hybrid composite restorations.[1,5]

Successful restorations are not only dependent on the type of instrument but also rely greatly on correct finishing and polishing implementations.[4] An improperly finished or polished restoration causes several complications such as plaque accumulation, discoloration (surface staining), gingival irritation, secondary caries, and excessive wear of the opposing enamel.[8,9] Therefore, a high-caliber quality of finishing and polishing technique greatly contributes to both health and longevity of the restoration.[4]

The survival of composite restorations and the esthetics are also dependent on the restorative material used. Resin-based composites (RBCs) or simply composite resins have appropriated a wider acceptance among clinicians due to their superior esthetics and the general health concern of using metals in the mouth.[10] Resin composites are made of three key components, a resin matrix, chemically bonded fillers and coupling agents.[2,11] The filler particles can consist of a variety of materials including fiberglass, radiopaque glass, fused glass particles, quartz particles, amorphous silica or yttrium fluoride particles.[12,13]

Resin composites are often classified by filler particle technology. Macrofiller composites, microfiller composites, hy-

Table 1. Characteristics of the composite restorative materials.

Material	Material category	Matrix	Filler type (size)	Filler weight	Filler volume
Filtek P90	Microhybrid composite	Silorane, siloxane	Yttrium fluoride, 3,4-Epoxycyclohexaylcy clopolymethylsiloxane, silanized quartz (0.1–2µm)	76%	55%
IPS Empress Direct	Nanohybrid composite	Dimethacrylate monomer with reduced BisGMA	Ba-Al-SiO_4 glass (0.4-0.7µm), YtF_3 (0.1µm), SiO_2/ZrO_2 mixed oxide (0.15 µm), prepolymers (4-5µm)	77.5-79%	52-59%

Table 2. Composition of the polishing systems.

Polishing system	Composition	Abrasive type	Average abrasive particle size
PoGo One Step Diamond Micro-Polisher	Polishers - Polymerized urethane dimethacrylate resin, fine diamond powder, silicon oxide. Mandrel - Plastic.	Diamond	20 µm
OptraPol Next Generation	Polishing body - Silicone rubber, diamond particles. Red core - silicone rubber, aluminum oxide, iron oxide, Irgazin red. Polishing body and core - Stainless steel shanks.	Diamond	12 µm

brid filler composites, microhybrid composites, nanofiller composites and nanohybrid composites are a few of the most widely used filler resins among dentists.[14,15] Smaller filler particle size allows greater polishability and esthetics, while larger size provides strength.[16] Thus, hybrid resins strive to achieve a balance between strength and esthetics by combining various particle sizes.[17]

Microhybrid composites contain both macro and micro sized particles with a mean size less than 1 µm and microfillers with approximate size of 0.04 µm. The combination of various particle sizes gives the resin composites both reliable mechanical properties (handling, wear, strength) as well as a smooth polished surface similar to natural teeth.[18-20] Nanohybrid composites also combine various particle sizes along with smaller nanoparticles in the range of 50-100 nm. The use of nanotechnology gives nanohybrid composites the advantage of compacting a greater amount of filler, which improves strength and provides superior surface smoothness.[20,21]

Different combinations of polishing systems and resin materials may or may not produce the same results. Some studies[22-24] observed that clinically no significant differences in surface roughness were observed among composite restorative materials when subjected to diverse polishing systems. On the other hand, several studies[1,6,9,25] concluded that the effect of polishing systems on surface finishing of a restoration is strictly material dependent.

Therefore, there is a continuous need for more investigations and studies to explore different combinations of polishing systems and materials. Another definitive reason for continuous studies is that by the time a research study was concluded, the instruments or the restoration materials were replaced by newer devices/materials.[26] This study adds to the requisite of continuous research with the aim to compare the effect of one-step polishing systems on surface roughness of nanohybrid and microhybrid resin composites. An alternative hypothesis was tested, in that different brands of one-step polishers would provide different levels of surface roughness dependent on the classification of composites tested.

Materials and Methods

Material and instrument selection – Two types of restorative resin composites and two one-step finishing-polishing systems were used in this study. IPS Empress Direct[a] was selected as the nanohybrid resin composite. Filtek P90[b] was selected as the microhybrid resin composite. Table 1 shows the characteristics of the two composites. For finishing-polishing systems, PoGo One Step Diamond Micro-Polisher[c] and OptraPol Next Generation[a] were selected. PoGo uses a polymerized urethane dimethacrylate resin, silicon oxide and fine diamond powder. OptraPol uses a mixture of silicone rubber, aluminum oxide, and iron oxide, with micro-fine diamond crystallites. Both polishers use diamond as the main abrasive type. The detailed compositions of the two polishing systems are shown in Table 2.

Specimen preparation - Using the two materials, a total of 120 discs were fabricated (n=120). The resin material was packed into cylindrical Teflon molds (10 mm in diameter and 2 mm thickness) using an OptraSculpt[a] modeling instrument. The molds were confined between two opposing transparent Mylar[d] strips. A glass microscope slide (1 mm thick) was then placed over the Mylar strips before curing. Constant pressure was applied to extrude excess material and flatten the surface. All of the restorative materials were polymerized following the manufacturers' recommendations. Blue-phase C8[a] LED curing light, emitting high-intensity light at 1,200 mW/cm^2, was used. Before each polymerization, the emitted light was verified using the radiometer included in the curing unit. Each side of the specimen was exposed to the curing light for 40 seconds. The guide of the light was positioned perpendicular to the specimen's surface at a distance of 1 mm. The cured samples were then stored in water in a dark environment at 37°C for 24 hours prior to finishing.

Polishing procedures - To avoid discrepancies in different techniques, one operator performed all the procedures. To analyze the surface roughness, before and after polishing, the specimens were divided into six groups of n=20 each. The groups were labeled accordingly: IPS-Mylar; IPS-PoGo; IPS-OptraPol; P90-Mylar; P90-PoGo; P90-OptraPol. The control groups (IPS-Mylar, P90-Mylar) received no finishing-polishing treatment. The remaining four groups were wet-finished with a 600-grit silicon carbide abrasive paper[d] (SiC) on a rotary polisher (Buehler Metaserv[e]) for 30 seconds to obtain a baseline

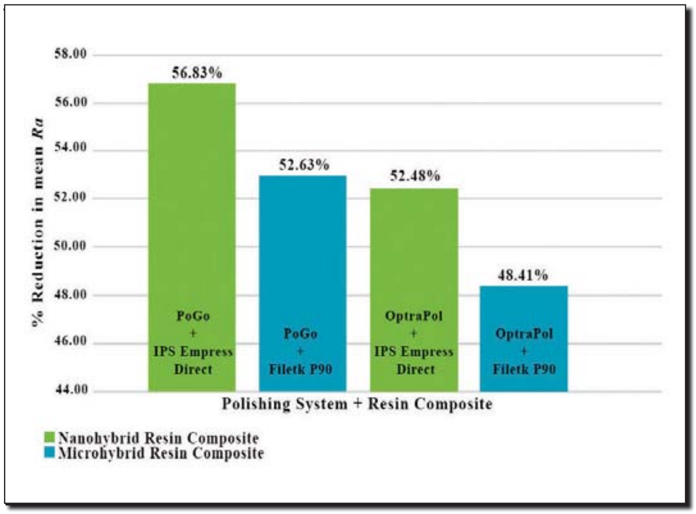

Fig. 1. Comparison of the percentage reduction in surface roughness after polishing, from minimum to maximum, for each system-material pair. Highest percentage value indicates maximum reduction in surface roughness.

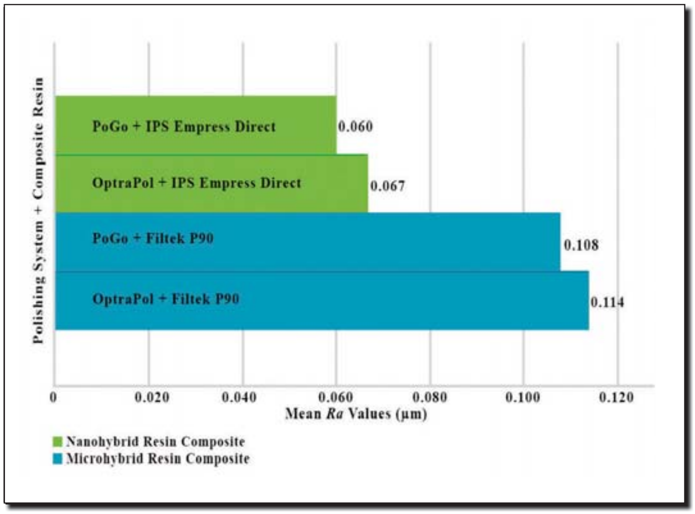

Fig. 2. Comparison of the surface roughness values after polishing, from minimum to maximum, for each system-material pair. Smallest Ra (µm) value indicates the smoothest surface.

Table 3. Comparison of Ra values before and after polishing.

Group	N	Ra value µm (SD) before polishing*	P-value	Ra value µm (SD) after polishing*	P-value
IPS-Mylar (Control)	20	0.051 (±0.007)	<0.0001†	0.051 (±0.009)	<0.0001†
IPS-PoGo	20	0.139 (±0.134)	<0.097§	0.060 (±0.064)	<0.088§
IPS-OptraPol	20	0.141 (±0.145)		0.067 (±0.070)	
P90-Mylar (Control)	20	0.049 (±0.004)	<0.0001†	0.048 (±0.004)	<0.0001†
P90-PoGo	20	0.228 (±0.227)	<0.239§	0.108 (±0.101)	<0.187§
P90-OptraPol	20	0.221 (±0.225)		0.114 (±0.110)	
Total	120				

*Median (IQR); ‡Kruskal-Wallis H test; §Between the two polishing systems; †Comparison to both non-controls.

before using the finishing-polishing systems. The surface roughness of the discs was measured before polishing. For both PoGo and OptraPol, flat micro-polisher discs were utilized to obtain direct contact with the specimen surface. Polishing was performed using a slow-speed hand piece under dry conditions for 30 seconds at 12,000 rpm. Light pressure was applied using a constantly moving, repetitive stroking action in one direction to prevent heat buildup and the formation of surface grooves. After polishing, the specimens were ultra-sonicated in a water bath for 5 minutes to remove any remaining debris. All the specimens were stored in water in a dark environment at 37°C for 24 hours prior to measuring surface roughness.

Surface roughness measurements - A surface profilometer Talysurf Intra[f] was used to measure the surface roughness (Ra) value of each specimen before and after polishing. The resolution was set to 0.01 µm, the interval (cutoff length) was set to 0.8 mm, and the traverse length of 2.5 mm was selected. The profilometer was calibrated using a standard highly polished tungsten carbide precision ball before each measuring session. For each surface, Ra readings were obtained thrice using a conisphere diamond stylus with a radius of 2 µm and a speed of 0.1 mm/second. The mean Ra value of the three readings for each surface was calculated and recorded as the Ra value of the specimen.

Statistical analysis - Data were analyzed using IBM SPSS[g] statistical software, vers. 22. Descriptive statistics, medians and inter-quartile ranges (IQRs) were used to describe the skewed disc Ra (surface roughness) values (outcome variable). Non-parametric statistical tests were used to analyze the results. For each material, the Kruskal-Wallis H test was used to compare the mean ranks of the Ra values of each polishing treatment according to the resin used, whereas the Mann-Whitney U test was used to determine the effects of each polishing system on the two types of composite resin. A P-value of ≤ 0.05 was considered statistically significant.

Results

Statistical analysis revealed that maximum reduction in the surface roughness (mean Ra value) was achieved by polishing IPS Empress Direct with PoGo polishing system with a reduction of 56.83% with $P< 0.001$. PoGo also recorded a reduction of 52.63% for the P90-Pogo group with $P < 0.002$. OptraPol showed a comparatively similar outcome with a highly significant reduction of 52.48% for IPS Empress Direct with $P< 0.001$. The P90-OptraPol group exhibited the least reduction in surface roughness with a 48.41% ($P< 0.025$) reduction in the mean Ra value (Fig. 1).

Both materials recorded highly significant differences, regardless of the polishing system used when compared to the control with $P< 0.0001$ (Table 3). When strictly comparing mean Ra values to the control groups, PoGo polishing system recorded the lowest surface roughness. Pogo results were highly significant in case of both IPS Empress Direct and Filtek P90 composite materials, with mean Ra values of 0.060 µm and 0.108 µm, respectively at $P< 0.001$ and $P< 0.002$. OptraPol on the other hand, recorded mean Ra values of 0.067 µm (P< 0.001) and 0.114 µm (P< 0.025) for both IPS Empress Direct and Filtek P90 respectively. The comparison within the groups for both IPS-PoGo and IPS-OptraPol after polishing was marginally significant with P< 0.088. The P90 groups (P90-Pogo and P90-OptraPol) recorded no significance with P< 0.187. An overall comparison of the surface roughness values, from minimum to maximum, for each system-material pair is shown in Fig. 2.

Discussion

The results of the surface smoothness of a restoration are typically assessed by measuring the mean height of the surface roughness compared to a reference mean line. The most commonly used parameter to express surface roughness is with an arithmetic mean value Ra.[9,27] Patient discomfort and bacterial retention are two complications caused by high surface roughness. It has been reported that restorations that are not finished to a Ra value of at least 0.28-0.30 µm result in increased patient discomfort.[27] Additionally, Ra values above 0.2 µm lead to increased plaque buildup, higher risk for caries and periodontal inflammation.[19,28] In this study, the results of the finishing-polishing systems were clinically acceptable because the roughness values recorded were significantly less than 0.2 µm.

The composites were purposefully cured using Mylar strips, to prevent common defects caused by oxygen in the air when curing resin-based composites (RBCs) with LED light. Composites can be cured without using appropriate matrix strips, but oxygen in the air interferes with the polymerization process and can result in leaving the surface of the composites with an oxygen-inhibited layer. The resulting outermost layer is uncured, sticky, rich in soft resin and can cause extensive damage to the finishing-polishing systems.[1,29]

The use of the matrix strips minimizes the presence of an oxygen-inhibited layer and usually results in maximum surface smoothness. The Ra values obtained by Mylar strips (control) also exhibited maximum surface smoothness and the results were in agreement with previous studies.[6,30] However, the smooth surface obtained by matrix strips is not practical and additional contouring, finishing-polishing is imperative due to intricate occlusal structure.[31,32] In addition, further finishing-polishing is necessary to remove the softer outermost surface material by at least 0-25 mm in order to obtain a harder, more wear resistant surface that is both maintainable in the long run and esthetically more stable.[30,32]

The study revealed significant differences in the surface roughness between the two types of the resin composites after polishing treatments at P< 0.0001. Both Filtek P90 (microhybrid) and IPS Empress Direct (nanohybrid) resin composites were significantly affected by the polishing systems compared with the control (unpolished) surface. Each pair of a polishing system with a composite material recorded different Ra values. These roughness values were influenced by both the composition of the polishing systems and the resins.

When observing the composition of the two polishing systems used, PoGo and OptraPol both utilize diamond as the main abrasive. Diamond is a harder abrasive compared to other materials such as alumina[33] or carbide.[34] Literature states that in order for an abrasive system to produce efficient results, the abrasive particles should be comparatively harder than the filler material.[1,31] If the opposite is true, the harder particles are left protruding out and the soft resin matrix is removed, leaving a comparatively rougher surface.[33,35] Diamond, which is composed of carbon, is the hardest substance known and comparatively harder than all the materials used in both the composites.[34] The filler volume and weight of the filler material can also play a role in protecting the soft resin matrix. The matrix in nanohybrids is better protected than microhybrids, as the filler particles are compacted together more closely which ensures smaller inter-particle spacing.[1] This is one of the reasons IPS Empress Direct (nanohybrid) recorded lower Ra values than Filtek P90 (microhybrid).

Quiroz & Lentz[36] reported that because of the mixture of different sizes of particles in hybrid composites, diamond-based polishers can produce uneven and irregular surfaces. The irregularities on the composite surface are the result of diamond polishers frequently tearing out the filler particles. However, Goldstein & Waknine[37] concluded in their research that although diamond burs gave rougher surfaces, overall the gouges were not as deep as with carbide burs and could therefore more easily be polished to a smooth surface. The same was observed by Kaplan et al,[38] who reported that diamond based polishing systems can cause a greater degree of gouging but depending on the type of composite material these gouges are not as deep and therefore can be polished to a smoother surface. This could imply that the irregularities caused by diamond polishing instruments depend on the type of hybrid composite and in turn influence the final outcome of the polishing procedure. This observation can explain the outcome of different Ra values for each pair. It can also explain why the microhybrid based composite, Filtek P90, polished with OptraPol polishing system recorded the lowest percentage reduction in surface roughness.

Polishing instruments can have a common type of abrasive, yet clinically perform differently depending on the size, spacing, uniformity, exposure and bonding of the abrasive particles.[34] The average abrasive particle size of OptraPol (12 µm) is smaller than that of PoGo (20 µm) but the latter contains finer diamond particles than OptraPol. This distinction had an effect on the surface roughness results recorded, as PoGo produced a higher percentage reduction in surface roughness compared to OptraPol. Besides, the size of the abrasive particles, the backing material of the abrasive is another factor that can influence the polishing effect. Marigo et al[39] reported that the flexibility of the backing material in which an abrasive is embedded contributes to the final polishing outcome. The flexible micro-polisher discs in Pogo tend to polish the composite surface more uniformly resulting in a smoother surface.[1,30] The better performance of PoGo can also be attributed to the cured urethane dimethacrylate resin delivery medium compared to the mixture of silicones in OptraPol.[33]

The composition of the resin composites equally contributed in producing varied Ra values when subjected to the two polishing systems. IPS Empress Direct recorded lower Ra values when compared with the Filtek P90. This finding may be credited to the presence of nanohybrid fillers, which enhance polishability of the materials. The literature supports this finding by stating that the nanohybrid materials exhibit a smoother surface and more strength compared with microhybrid resins.[20,25] The results also coincide with other studies that have concluded that smaller surface roughness values are linked with smaller filler particles in nanohybird composites when compared to larger filler particle size in microhybrid composites. As larger filler particles, especially irregular ones tend to protrude from the surface and can result in greater surface roughness.[40]

The prepolymerized nanofillers in nanohybrids efficaciously increase the compactness and the filler load.[1,40] As stated earlier, the lesser load compactness combined with larger filler particle size of microhybrid composites results in having irregular particles plugged out of the surface and thus record a higher Ra value.[31,40] The above fact is more evident since the nanohybrid composite (IPS Empress Direct), with smaller filler particles recorded comparatively lower surface roughness values compared to microhybrid groups when subjected to the same polishing system.

Similar to the results in this research, many studies have concluded that nanohybrids perform better than microhybrids[20,21,40] and PoGo polishing systems produce smoother surfaces when compared to various other polishing systems.[1,6,30,41] Contrary to the results of this study, Korkmaz et al[5] reported higher surface roughness values produced by PoGo when compared to OptraPol for a microhybrid (Filtek Z250) composite and two nanohybrid (Tetric EvoCeram, Grandio) composites.

Antonson et al[22] and Santos et al[23] concluded that not only does composition of restorative materials have a major impact on the Ra values, the type of polishing systems and the techniques used also contribute directly to the final surface roughness of the composites. This is attributed to the efficiency of the finishing-polishing systems which rely on numerous factors such as type of impregnated abrasive material, flexibility and reach of the backing material, shape of the discs, cups, points in direct contact with the restoration, hardness of the abrasive compared to the composite material, pressure applied, speed of the instrument, time spent with each abrasive, and the experience, technique, and proficiency of the operator.[1,31]

In agreement with the above studies, the roughness values recorded in this study also varied significantly with different combinations of polishing systems and composite materials. These values were the result of similar contributing factors as cited earlier. Thus, the hypothesis that different brands of one-step polishers would provide different levels of surface roughness dependent on the classification of composites tested, was accepted. In addition, the research concluded that the PoGo polishing system exhibited increased surface smoothness compared to OptraPol; IPS Empress Direct nanohybrid resin composite exhibited increased surface smoothness compared to Filtek P90 microhybrid material when polished with either polishing system; IPS Empress Direct polished with PoGo exhibited the maximum surface smoothness; Filtek P90 polished with OptraPol resulted in the least surface smoothness.

The present study had a few limitations. Being an in vitro study, the studied specimens were flat, whereas clinically, composite restorations have different shapes depending on the surface (i.e., convex or concave) which might make the application of a finishing-polishing procedure difficult to perform in vivo. The study suggests that long-term in vivo trials are necessary, with multiple devices and materials, to identify enduring, efficient and cost-effective interactions between the composite materials and finishing-polishing systems. To keep up with the dental technology advancements, continuous studies are needed to determine which polishing systems are best suited for which resin composites to achieve optimum results.

a. Ivoclar Vivadent, Schaan, Liechtenstein.
b. 3M ESPE, St. Paul, MN, USA.
c. Dentsply/Caulk, Milford, DE, USA.
d. DuPont, Wilmington, DE, USA.
e. Buehler, Esslingen, Germany.
f. Taylor Hobson Ltd., Leicester, UK.
g. SPSS, New York, NY, USA.

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