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Finishing Systems on the Final Surface Roughness of Composites

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Abstract

Aim: This study evaluated differences in surface roughness of a microhybrid (Gradia™ Direct, GC America) and a nanofil (Filtek™ Supreme, 3M™ ESPE™) composite using four polishing systems: PoGo™/Enhance® (DENTSPLY/Caulk), Sof-Lex™ (3MTM ESPE™), Astropol® (Ivoclar Vivadent), and Optidisc™ (KerrHawe).

Methods and Materials: An aluminum mold was used to prepare 2 X 60 composite disks (10 mm X 2 mm). Composite was packed into the mold, placed between two glass slabs, and polymerized for 40 seconds from the top and bottom surfaces. Specimens were finished to a standard rough surface using Moore's disks with six brushing strokes. Specimens were rinsed and stored in artificial saliva in individual plastic bags at 36°C for 24 hours prior to testing. Specimens were randomly assigned to one of the four polishing systems and were polished for 30 seconds (10 seconds per grit) with brushing strokes according to the manufacturer's instructions. Mean surface roughness (Ra) was recorded with a surface-analyzer 24 hours after storage in artificial saliva, both before and after polishing. Means were analyzed using two-way and one-way analysis of variance (ANOVA) and Tukey multiple comparison tests at $p < 0.05$.

Results: There was a statistically significant difference for baseline measures between Filtek™ and Gradia™ ($p=0.0338$). For Filtek™, Sof-Lex™ provided a significantly smoother surface (Ra=0.80 ± 0.21) than Optidisc™ (Ra=0.93 ± 0.28), Astropol® (Ra=1.15 ± 0.24), and Pogo™/Enhance® (Ra=1.39 ± 0.39). For Gradia, Sof-Lex™

provided a significantly smoother surface (Ra=0.47 ± 0.09) and Astropol® provided a significantly rougher surface (Ra=1.39 ± 0.19) than Pogo™/Enhance® (Ra=1.11 ± 0.20) and Optidisc™ (Ra=1.15 ± 0.18). There was no significant difference in roughness between composites for individual polishing systems (p=0.3991).

Conclusion: Filtek™ specimens were smoother than Gradia™ specimens after baseline roughening. Sof-Lex™ provided the smoothest final surface when used with either composite. Astropol® provided a rough surface for Gradia™ specimens.

Keywords: Finishing systems, microhybrid composites, surface roughness, polishing systems, nanofil composites

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Introduction

The esthetic appearance and lack of mercury are characteristics that have made composites a desirable and popular restorative material among clinicians. There are many kinds of composite materials. They vary by the filler type and content which affects their handling characteristics and physical properties.

Mitra et al.[1] compared properties of nanocomposites with other commercial composites in a laboratory setting. The results showed nanocomposites possess high translucency, high polish, and polish retention similar to microfills while having physical properties and wear resistance equivalent to some hybrids.[1] Therefore, the strength and esthetic properties of the nanocomposites should allow the clinicians to use them for both anterior and posterior restorations.[1]

The esthetics of composite restorations are strongly influenced by the final surface polish at initial placement.[4,10,11] Restorations that are smooth, uniform, and highly polished are more esthetic and can be more easily maintained than restorations with rougher surfaces. The result is longer lasting restorations and satisfied patients.[2] A smooth surface restoration is ideal to prevent secondary caries and stains resulting from plaque retention.[2,11,12] It has been demonstrated plaque accumulates on composite specimens with a surface roughness (Ra) of 0.7-1.44µm.[2] However, it is difficult to obtain a uniform, well-finished, and polished surface with all composites. Even though the resin matrix is similar among all types (TEGDMA/BisGMA), composite fillers differ in size and hardness. In addition, the fillers differ by percent weight, which is the amount of filler in each type of composite. The higher the percent weight indicates a greater amount of filler in a composite. The result is a highly viscous material. On the other hand, flowable composites can be obtained by reducing the percent weight of filler in proportion to the amount of resin matrix. Altering the matrix to filler ratio will have a great impact on the polishability of a composite.

Polishing is the reduction of roughness and scratches created by the finishing instruments.[18] Within composite material, the resin matrix and filler do not polish to the same degree due to differences in hardness. Small voids form on the surface from the removal of resin matrix and displacement of filler particles during polishing. This causes microscopic irregularities on the surface after polishing. Therefore, both resin matrix and fillers play a role in the final smoothness of the composites.

Several studies demonstrated the smoothest surface for composite restorations is achieved when using a Mylar strip in contact with the restoration during curing.[3,4] Therefore, it has been an accepted goal of polishing to duplicate that standard.[3,16] However, the use of Mylar strips does not eliminate the need for contouring and finishing.[3,4,5] Thus, it is necessary to use a finishing and polishing technique to produce the smoothest possible composite restoration.

Various types of polishing systems have been evaluated in the literature. Several studies reported flexible aluminum oxide disks were the best instruments for producing smooth surface restorations compared to abrasive impregnated disks.[4,6,7] However, one study showed both types of disks provided a similar surface finish.[8] Recently, new polishing systems have been introduced, such as one-step diamond coated disks and damage-proof aluminum oxide disks.

A study by Chung[8] compared the surface roughness of hybrid and microfilled composites using three different types of polishing systems. As expected, the surface of a microfilled composite was significantly smoother than the hybrid composite when polished. Hoelscher et al.[13] revealed Enhance® and Sof-Lex™ produced significantly smoother surfaces compared to finishing burs. Setcos et al.[14] compared seven composites based on surface roughness using three types of polishing systems. This study concluded Super-Snap™ and Sof-Lex™ systems produced the smoothest surfaces for all composites tested. Enhance® produced clinically acceptable but less smooth surfaces. Therefore, they concluded the Enhance® system may be used clinically in areas not accessible to disks such as occlusal surfaces.[5,14]

A study by Stoddard et al.[15] was designed to evaluate the effectiveness of various polishing instruments on eight different composites. Moore™ disks provided a surface similar to that of a Mylar strip.[15] Super-Snap™ and Moore™ disks produced a smoother surface than Sof-Lex™ for anterior composites, but gave relatively similar results for posterior composites. This study suggested surface roughness could be determined by both the characteristics of the polishing instruments and by the properties of the composite (filler type, particle size, amount of filler, and type of resin). They concluded that using identical instruments on different composites produced different surface roughness. Other factors that could affect polishing results were amount of pressure used, the orientation of the abrading surface, and the amount of time used with each abrasive material.[15]

Fruits et al.[19] evaluated the affect various motions used during polishing had on developing an optimal surface. The results of this study showed a planar motion (the axis of rotation of the abrasive device is perpendicular to the surface being smoothed) achieved the lowest average roughness values.

A recent study by Turkun et al.[18] evaluated the effectiveness of PoGo™, a new diamond micro-polisher, which according to manufacturer's claims, reduces the steps and time necessary to polish composites. The results show that PoGo™ produced surface roughness comparable to that of Mylar strips for all composites.[18] However, this study showed that smoothness was not dependent on the use of the systematic series of instruments and polishing materials characterized by decreasing abrasive particle size. On the other hand, another study by Herrgott et al.,[11] using scanning electron microscope, reported Sof-Lex™ disks produced surface finish similar to Mylar strips.

The purpose of this study was to evaluate the surface roughness of two types of composites using three different polishing systems.

Methods and Materials

Two light-cured composites (shade A3) were used in this study: Gradia™ Direct (GC America, Alsip, IL, USA) and Filtek™ Supreme (3M™ ESPE™, St. Paul, MN, USA) listed in Table 1.

All specimen preparation, finishing, and polishing procedures were done by the same investigator to reduce variability. An aluminum mold was used to prepare 10 mm x 2 mm disk specimens. The mold was placed on a clean glass slab and a composite was packed into the mold. These specimens were polymerized for 40 seconds from the top and bottom surfaces using a Demetron 501 curing light (Kerr Manufacturing Co., Orange,

Table 1. The composition and manufacturers of the composites tested.

Composites	Composition	Manufacturers
Filtek™ Supreme (nanofil)	Combination of non agglomerated/non-aggregated, 75nm silica nanofiller, and a loosely bound agglomerate silica nanocluster consisting of agglomerates of primary silica nanoparticles of 75nm size fillers.	3M ESPE Dental Products, St. Paul, MN, USA
Gradia™ Direct (microhybrid)	Micro-fine silica, pre-polymer resin fillers, urethane dimethylacrylate co-monomer matrix.	GC America, Alsip, IL, USA

CA, USA). The intensity of the light was checked every 15 specimens with an Espectro-photometer (3M™ ESPE™, Minneapolis, St. Paul, MN, USA) to ensure a constant light output. Sixty disks were fabricated for each composite for a total of 120 disks. The cured specimens were finished with six brush strokes, in the same direction (an arrow was drawn to record the direction), using Moore's disks (E.C. Moore Co., Dearborn, MI, USA) to produce a standard rough surface. The specimens were rinsed and stored in Saliva Substitute (Roxane Laboratories Inc., Columbus, OH, USA) in individual plastic bags at 36°C 24 hours prior to reading.

Baseline surface roughness measurements were made for all the disks using a profilometer (Surfanalyzer 4000, Mahr Federal Inc., Providence, RI, USA). Three measurements were made for each specimen at each time interval. Each was scanned with a high-resolution diamond stylus (EPT-01049, 0.001 inch/2.54 µm radius). Two lines were drawn that intersected the arrow at a 60° angle on the surface of the composites. The measurements were within 1 µm of accuracy, and the average surface roughness was calculated by taking the arithmetic mean roughness from the three lines. The mean surface roughness was determined for each sample, and the overall surface roughness was determined for each composite group.[14]

The specimens were randomly assigned to one of the four polishing systems: PoGo™/Enhance® (DENTSPLY/Caulk, Milford, DE, USA), Optidisc™ (KerrHawe, Bioggio, Switzerland), Astropol® (Ivoclar Vivadent, Amherst, NY, USA), and Sof-Lex™ (3M™ ESPE™, St. Paul, MN, USA), listed in Table 2. The same slow-speed handpiece was used for all systems. The polishing procedure used consisted of repetitive strokes for 30 seconds, ten seconds per step of the system, to prevent heat buildup and formation of grooves. A conscious effort was made to standardize the strokes, downward force, and the number of strokes for each polishing procedure. According to manufacturer's instructions, Sof-Lex™ and Optidisc™ were used dry whereas Astropol® and Pogo™/Enhance® were used with water. Mean surface roughness was recorded again after polishing and storage for 24 hours in artificial saliva.

Means were analyzed using two-way and one-way analysis of variance (ANOVA) and Tukey multiple comparison tests at $p<0.05$.

Results

After the baseline surface roughening procedure, Filtek™ Supreme had a significantly smoother baseline surface (Ra=4.74) when compared to Gradia™ Direct specimens (Ra=5.05) p=0.0338 (Table 3). After the specimens were polished, the surface roughness readings were not significantly different for specimens of the two composites (Filtek™ Supreme Ra=1.07 and Gradia™ Direct Ra=1.03) (Table 4).

Data for each polishing system sub-group for Filtek™ Supreme is shown in Table 5. Enhance® PoGo™ produced the roughest surface compared to the other finishing systems (Ra=1.39 ± 0.39), and Sof-Lex™ produced the smoothest surface (Ra=0.80 ± 0.21). A highly significant difference

Table 2. The composition of the polishing systems investigated.

Polishing Systems	Composition	Manufacturers
PoGo™/Enhance®	Diamond coated micro-polisher	Dentsply/Caulk, Milford, DE, USA
OptiDisc	Aluminum oxide particles	KerrHawe, Bioggio, Switzerland
Astropol®	• **F (grey):** Caoutchouc, silicon carbide, aluminum oxide, titanium oxide, iron oxide. • **P (green):** Caoutchouc, silicon carbide, aluminum oxide, titanium oxide, iron oxide. • **HP (pink):** Caoutchouc, silicon carbide, aluminum oxide, titanium oxide, iron oxide, diamond dust.	Ivoclar Vivadent, Amherst, NY, USA
Sof-Lex™ Pop-On Disks	• Medium aluminum oxide disc (40 µm) • Fine aluminum oxide disc (24 µm) • Ultra-fine aluminum oxide disc (8 µm)	3M ESPE Dental Products, St. Paul, MN, USA

Table 3. Baseline surface roughness of composites.

Composite	Sample Numbers	Baseline Ra (µm)	p-value*
Filtek™ Supreme	60	4.74	A
Gradia™ Direct	60	5.05	B

* Values are significantly different at $p=0.0338$

Table 4. Polished surface roughness of composites.

Composite	Sample Numbers	Baseline Ra (µm)	p-value*
Filtek™ Supreme	60	1.07	A
Gradia™ Direct	60	1.03	A

* Values are significantly different at $p=0.3991$

Table 5. Polished surface roughness of Filtek™ Supreme.

Sample Numbers	Polishing System	Mean Ra ± SD (µm)	p-value*
15	PoGo™/Enhance®	1.39 ± 0.39	A
15	Astropol®	1.15 ± 0.24	AB
15	OptiDisc™	0.94 ± 0.25	BC
15	Sof-Lex™	0.80 ± 0.21	C

* Values with different letters are significantly different at $p<0.0001$

Table 6. Polished surface roughness of Gradia™ Direct.

Composite	Polishing System	Mean Ra ± SD (µm)	p-value*
15	Astropol®	1.39 ± 0.10	A
15	OptiDisc™	1.15 ± 0.18	B
15	PoGo™/Enhance®	1.11 ± 0.20	B
15	Sof-Lex™	0.47 ± 0.09	C

* Values with different letters are significantly different at $p<0.0001$

was detected in surface roughness between Enhance® PoGo™ and Sof-Lex™ ($p<0.0001$). For Gradia™ Direct specimens, the finishing systems produced different results (Table 6). Astropol® specimens had the roughest surface (Ra=1.39 ± 0.10), while Sof-Lex™ specimens had again a significantly smoother surface (Ra=0.47 ± 0.09) $p<0.0001$.

Discussion

Finishing and polishing are significant procedures after placement of resin-based composite restorations. Proper finishing and polishing have been related to less plaque retention and margin discoloration, thus, enhancing longevity and esthetics of the restorations.[2] In several studies the smoothest surfaces were produced with Mylar strips on all composites.[3,10,15]

After a standard roughening procedure, this study showed there was a significant difference in surface roughness between the two composites tested. The surfaces of the nanofilled Filtek™ Supreme were significantly smoother than those of the microhybrid, Gradia™ Direct (Table 3), which was in agreement with Stoddard et al.[15] This present study showed identical instruments on different composites produced different surface finish results. This difference was probably due to the composites having different particle sizes. One could speculate other factors could have affected the results, such as amount of pressure used, the orientation of the abrading surface, and the amount of time used with each abrasive material. However, the pressure used in this study was controlled by a conscious effort to standardize the stroke with a downward intermittent force as well as the number of strokes for each polishing procedure. In a clinical situation overheating would be detrimental to the pulp and, therefore, it is avoided by intermittent strokes to the surface, allowing just enough time for the composite to cool down. A planar motion was used in all the specimens; as a previous study demonstrated, this motion produced significantly lower mean surface roughness values.[19] The amount of time to finish each sample with each abrasive material was also carefully controlled. Therefore, the difference in baseline surface roughness readings was likely due to inherent differences between the two composites.

The surface smoothness of Filtek™ Supreme and Gradia™ Direct were not significantly different after polishing with the tested polishing systems (Table 4), which is in agreement with Hoelscher et al.[13] No significant difference was found in surface roughness when specimens were polished with either Enhance® or Sof-Lex™. It was concluded the smoothest finish for microfilled composites was achieved with either Sof-Lex™ or Enhance®. Hergott et al.,[11] showed similar results and concluded surface roughness of finished composites was not dependent on the size of filler particles.

Sof-Lex™ resulted in significantly smoother surfaces when compared to the other finishing systems for both Filtek™ Supreme and Gradia™ Direct specimens. The findings of the present study are in agreement with previous studies which also showed a smoother finish being achieved with the Sof-Lex™ system.[7,8,14] However, Hoelscher et al.[13] found no difference between Enhance® and Sof-Lex™ systems.

To test the finishing systems, the composite specimens were roughened using Moore's disks to achieve a standard rough baseline surface.

Since the aim of this study was final finishing, the coarsest grit of the Sof-Lex™ system was not used because they are primarily indicated for contouring and gross finishing. Therefore, all systems had a sequence of three grits. Each grit was used for ten seconds for a total time of 30 seconds, which is more than normally used in a clinical setting. However, the increased time was necessary because the surface area of the specimens was much greater than any dental restoration.[10]

It is interesting to note this study was in contrast with the results of Turkun et al.,[18] who showed Pogo™ provided a smoother surface compared with two conventional multi-step polishing systems (Enhance® and Sof-Lex™) also used in this study. They concluded the Pogo™ finish resembles a Mylar strip finish, while Enhance® and Sof-Lex™ produced rougher surfaces.

According to Mitra et al.[1] the wear patterns of microhybrids were similar to hybrid composites but different from nanocomposites. Individual filler particles were displaced, leaving voids on the surface. The filler particles were smaller in nanocomposites, thus, leaving smaller voids and resulting in a significantly smoother surface. Their study showed smoothness was not dependent on the use of a systematic series of instruments and polishing materials characterized by decreasing abrasive particle size, which is not related to the results in this current study.

An ideal polishing system must have abrasive particles which are harder than the filler materials, therefore, allowing reduction of both the resin matrix and filler particles of the composites during polishing. If the abrasive particles were softer than the fillers, then only the resin matrix would be removed and filler particles would be protruding from the surface. The hardness of aluminum oxide, which is present in most of the polishing systems, is significantly higher than the hardness of silicone oxide as well as most filler particles in composites.[20] Thus, the use of systems containing aluminum oxide tend to produce smoother surfaces.

To make this study more clinically relevant, instead of using Moore's disks to provide a standardized roughened surface, a finishing bur could have been used. In a clinical situation a finishing bur is often used for initial smoothing and shaping after curing the composite. Then the restoration is polished to create its final surface. Also, interpretation of results of *in vitro* studies may vary from *in vivo* studies. In clinical settings, the surface of composite restorations is not usually flat. They are generally convex or concave with limited access by the finishing systems. Therefore, the systems that have cup and cone shaped finishers are very convenient to access the irregularities of tooth anatomy. Further studies are needed where finishing techniques can be tested in clinical settings. In this study all finishing systems were found to be clinically acceptable to polish the composites tested.

Conclusion

From the results of this study, it can be concluded the Filtek™ Supreme specimens were smoother than the Gradia™ Direct specimens after standard baseline roughening. The Sof-Lex™ system produced the smoothest final surface for both composites. Polishing with Astropol® resulted in a significantly rougher surface for Gradia™ Direct specimens.

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