©Operative Dentistry, 2019, **44-3**, E122-E132

Influence of Polishing Systems on Surface Roughness of Composite Resins: Polishability of Composite Resins

L St-Pierre • C Martel • H Crépeau • MA Vargas

Clinical Relevance

Not all composite resins have the same polishability, nor do all polishers produce acceptable surface roughness.

SUMMARY

Objectives: The objective of this *in vitro* study was to compare, with a threshold value of 200 nm, the surface roughness obtained when using 12 different polishing systems on four different composite resins (microfill, nanofill, and two nanohybrids).

Methods and Materials: A total of 384 convex specimens were made using Durafill VS, Filtek Supreme Ultra, Grandio SO, and Venus Pearl. After sandblasting and finishing with a medium-grit finishing disc, initial surface roughness was measured using a surface roughness tester. Specimens were polished using 12 different polishing systems: Astropol, HiLuster Plus, D♦Fine, Diacomp, ET Illustra, Sof-Lex Wheels, Sof-Lex XT discs, Super-Snap, Enhance/Pogo, Optrapol, OneGloss and ComposiPro Brush (n=8). The final surface roughness was measured, and data were analyzed using two-way analysis of variance. Pairwise comparisons were made using protected Fisher least significant difference.

Results: There were statistical differences in the final surface roughness between polishing systems and between composite resins ($p<0.05$). The highest surface roughness was observed for all composite resins polished with OneGloss and ComposiPro Brush. Enhance/Pogo and Sof-Lex Wheels produced a mean surface roughness greater than the 200-nm threshold on Filtek Supreme Ultra, Grandio SO, and Venus Pearl. Data showed that there was an interaction between the composite resins and the polishing systems.

Conclusions: A single polishing system does not perform equally with all composite resins. Except for Optrapol, multi-step polishing systems performed generally better than one-step

*Laurie St-Pierre, DMD, MS, Université Laval, Operative Dentistry, Quebec City, Quebec, Canada

Caroline Martel, dental student, Université Laval, Quebec City, Quebec, Canada

Hélène Crépeau, MS, PStat, Université Laval, Department of Mathematics and Statistics, Quebec City, Quebec, Canada

Marcos A. Vargas, DDS, MS, professor, University of Iowa, Department of Family Dentistry, Iowa City, IA, USA

*Corresponding author: 2420 Rue de la Terrasse, Quebec City, Quebec G1V 0A6, Canada; e-mail: laurie.st-pierre@fmd.ulaval.ca

DOI: 10.2341/17-140-L

systems. Excluding Enhance/Pogo, diamond-impregnated polishers led to lower surface roughness. Durafill VS, a microfill composite resin, may be polished more predictably with different polishers.

INTRODUCTION

Composite resin is extensively used as a dental restorative material, as it is very conservative and has high esthetic potential. Although composite resin is used frequently, it remains a challenge to identify appropriate polishing systems to obtain high surface gloss. A smooth surface is important to prevent discoloration and plaque accumulation, which can increase caries risk and gingival inflammation.[1,2] A surface roughness value of 200 nm has been established as the threshold under which bacterial adhesion could be prevented.[3] Long-term success and the esthetics of composite resin restorations may be improved through proper polishing, which prevents marginal staining and discoloration.[4-8] Moreover, proper polishing may preserve high surface quality and gloss over time.[9]

The surface quality of composite resin is influenced by several factors, including filler particle size, filler loading and resin content, type of filler, and particle morphology.[10-13] Polishing success is reported to be increased when smaller particles are included in composite resin materials.[14] Microfilled composite resins are known to obtain the highest gloss and surface quality because of their small particles and high resin content. However, microfilled composite resins have lower mechanical properties than universal composite resins, such as nanohybrid and nanofill composite resins.[12]

Several systems are available to finish and polish composite resin materials. These systems require one or multiple steps, and they differ greatly in their composition, presentation, type and hardness of abrasive particles. These differences significantly influence the surface gloss and roughness of composite resin materials.[8,9,15-19] Considering that simplified systems are less time-consuming, it is important for dental practitioners to know what systems offer adequate surface quality to improve both esthetics and longevity of composite resin restorations.

Several studies[9,16-25] have assessed different finishing and polishing systems using various types of composite resins. However, many of these studies limit the number of finishing/polishing systems evaluated and use discs of composite resin presenting flat surfaces. To the knowledge of the authors, there is currently no study comparing the surface roughness obtained when using several different polishing systems on convex composite resin surfaces, as is normally the case in clinical situations.

Figure 1. *Impression of a Vita Shade guide in which composite resin was inserted in one increment.*

Figure 2. *A flat-end screw was inserted in the back of the specimen in its cervical portion to a depth of approximately 1.5 mm for handling purposes.*

The purpose of this study was to compare the surface roughness obtained when using 12 different polishing systems commonly used in private dental practice on four different composite resin specimens with a convex surface. The main null hypothesis was that there is no difference in surface roughness between the different polishing systems tested for each composite resin. Secondary null hypotheses were that there are no differences in the surface roughness between the four composite resins tested for each polishing system and that there is no interaction among the two variables: polishing system and composite resin.

METHODS AND MATERIALS

Impressions of a VITA shade tab (VITA North America, Yorba Linda, CA, USA) were made using polyvinyl siloxane putty material (Extrude XP, Kerr Corporation, Orange, CA, USA) Specimens of each composite resin were made by placing composite resin in one increment into the mold (Figure 1). A total of 384 specimens were fabricated: 96 specimens were made from a nanofill composite resin (Filtek Supreme Ultra), 96 from a nanohybrid composite resin (GrandioSO), 96 using a second nanohybrid composite resin (Venus Pearl), and 96 from a microfilled composite resin (Durafill VS). Composite resin specifications are listed in Table 1.

To improve handling during finishing and polishing procedures, a lubricated flat-end screw was inserted in the back of the specimen in its cervical portion to a depth of approximately 1.5 mm (Figure 2) before polymerization. The composite resin was

Table 1: *Specifications of Composite Resin Tested*

Composite Resin	Manufacturer	Shade	Type	Organic Matrix	Abrasive Particles and Particles Size	% Filler Content (% wt)	Batch Number
Durafill VS	Heraeus Kulzer, Hanau, Germany	A2	Microfill	BisGMA UDMA TEGDMA	Silicon dioxide (20-70 nm) Prepolymer (<20 nm)	50.5[26]	010222
Filtek Supreme Ultra	3M, St Paul, MN, USA	A2	Nanofill	BisGMA UDMA TEGDMA PEGDMA BisEMA	Silica (20 nm), zirconia (4-11 nm), zirconia-silica nanoclusters	78.5	N495465
GrandioSO	Voco America Inc, Indian Land, SC, USA	A2	Nanohybrid	BisGMA BisEMA TEGDMA	Glass ceramic (average 1 um) Silicon dioxide (20-40 nm) Pigments: iron oxide, titanium dioxide	89	1512206
Venus Pearl	Heraeus Kulzer Hanau, Germany	A2	Nanohybrid	Patented monomer (TCD-DI-HEA)	5 nm to 5 μm and prepolymerized filler	80	010028

Abbreviations: BisEMA, ethoxylated bisphenol A dimethacrylate; BisGMA, bisphenol A diglycidyl ether dimethacryalate; PEGDMA, polyethylene glycol dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

subsequently light-cured for 40 seconds (Optilux 501, Demetron, Kerr, Danbury, CT, USA). After the first polymerization cycle, the screw was removed, and the specimens were light-cured for an additional 40 seconds. The specimen was then removed from the putty material, and the unexposed surface was light-cured for an additional 40 seconds. The intensity of the curing light was verified periodically (after curing five specimens) using the radiometer on the unit to ensure that at least 600 mW/cm^2 was delivered to the material.

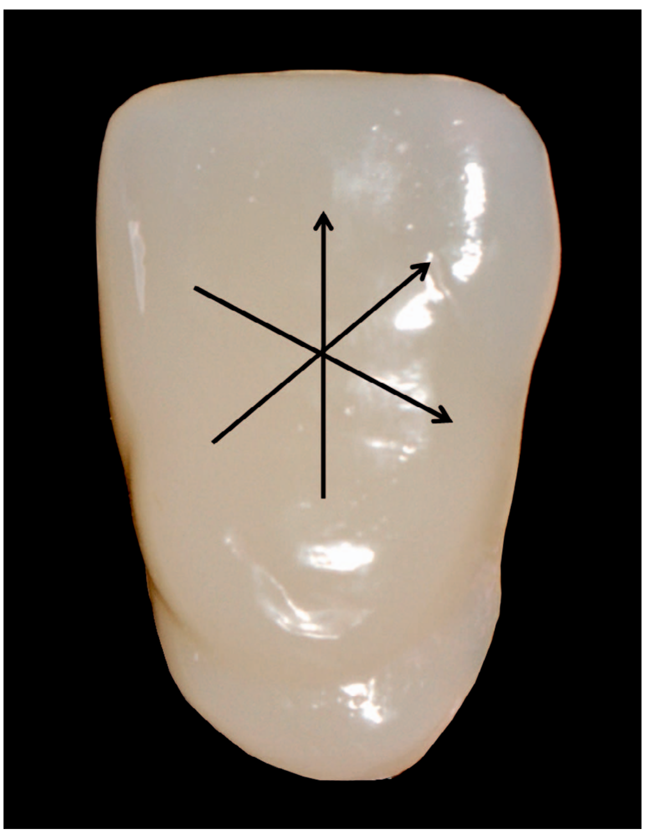


Figure 3. *Three surface roughness measurements were taken by rotating the specimen at an angle of 60°.*

To ensure uniform initial roughness, the composite resin surface was first sandblasted with 50-μm aluminum oxide particles until the surface layer appeared uniformly rough (Microetcher II, Danville, San Ramon, CA, USA). Specimens were then cleaned in 70% ethanol in an ultrasonic bath (Ultrasonic 08849-00, Cole-Parmer, Vernon Hills, IL, USA) for 2 minutes, rinsed, and dried. Finishing was simulated using a medium-grit Sof-Lex XT disc with an electric handpiece (ForZaElm, Brasseler, Savannah, GA, USA). Next, specimens were rinsed with combined air and water spray and air-dried to remove excess moisture. To further remove surface debris, impressions using a low-viscosity polyvinyl siloxane (Aquasil XLV Ultra, fast set, Dentsply Caulk, Milford, DE, USA) were taken and allowed to set for 5 minutes. These impressions were discarded.

The initial surface roughness (Ra) of each specimen was then measured with a surface roughness tester (Surftest 402, Mitutoyo, Kanagawa, Japan) using a tracing length of 3 mm and a cutoff λC of 0.25 mm. Three measurements were taken of each specimen by rotating the specimen 60°, and the average was calculated for statistical analysis (Figure 3).

Table 2: *Finishing and Polishing Systems Evaluated*

Polishing System	Manufacturer	Type	Abrasive Particle	Particle Size	Batch Number
Astropol	Ivoclar Vivadent Inc, Amherst, NY, USA	Three-step rubber polishing system	Diamond	36.5 μm (F)[16] 12.8 μm (P)[16] 3.5 μm (HP)[16]	RL0751
HiLuster Plus	Kerr Corporation, Orange, CA, USA	Two-step rubber polishing system	Aluminum oxide, diamond	—	5462546
D♦Fine	Clinician's Choice, New Milford, CT, USA	Two-step rubber polishing system	Diamond	45 μm [7] 5 μm[27]	—
Diacomp	Brasseler Savannah, GA, USA	Two-step rubber polishing system	Diamond	40-60 μm[27] 1-3 μm[27]	KR6FF KR8MZ
ET Illustra	Brasseler Savannah, GA, USA	Two-step rubber polishing system	"Proprieraty abrasive particles," manufacturer's information	—	KB7EM
Sof-Lex Spiral Wheels	3M, St Paul, MN, USA	Two-step rubber wheel polishing system	Aluminum oxide	—	N511340
Sof-Lex XT Discs	3M St Paul, MN, USA	Four-step rubber polishing discs	Aluminum oxide	Coarse: 60 μm[28] Medium (29 μm)[16,19] Fine (14 μm)[16,19] Extra fine (5μm)[16,19]	
Super-Snap	Shofu, San Marcos, CA, USA	Four-step rubber polishing discs	Silicon carbide, aluminum oxide	Black: 60 μm[28] Violet: 30 μm[28] Green: 20 μm[28] Red: 7 μm[28]	0312012
Enhance-Pogo	Dentsply Milford, DE, USA	Two-step rubber finishing and polishing (single polishing step)	Aluminum oxide, diamond	Enhance: 40 μm[16,19] Pogo: 7 μm[16,29]	120609
Optrapol	Ivoclar Vivadent	One-step rubber finishing and polishing system	Diamond	12 μm	PL1811
OneGloss	Shofu, San Marcos, CA, USA	One-step rubber finishing and polishing system	Aluminum oxide	80 μm[27]	0112918
Composipro Brush	Brasseler Savannah, GA, USA	One-step polishing system	Silicon carbide	N/A	—

Specimens of each composite resin type were then randomly and equally divided into 12 groups according to the finishing and polishing system used, as listed in Table 2 (n=8).

Specimens were polished by a single operator according to the polisher manufacturer's instructions regarding the speed, pressure, and need for water during the procedure (Table 3). Specimens were thoroughly rinsed with water between each polishing step. An electric handpiece was used to standardize the polishing speed, and a chronometer (Traceable timer, Control Company, Webster, TX, USA) was used to control the polishing time. The operator rehearsed and tested the protocol until the highest gloss was achieved for each polisher using extra specimens of Filtek Supreme Ultra that were discarded.

To minimize the variable of operator improvement throughout the experiment, a list of specimens placed in random group order was established using a random-sequence generator (Random.org, Dr. Mads Haahr, School of Computer Science and Statistics, Trinity College, Dublin, Ireland). The goal was to randomly polish one specimen in each group before moving forward to the second specimen.

Surface roughness was then measured with the same surface roughness tester (Surftest 402, Mitutoyo) using the same protocol as for the initial surface roughness measurements.

Statistical analysis was conducted using SAS for Windows (version 9.4, 2015, SAS Institute Inc, Cary, NC, USA). A two-way analysis of variance (ANOVA) model was used to study the effect of polishing system and composite resin on surface roughness. The model was adjusted for the roughness measurements before and after polishing. Pairwise comparisons were made using protected Fisher least significant difference. A p-value of less than 0.05 was used as a criterion for statistical significance. Residual analysis was performed to verify the

Table 3: *Polishing Protocol Followed*

Polishing System	Abrasive	Speed, RPM	Duration, s	Pressure	Water Coolant
Astropol	1. Grey	10,000	60	Moderate	Yes
	2. Green	10,000	60	Moderate	Yes
	3. Pink	10,000	60	Moderate	Yes
		10,000	30	Low	Yes
HiLuster Plus	1. Blue	10,000	60	Moderate	Yes
	2. Gray	10,000	60	Moderate	No
		10,000	30	Low	No
D♦FINE	1. Gray	10,000	60	Moderate	Yes
	2. Pink	10,000	60	Moderate	Yes
		10,000	30	Low	Yes
Diacomp	1. Green	15,000	60	Moderate	Yes
	2. Gray	15,000	60	Moderate	No
		6000	30	Moderate	No
ET Illstra	1. Purple	12,000	60	Moderate	No
	2. Gray	7000	60	Moderate	No
		7000	30	Low	No
Sof-Lex Wheels	1. Yellow	10,000	60	Low	No
	2. White	10,000	90	Low	No
Sof-Lex Discs	1. Light orange	10,000	60	Low	No
	2. Yellow	10,000	90	Low	No
Super-Snap	1. Purple	10,000	30	Low	No
	2. Green	10,000	60	Low	No
	3. Pink	10,000	60	Low	No
Enhance/Pogo	1. Brown	10,000	60	Moderate	No
	2. Gray	10,000	60	Moderate	No
		10,000	30	Low	No
OptraPol	1	8000	60	Moderate	Yes
		8000	60	Low	Yes
OneGloss	1	5000	60	High	Yes
		5000	60	Low	No
ComposiPro Brush	1	5000	60	High	No
		5000	60	Low	No

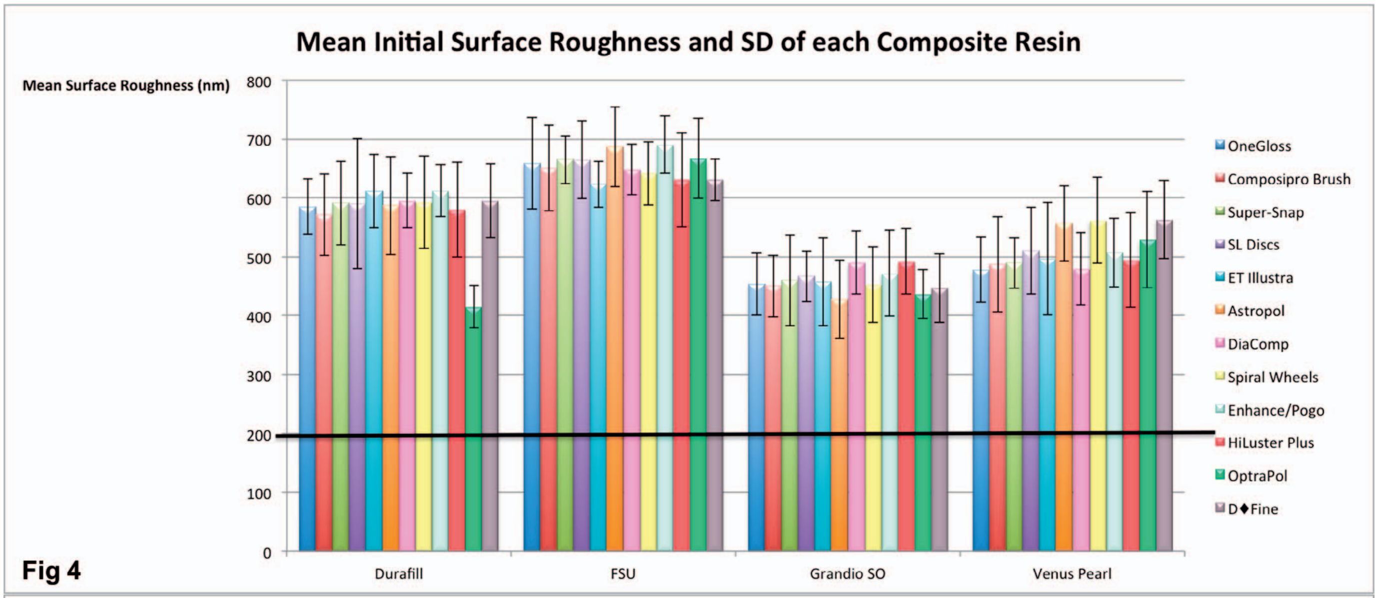
normality and the homogeneity of the variance assumptions.

RESULTS

Descriptive statistics for initial surface roughness and final surface roughness measurements are presented in Figures 4 and 5. Figure 4 shows that the initial surface roughness is greater than the 200-nm threshold for all composite resins tested and that Grandio SO and Venus Pearl have an overall lower surface roughness value. Figure 5 depicts that the highest final surface roughness for each composite resin was observed with OneGloss and ComposiPro Brush. Enhance/Pogo and Sof-Lex Wheels produce a surface roughness below the 200-nm threshold on Durafill VS, whereas the surface roughness was above the threshold on Filtek Supreme Ultra, Grandio SO, and Venus Pearl.

Results of the two-way ANOVA are presented in Table 4. For initial surface roughness, only the main effect of composite resins was significant ($p<0.0001$), meaning that the mean initial surface roughness measurements between the composite resins tested were statistically different. Furthermore, differences observed between composite resins were the same for all polishing systems, since the interaction term was not significant ($p=0.34$). Pairwise comparisons of composite resins are presented in Table 5, which shows that Filtek Supreme Ultra had the highest initial surface roughness and Grandio SO the lowest.

Regarding the final surface roughness, results of the two-way ANOVA revealed that the interaction



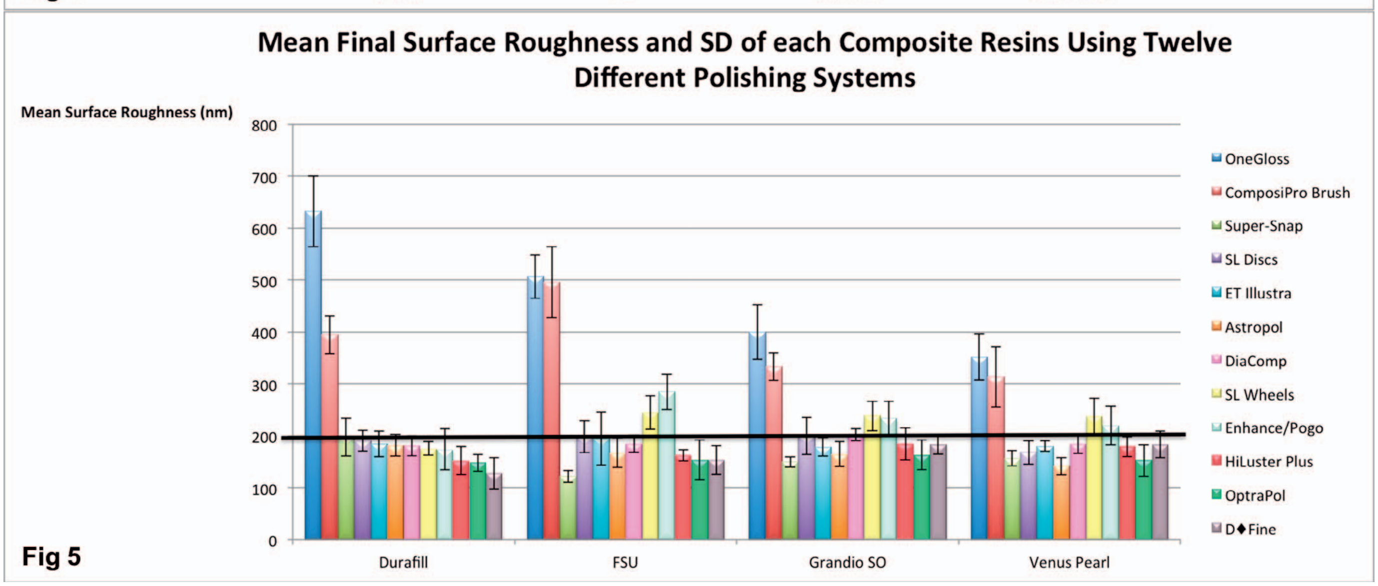


Figure 4. *Initial surface roughness measurements after sandblasting procedures and medium grit Sof-Lex XT disc.*

Figure 5. *Comparison of composite resin final surface roughness measurements after polishing with different systems.*

between composite resins and polishing systems was statistically significant ($p<0.0001$). This indicated that the final surface roughness obtained with different polishing systems was not the same for each composite resin tested. Table 6 illustrates the pairwise comparisons of different polishing systems for each composite resin as well as the pairwise comparisons of different composite resins for each polishing system. It may be concluded from this table that the polishing systems leaving the smoothest

Table 4: *Results of the Analysis of Variance for Both Initial and Final Surface Roughness Measurements*

Effect	Num *df*	Den *df*	Initial Measurement		Final Measurement	
			F Value	*p* Value	*F* Value	*p* Value
Composite resin	3	336	168.01	<0.0001	18.57	<0.0001
Polishing system	11	336	0.61	0.8188	310.86	<0.0001
Composite × polishing	33	336	1.09	0.3432	17.78	<0.0001

Table 5: *Initial Surface Roughness (nm) Difference Between Composite Resins*[a]

Composite Resin	Mean Surface Roughness, nm	Standard Deviation	Group Comparison
Filtek Supreme Ultra	655.0	6.63	A
Durafill VS	589.6	6.63	B
Venus Pearl	513.0	6.63	C
Grandio SO	459.0	6.63	D

[a] *Different letters indicate statistical differences between groups ($p<0.05$).*

surfaces for each composite resin are not the same. Durafill VS, D♦Fine, Optrapol, and HiLuster Plus produced the lowest surface roughness. However, except for OneGloss and Composipro Brush, most systems reached a mean surface roughness below the 200-nm threshold, although some standard deviations were slightly higher. For Filtek Supreme Ultra, Super-Snap achieved the smoothest surface, but Astropol, HiLuster Plus, D♦Fine, Diacomp, and OptraPol also obtained mean surface roughness value less than 200 nm. For Grandio SO and Venus Pearl, the lowest surface roughness was obtained when using Super-Snap, OptraPol, and Astropol adding ET Illustra for Grandio SO and Sof-Lex discs for Venus Pearl.

DISCUSSION

Composite resin surface quality is important to optimize esthetics and longevity of restorations. The best surface quality with the lowest surface roughness has often been obtained with a composite resin cured against a Mylar strip.[17-19,26,30,31] However, this surface has a resin-rich layer and presents a lower hardness. To prevent wear and discoloration, it is suggested to finish and polish this surface.[32] This study evaluated the effect of different commercially available polishing systems on the surface roughness of composite resins.

The results of the present study suggest that a single polishing system does not produce the same surface quality for all composite resins. This may not be entirely attributed to the quality of the polishers but to the interaction between the polisher and the composite resin. This is in accordance with the findings of previous studies.[9,16,19] Several factors have been proposed to affect the polishability of composite resin, including the polishing system, the composite resin used, and variables associated with the operator.

Traditionally, ideal polishing protocols have been explained as a selective wear process using a sequence of abrasive particles from coarse grit gradually decreasing toward fine grit.[5,15] Currently, a variety of polishing systems are commercially available. Some systems require multiple steps, whereas others are simplified and require only one grit used with gradually decreasing pressure. The hardness of the backing or rubber media into which the abrasive particles are embedded influences the surface quality.[15] The hardness of the abrasive particles vary and may be classified as follows according to the Mohs's hardness scale: diamond >

Table 6: *Comparison of Mean Final Surface Roughness (nm) and Standard Deviation for Composite Resins and Polishing Systems*[a]

Polishing System	Composite Resin			
	Durafill VS	Filtek Supreme Ultra	Grandio SO	Venus Pearl
Astropol	181.4 ± 32.3 A, cd	167.5 ± 37.2 AB, de	164.5 ± 56.1 AB, ef	141.5 ± 28.8 B, f
HiLuster Plus	152.0 ± 38.8 B, def	162.3 ± 25.4 AB, e	184.0 ± 34.3 A, de	179.0± 26.9 AB, de
D♦FINE	127.7 ± 48.4 B, f	153.5 ± 46.5 AB, e	182.2 ± 30.8 A, de	183.1 ± 40.3 A, de
Diacomp	180.5 ± 36.3 A, cd	184.4 ± 26.1 A, de	201.4 ± 37.5 A, d	184.5 ± 34.0 A, d
ET Illustra	184.2 ± 36.8 A, c	194.7 ± 60.7 A, d	178.1 ± 37.1 A, def	179.9 ± 21.9 A, de
Sof-Lex Wheels	175.2 ± 35.8 B, cde	245.0 ± 42.4 A, c	237.6 ± 34.9 A, c	236.4 ± 50.3 A, c
Sof-Lex Discs	190.8 ± 51.5 A, c	198.3 ± 37.0 A, d	199.0 ± 41.2 A, d	167.8 ± 31.7 A, def
Super-Snap	197.5 ± 45.8 A, c	121.3 ± 22.7 C, f	149.4 ± 20.1 BC, f	156.7 ± 29.2 B, def
Enhance/Pogo	173.7 ± 65.3 C, cde	284.8 ± 64.6 A, b	233.4 ± 72.3 B, c	219.3 ± 79.5 B, c
OptraPol	147.8 ± 28.3 A, ef	153.5 ± 42.0 A, e	162.8 ± 35.0 A, ef	152.3 ± 38.2 A, ef
OneGloss	632.3 ± 95.8 A, a	506.8 ± 89.6 B, a	400.0 ± 78.4 C, a	352.0 ± 58.3 D, a
ComposiPro Brush	394.4 ± 85.9 B, b	495.8 ± 83.4 A, a	332.5 ± 38.3 C, b	313.5 ± 68.7 C, b

[a] *Capital letters represent statistical differences among composite resins (within the row), and lowercase letters represent statistical differences among polishing systems (within the column). Different letters indicate statistical differences between groups ($p<0.05$).*

silicon carbide > tungsten carbide > aluminum oxide > zirconium silicate.[15] The hardness and the size of abrasive particles are very important. First, the abrasive particles must be harder than the filler particles present in the composite resin to avoid abrading only the resin matrix and leaving the filler particles protruding. Second, the abrasive particles must be small to prevent scratches on the composite resin. Multi-step systems use smaller particles for each step to remove scratches from the previous polisher until a highly shined surface is obtained. For one-step systems, the grit size is important because it may leave scratches on the composite resin. Some studies reported that multi-step polishers perform better than one-step polishers.[9,16] Indeed, in the literature, it may be found that Sof-Lex discs produced higher gloss along with Astropol,[8,9,16] whereas brushes produced high surface roughness.[16] On the contrary, some studies reported that the Pogo system, used as a one-step or a two-step system, showed the highest gloss, whereas aluminum oxide discs produced a poorer surface finish.[16-19] In the present study, data showed that following final polishing, most polishing systems obtained a clinically adequate surface roughness of less than 200 nm. However, OneGloss and CompoSiPro Brush, two simplified one-step polishing systems, were unable to reach an acceptable surface roughness and left roughness significantly above the threshold for all the composite resins tested. The final surface roughness obtained with OneGloss was even higher than before polishing procedures. Of the one-step systems, only Optrapol had a surface of less than 200 nm. Therefore, multi-step systems generally provided a better surface finish, a finding that is in partial agreement with the current literature. Although the Enhance/Pogo system showed good results in a previous study, the present data revealed that it left surface roughness above the 200-nm threshold on Filtek Supreme Ultra, Grandio SO, and Venus Pearl. Therefore, except for the Enhance/Pogo system, polishing systems containing diamond particles produced, in general, a superior surface finish, which is consistent with previous studies.[15,16] Super-Snap, which contains silicon carbide and aluminum oxide particles, also left an excellent surface roughness, especially with Filtek Supreme Ultra. The Sof-Lex Wheels left a surface roughness greater than 200 nm on Filtek Supreme Ultra, Grandio SO, and Venus Pearl. The Sof-Lex Wheels used in the present study contained only aluminum oxide particles. Since the study was performed, the manufacturer modified the composition of the final polisher by replacing aluminum oxide with diamond particles. This would have probably altered the efficacy of this system.

Factors related to the composite resin also influence surface quality. These include the resin matrix content and formulation, the filler particle characteristics (type, hardness compared with the abrasiveness of the polishers, size, and shape), the composite resin filler load, the quality of the silane coupling agent, and the degree of conversion after light curing.[33-36] The matrix and filler particles have different hardness, which may influence the polishability of the composite resins. Insufficient abrasiveness of the polisher particles compared with the composite resin fillers will mostly abrade the matrix, leaving the filler particles in protrusion. In addition, insufficiently bonded fillers may debond and dislodge, leaving a dull surface. Therefore, the results suggest that the combination of composite resin and polisher has an influence on the result, with some polishers leaving an excellent finish on some composite resins but a less optimal finish on others. It is well known that smaller particles reduce the surface roughness after polishing procedures.[34] It has also been reported that spherical particles allow for a better light reflection than irregular particles.[36] It has been suggested that composite resin should be polished with the polishing system of the same manufacturer,[37] an assertion that could not be confirmed in the present study. The result of the present study reveals that, although not statistically different for all polishing systems used, Durafill VS, a microfill composite resin containing small particles and high resin content, showed less variability among the polishing systems. Filtek Supreme Ultra, a nanofilled composite resin, was reported by the manufacturer to have a unique formulation, in which nanosized particles were individually silanized[38] and agglomerations or nanoclusters that seem to resist particle loss during the polishing procedure, leaving a more uniform surface with less roughness.[33] The results of this study generally confirm this, except when using some polishers (Enhance/Pogo and Sof-Lex Wheels).

A high surface roughness has been found with Grandio in some studies.[8,9] However, compared with the other composite resins tested in the present study, this high surface roughness was not observed. Although the mean surface roughness was close to the threshold for some polishers (Sof-Lex discs and Diacomp) or above the threshold for some others (Enhance/Pogo, Sof-Lex Wheels, OneGloss, and CompoSiPro Brush), many polishing systems left a mean surface roughness less than 200 nm. This may be due to the recent improvement in the Grandio SO formulation to obtain a better surface finish. Venus Pearl also seemed to adequately polish, with most polishers tested except with Sof-Lex Wheels and Enhance/Pogo.

An interaction was found in the present study, meaning that the surface roughness depends on the combination of polishing system used and composite resin. This is in accordance with the results of previous studies comparing polishing systems and composite resins.[18,26]

Possible bias may be attributed to operator variables such as the polishing time, the speed of the handpiece, the pressure applied to the composite resin, the hand skill improvement, and the experience of the operator. Heintze and others reported that surface roughness and gloss are time dependant, with the greatest improvement after five seconds and continued improvement for up to 30 seconds for each of the steps of the Astropol system (three-step polishing system).[39] In the present study, the operator, in accordance with the manufacturer's instructions, established the best polishing protocol (pressure, speed, and time) for all polishers to obtain the highest surface quality possible. These specimens were not included in the study. In the present study, specimens were polished for a minimum of 30 seconds for each step controlled with a chronometer (Table 3). Establishing this protocol also allowed the operator to rehearse prior to the study to obtain a standardized pressure while polishing the composite resin specimens. The speed of the handpiece was standardized using an electric handpiece. All steps were performed by the same rehearsed operator, who was a trained second-year dental student. According to Zimmerli and others, the age and experience of the operator do not seem to influence the surface quality of the composite resin after polishing procedures.[40] However, to control for the variability of improvement in hand skills throughout the study, specimens were polished in random order.

Previous studies evaluating the efficacy of polishing protocols in terms of surface roughness and gloss are mostly performed on discs of composite resin.[8,9,18,26,29,41,42] However, in clinical situations, composite resin is often placed in convex morphology, which may influence the result of polishing procedures, and this is the reason why convex specimens were used in the present study. Although disks allow gloss measurements, only surface roughness was measured in the present study because it was impossible to obtain reproducible gloss values due to specimens' convexity.

To establish an initial roughness for all the composite resins tested, specimens were first roughened using the same sequence of sandblasting (50 μm aluminum oxide particle) followed by a medium-grit Sof-Lex XT disk indicated for excess composite resin removal and recontouring before polishing. Although the same procedure was applied to all specimens, the initial roughness varied among the four composite resins tested. However, these differences did not seem to influence the final surface roughness results.

Many different factors may affect polish retention over time. It has been shown that the surface may be altered by bacterial biodegradation.[43] Surface quality may also be influenced by alcohol and acidic solution exposure.[44-49]

The results of the present study should be interpreted with caution and may not apply to other composite resins, polishing instruments, or polishing techniques. Clinical studies evaluating the effect of polishing quality on the longevity of composite resin restorations would be relevant.

CONCLUSION

The null hypotheses were rejected, since surface roughness was influenced by the polishing system and the composite resin tested. In addition, there was an interaction between the polishing systems and the composite resins. Indeed, a given polishing system does not perform equally with all composite resins. The results of the present study suggest that, except for Optrapol, multi-step polishing systems performed generally better than one-step systems. Moreover, excluding Enhance/Pogo, diamond-impregnated polishers allowed for lower surface roughness. In addition, Durafill VS, a microfill composite resin, may be polished more predictably with different polishers.

Acknowledgements

The authors would like to thank the Fonds Émile-Beaulieu and The Network for Oral and Bone Health Research for their grant support as well as 3M, Heraeus Kulzer, Brasseler, Ivoclar Vivadent, and Shofu et Denstply for donating their products.

Conflict of Interest

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

(Accepted 30 July 2018)

REFERENCES

1. Aykent F, Yondem I, Atilla G, Gunal SK, & Mustafa C (2004) Effect of different finishing techniques for restorative materials on surface roughness and bacterial adhesion *Journal of Prosthetic Dentistry* **103(4)** 221-227.
2. Park JW, Song CW, Jung JH, Ahn SJ, & Ferracane JL (2012) The effects of surface roughness of composite resin on biofilm formation of *Streptococcus mutans* in the presence of saliva *Operative Dentistry* **37(5)** 532-539.
3. Bollen CML, Lambrechts P, & Quirynen M (1997) Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature *Dental Materials* **13(4)** 258-269.
4. Yap A, Ang H, & Chong K (1998) Influence of finishing time on marginal sealing ability of new generation composite bonding systems *Journal of Oral Rehabilitation* **25(11)** 871-876.
5. Jefferies S (1998) The art and science of abrasive finishing and polishing in restorative dentistry *Dental Clinics of North America* **42(4)** 613-627.
6. Powers J, Craig R, & Sakaguchi R (2006) *Craig's Restorative Dental Materials* **2nd edition** Elsevier Mosby, St Louis MO.
7. Lu H, Roeder LB, Lei L, & Powers JM (2005) Effect of surface roughness on stain resistance of dental resin composites *Journal of Esthetic and Restorative Dentistry* **17(2)** 102-108.
8. Gönülol N & Yilmaz F (2012) The effects of finishing and polishing techniques on surface roughness and color stability of nanocomposites *Journal of Dentistry* **40(Supplement 2)** 64-70.
9. Rodrigues-Junior SA, Chemin P, Piaia PP, & Ferracane JL (2015) Surface roughness and gloss of actual composites as polished with different polishing systems *Operative Dentistry* **40(4)** 418-429.
10. Ergucu Z & Turkun L (2007) Surface roughness of novel resin composites polished with one-step systems *Operative Dentistry* **32(2)** 185-192.
11. Marghalani H (2010) Effect of filler particles on surface roughness of experimental composite series *Journal of Applied Oral Sciences* **18(1)** 59-67.
12. Janus J, Fauxpoint G, Arntz Y, Pelletier H, & Etienne O (2010) Surface roughness and morphology of three nanocomposites after two different polishing treatments by a multitechnique approach *Dental Materials* **26(5)** 416-425.
13. Joniot S, Salomon JP, Dejou J, & Grégoire G (2006) Use of two surface analyzers to evaluate the surface roughness of four esthetic restorative materials after polishing *Operative Dentistry* **31(1)** 39-46.
14. Venhoven B, de Gee A, Werner A, & Davidson C (1996) Influence of filler parameters on the mechanical coherence of dental restorative resin composites *Biomaterials* **17(7)** 735-740.
15. Jefferies S (2007) Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review *Dental Clinics of North America* **51(2)** 379-397.
16. Jung M, Eichelberger K, & Klimek J (2007) Surface geometry of four nanofiller and one hybrid composite after one-step and multiple-step polishing *Operative Dentistry* **32(4)** 347-355.
17. Turkun L & Turkun M (2004) The effect of one-step polishing system on the surface roughness of three esthetic resin composite materials *Operative Dentistry* **29(2)** 203-211.
18. Ereifej N, Oweis Y, & Eliades G (2013) The effect of polishing technique on 3-D surface roughness and gloss of dental restorative resin composites *Operative Dentistry* **38(1)** E9-E20.
19. Almeida K, Almeida K, Madeiros I, Costa J, & Alves C (2009) Effect of different polishing systems on the surface roughness of microhybrid composites *Journal of Applied Oral Science* **17(1)** 21-26.
20. Da Costa J, Ferracane J, Paravina R, Mazur R, & Roeder L (2007) The effect of different polishing systems on surface roughness and gloss of various resin composites *Journal of Esthetic Restorative Dentistry* **19(4)** 214-246.
21. Barbosa S, Zanata R, Navarro M, & Nunes O (2005) Effect of different finishing and polishing techniques on the surface roughness of microfilled, hybrid and packable composite resins *Brazilian Dental Journal* **16(1)** 39-44.
22. Kameyama A, Nakazawa T, Haruyama A, Haruyama C, Hosaka M, & Hirai Y (2008) Influence of finishing/polishing procedures on the surface texture of two resin composites *Open Dentistry Journal* **2** 56-60.
23. Korkmaz Y, Ozel E, Attar N, & Aksoy G (2008) The influence of one-step polishing systems on the surface roughness and microhardness of nanocomposites *Operative Dentistry* **33(1)** 44-50.
24. Paravina R, Roeder L, Lu H, Vogel K, & Powers J (2004) Effect of finishing and polishing procedures on surface roughness, gloss and color of resin-based composites *American Journal of Dentistry* **17(4)** 262-266.
25. St-Georges A, Bolla M, Fortin D, Muller-Bolla M, Thompson J, & Stamatiades P (2005) Surface finish produced on three resin composites by new polishing systems *Operative Dentistry* **30(5)** 593-597.
26. Can Say E, Yurdagüven H, Yaman BC, & Ozer F (2014) Surface roughness and morphology of resin composites polished with two-step polishing systems *Dental Materials Journal* **33(238)** 332-342.
27. Blackham JT, Vandewalle KS, & Lien W (2009) Properties of hybrid resin composite systems containing prepolymerized filler particles *Operative Dentistry* **34(6)** 697-702.
28. Reality Publishing Co. (2005) Polishing instruments. **19** p.835-861, retrieved online September 7, 2018 from https://www.realityesthetics.com/protected/book/2005/Polishing_Instruments.pdf
29. da Costa J, Goncalves F, & Ferracane J (2011) Comparison of two-step versus four-step composite finishing/polishing disc systems: evaluation of a new two-step composite polishing disc system *Operative Dentistry* **36(2)** 205-212.

30. Baseren M (2004) Surface roughness of nanofill and nanohybrid composite resin and ormocer-based tooth-colored restorative materials after several finishing and polishing procedures *Journal of Biomaterials Applications* **19(2)** 121-134.

31. Senawongse P & Pongprueksa P (2007) Surface roughness of nanofill and nanohybrid resin composites after polishing and brushing *Journal of Esthetic and Restorative Dentistry* **19(5)** 265-273.

32. Hosoya Y, Shiraishi T, Odatsu T, Nagafuji J, Kotaku M, Miyazaki M, & Powers JM (2011) Effects of specular component and polishing on color of resin composites *Journal of Oral Science* **53(3)** 283-291.

33. Turssi CP, Ferracane JL, & Serra MC (2005) Abrasive wear of resin composites as related to finishing and polishing procedures *Dental Materials* **21(7)** 641-648.

34. Turssi CP, De Moraes Purquerio B, & Serra MC (2003) Wear of dental resin composites: insights into underlying processes and assessment methods—a review *Journal of Biomedical Materials Research. Part B, Applied Biomaterials* **65(2)** 280-285.

35. Condon JR & Ferracane JL (1997) *In vitro* wear of composite with varied cure, filler level, and filler treatment *Journal of Dental Research* **76(7)** 1405-1411.

36. Lee YK, Lu H, Oguri M, & Powers JM (2005) Changes in gloss after simulated generalized wear of composite resins *Journal of Prosthetic Dentistry* **94(4)** 370-376.

37. Berger SB, Palialol ARM, Cavalli V, & Giannini M (2011) Surface roughness and staining susceptibility of composite resins after finishing and polishing *Journal of Esthetic and Restorative Dentistry* **23(1)** 34-43.

38. Sakaguchi RL & Powers JM (2012) *Craig's Restorative Dental Materials* **13th edition** (E. Mosby, Philadelphia PA.

39. Heintze S, Forjanic M, & Rousson V (2006) Surface roughness and gloss of dental materials as a function of force and polishing time *in vitro Dental Materials* **22(2)** 146-165.

40. Zimmerli B, Lussi A, & Flury S (2011) Operator variability using different polishing methods and surface geometry of a nanohybrid composite *Operative Dentistry* **36(1)** 52-59.

41. Sirin Karaarslan E, Bulbul M, Yildiz E, Secilmis A, Sari F, & Usumez A (2013) Effects of different polishing methods on color stability of resin composites after accelerated aging *Dental Materials Journal* **32(1)** 58-67.

42. Hosoya Y, Shiraishi T, Odatsu T, Ogata T, Miyazaki M, & Powers JM (2010) Effects of specular component and polishing on color of resin composites *Journal of Oral Science* **52(4)** 599-607.

43. Padovani G, Fúcio S, Ambrosano G, Sinhoreti M, & Puppin-Rontani R (2014) *In situ* surface biodegradation of restorative materials *Operative Dentistry* **39(4)** 349-360.

44. Bansal K, Acharya SR, & Saraswathi V (2012) Effect of alcoholic and non-alcoholic beverages on color stability and surface roughness of resin composites: an *in vitro* study *Journal of Conservative Dentistry* **15(3)** 283-288.

45. Da Silva MAB, Vitti RP, Sinhoreti MAC, Consani RLX, da Silva-Júnior JG, & Tonholo J (2016) Effect of alcoholic beverages on surface roughness and microhardness of dental composites *Dental Materials Journal* **35(4)** 621-626.

46. Karaman E, Tuncer D, Firat E, Ozdemir OS, & Karahan S (2014) Influence of different staining beverages on color stability, surface roughness and microhardness of silorane and methacrylate-based composite resins *Journal of Contemporary Dental Practice* **15(3)** 319-325.

47. Tantanuch S & Kukiattrakoon B (2016) Surface roughness and erosion of nanohybrid and nanofilled resin composites after immersion in red and white wine *Conservative Dentistry* **19(1)** 51-55.

48. Hamouda IM (2011) Effects of various beverages on hardness, roughness, and solubility of esthetic restorative materials *Journal of Esthetic and Restorative Dentistry* **23(5)** 315-322.

49. de Gouvea CV, Bedran LM, de Faria MA, & Cunha-Ferreira N (2011) Surface roughness and translucency of resin composites after immersion in coffee and soft drink *Acta Odontologica Latinoamericana* **24(1)** 3-7.