Surface characteristics of resin composite materials after finishing and polishing

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This in vitro study determined the surface roughness (R_a) and absolute gloss (AG) values for 2 resin composites: a microhybrid and a microfill. Eight groups (n = 4) of each resin composite were prepared, along with 4 controls (Mylar strip) for the 2 resin composites. After finishing with a medium polishing disc, the specimens from each resin composite material were subjected to 7 polishing procedures, and R_a measurements and AG values were determined. Two-way ANOVA and Fisher's LSD multiple comparisons revealed significant differences ($P \leq 0.05$). For both materials, the control group produced the lowest R_a values and highest AG values, and the medium polishing disc produced the highest R_a values and lowest AG values. Of the 2 resin composites, the microhybrid had lower mean R_a and higher mean AG than the microfill for the majority of the polishing procedures. Pearson's r correlation coefficient ($P \leq 0.001$) indicated an inverse linear relationship between R_a and AG.

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The selection of an appropriate resin composite material for use in areas of the dentition where esthetics are a major concern is often dependent on 2 factors: strength and polishability.[1,2] While strength is an inherent physical characteristic of the resin composite material, polishability can be significantly influenced by the polishing materials and procedures utilized.[3-5] For esthetic areas where high surface gloss is required and strength is a secondary factor, a microfilled resin composite would be a logical material selection.[1] Microfilled resin composites contain submicron inorganic filler particles that average 0.04 µm in diameter and include pre-polymerized particles. Since microfilled resin composites possess lower strength than resin composites that contain larger filler particles, their primary indication is placement in esthetic areas where a high surface polishability is paramount, such as in cervical Class 5 restorations or for direct composite veneers.[6,7]

When improved strength is a primary requirement, selecting a material in the hybrid resin composite category may be prudent. These resin composites typically contain a blend of small particle (1-4 µm) fillers and occasionally include 0.04 µm submicron particles, thereby allowing higher levels of filler loading and improvements in physical properties.[2] The hybrid resin composites can be polished to a high luster but may not always have the same degree of surface gloss that can be achieved and maintained with the microfilled resin composites.[2] The polishability of hybrid composites has been improved by incorporating filler particles of <1 µm with a narrow upper limit particle distribution and fumed silica (0.02-0.04 µm). These resin composites have been termed *microhybrid* or *nanohybrid* composites depending on the filler type, size, and distribution. Manufacturers of recently available nanohybrid resin composites claim that these materials have a smaller filler particle size and distribution than the hybrid or microhybrid classifications, combining the similar strength of the hybrids with polishability and gloss comparable to the microfilled materials.[8]

Surface texture and light reflection are also critical for clinical success with resin composite restorations for matching the gloss of the adjacent sound enamel or other esthetic restorations. Unfortunately, a single universal polishing armamentarium does not exist for the variety of resin composites available today. While finishing includes the shaping, contouring, and smoothing of the restoration, polishing is a separate and subsequent procedure to enhance the shine or surface luster on the restoration so that it is similar to the gloss of tooth enamel.[3] It has been demonstrated that the smoothest surface obtainable on a resin composite is that achieved with a Mylar strip.[9,10] It is not usually possible to leave the restoration in this unfinished condition; therefore, some contouring and margination of the restoration is typically required. Products available for finishing and polishing resin composite materials include carbide burs, diamond burs, flexible discs, rubber points or cups, metal or plastic finishing strips, and polishing pastes.[3,11] Multifluted carbide burs, diamond burs, and point-shaped rubber abrasives are necessary for finishing/polishing restorations with variable surface topography. Carbide burs, diamonds, flat flexible discs, and disc- or cup-shaped rubber abrasives can be used on smooth surfaces.[3] Fine-grit rubber abrasives containing diamond, silicon carbide, and aluminum oxide have recently become more popular with clinicians due to their ability to provide a high surface gloss, especially with microhybrid and nanohybrid resin composites.[4,5,12]

The purpose of this research was to compare the ability of different finishing/polishing procedures in producing a smooth surface and surface gloss by determining R_a and AG values (R_a: µm and AG: 1-10, respectively). The null hypothesis was that there would be no significant differences ($P \leq 0.05$) between the controls and the different finishing/polishing procedures with the 2 different resin composite materials.

Materials and methods

Using a 9 x 2 mm circular polyethylene mold, 36 specimens (shade A-2) of each resin composite material, Durafill VS (Heraeus Kulzer) and Vit-l-escence (Ultradent Products, Inc.) were prepared. Durafill VS is a light-polymerized BisGMA/UDMA-based microfilled resin composite containing 0.02-0.04 µm fumed silica particles filled 52% by

Table. Polishing materials, abrasive particle composition, and polishing procedures used in this study.

Polishing materials	Abrasive particles (particle size)	Finishing/polishing procedures[a]
Astropol polishers	Astropol P - silicon carbide and aluminum oxide (12.8 µm), Astropol HP - silicon carbide, aluminum oxide, fine diamond and titanium dioxide (3.5 µm).	Astropol P (green color) followed by Astropol HP (pink color)
Enhance	Aluminum oxide and silicon dioxide (45 µm)	Enhance disc
Jiffy	Aluminum oxide and silicon dioxide	Jiffy medium (yellow color) disc followed by the Jiffy fine (white color) disc
Jiffy composite polishing brush	Aluminim oxide, silicon carbide, and silicon dioxide	Jiffy medium (yellow color) disc followed by the Jiffy composite polishing brush
Jiffy HiShine	Silicon dioxide and fine diamond (2.5-4 µm)	Jiffy medium (yellow color) and Jiffy fine (white color) discs followed by the Jiffy HiShine (blue color) disc
PoGo	Fine diamond and silicon dioxide (2-4 µm)	Enhance disc followed by PoGo disc
Prisma polishing pastes	Aluminum oxide PrismaGloss (1 µm) and PrismaGloss Extra Fine (0.03 µm)	Enhance disc followed by a sequential application of PrismaGloss and PrismaGloss Extra Fine using a prophy cup
Sof-Lex XT discs	Aluminum oxide (Fine - 24 µm), Superfine (8 µm)	Fine (light orange color) Sof-Lex XT disc followed by the Superfine (yellow color) Sof-Lex XT disc

[a]With the exception of the control group, all resin composite specimens were finished with a medium Sof-Lex XT disc (orange color, 40 µm particle size) before proceeding with subsequent polishing methods. Between each abrasive used for the polishing methods, the resin composite surface was rinsed with water and dried.

weight and 39% by volume.[13] Vit-l-escence is a light-polymerized BisGMA-based microhybrid resin composite containing a blend of 0.4-0.6 µm radiopaque (barium aluminoborosilicate) glass filler particles, including silica filler particles ranging from 0.04 to 0.1 µm, filled 75% by weight and 58% by volume.[14]

The specimens were bulk-filled and light-activated for 40 seconds using an 11 mm curved light guide with an Optilux 501 quartz halogen curing light (Kerr Corporation) monitored for consistent light output of $\geq$400 mW/cm^2. Light pressure was placed on the Mylar strip with the light guide, taking care that no residual resin composite remained on the tip. Four control specimens were prepared for each resin composite. After mounting the intaglio side of the individual specimen on a glass slide with a glue gun, the remaining 32 specimens were finished flat with a medium Sof-Lex XT disc (3M ESPE). One clinician performed all of the finishing/polishing procedures and was unfamiliar with the expected polishing characteristics of both resin composite materials. Four specimens of each resin composite material were then subjected to the following 7 finishing/polishing procedures (while maintaining a wet surface) and rinsing with deionized water between abrasive sequences as indicated: Fine and Superfine Sof-Lex XT discs, Enhance disc, Enhance disc and Prisma polishing pastes (DENTSPLY International), Enhance and PoGo discs (DENTSPLY International), Medium through HiShine Jiffy discs (Ultradent Products, Inc.), Medium Jiffy disc, Jiffy polishing brush (Ultradent Products, Inc.), and Medium Astropol P through Astropol HP polishing discs (Ivoclar Vivadent, Inc.). The disc-shaped rubber abrasives, Enhance, PoGo, Jiffy, and Astropol were used with the polishing materials being studied. A consistent finishing/polishing protocol was carefully followed using a sweeping motion with light pressure for 10-15 seconds intermittently to avoid heat generation on the surface of the resin composite. All finishing/polishing steps were completed within 60 seconds. The Table provides a list of these polishing materials, the type of abrasive particles, and the finishing/polishing procedure sequence.

After all finishing/polishing treatments were completed, the specimens were stored in deionized water at room temperature for 7 days. The specimens were then dried, and the smoothness was determined by recording 3 R_a measurements for each specimen using a Surftest SJ-201P/M Profilometer (Mitutoyo America Corporation). Three AG measurements on each specimen were obtained using a gloss meter. The Beta Gloss meter (Beta Industries—product no longer commercially available) determined a gloss value of a sample on the absolute scale of 0.00 to 10.0 with 0.00 representing a totally diffuse (matte) surface and 10.0 representing a totally specular (glossy) surface.[15] Specimens were sputter-coated with a 30 µm layer of gold/palladium and examined using a JEOL JSM-6100 scanning electron microscope (SEM) (JEOL Ltd.) at 25 KVP. SEM photomicrographs were taken (magnification 250X) using a 55 degree tilt to facilitate visualization of the surface topography. Although not appropriate for statistical analysis, a loupe (magnification 2.5X) was used to observe the surface of the resin composite specimen for each finishing/polishing procedure in order to assess surface gloss in the manner that would be done when checking on a restoration for a patient.

A 2-way ANOVA was performed to determine the presence of significant interactions between the main effects of resin composites and finishing/polishing procedures on R_a and AG values ($P \leq 0.05$). Fisher's multiple comparison post hoc tests were subsequently performed to determine significant differences between the composites and finishing/polishing procedures ($P \leq 0.05$). Linear regression analysis ($P \leq 0.05$) was also utilized for Pearson's r-correlation and r^2 values to determine the relationship between the R_a and AG values.

Results

Two-way ANOVA indicated that the interaction of the main effects, which included the composites and finishing/polishing procedures, were significant ($P \leq 0.05$), and the null hypothesis was rejected. Fisher's LSD multiple comparisons indicated significant differences between the resin composite and the finishing/polishing procedures ($P \leq 0.05$). R_a comparisons between the 2 resin composites are illustrated in Figure 1. R_a values ranged from 0.196 to 0.468 µm for Durafill VS groups and from 0.078 to 0.327 µm for the Vit-l-escence groups. AG comparisons between the 2 resin composites are illustrated in Figure 2. AG values ranged from 5.508 to 9.109 for the Durafill VS groups and from 6.192 to 9.175 for the Vit-l-escence groups.

Although the control group demonstrated the lowest R_a values for each resin composite material, the control group R_a values for Durafill VS were significantly higher than those of the Vit-l-escence control group. The initial finishing/polishing procedure using medium Sof-Lex XT discs produced the highest R_a values for both resin composite materials. Similar to the control group, the medium Sof-Lex XT disc R_a values for Durafill VS were significantly higher than those for the Vit-l-escence control group ($P \leq 0.05$).

As illustrated in Chart 1—and not including the control group—the R_a values for Durafill VS were <0.3 µm for 4 of the finishing/polishing procedures. Their R_a value ranking (high to low) was Medium through HiShine Jiffy discs > Fine and Superfine Sof-Lex XT discs > Medium Jiffy disc and Jiffy polishing brush > Medium Astropol P through Astropol HP polishing discs. Chart 1—not including the control group— illustrates that the R_a values for the Vit-l-escence resin composites were <0.3 µm for 7 of the finishing/polishing procedures. Their R_a value ranking (high to low) was Fine and Superfine Sof-Lex XT discs > Enhance disc and PoGo disc > Medium through HiShine Jiffy discs > Medium Astropol P through Astropol HP polishing discs > Medium Jiffy disc and Jiffy polishing brush > Enhance disc > Enhance disc and Prisma polishing pastes. The Medium Sof-Lex XT finishing/polishing method had the highest R_a.

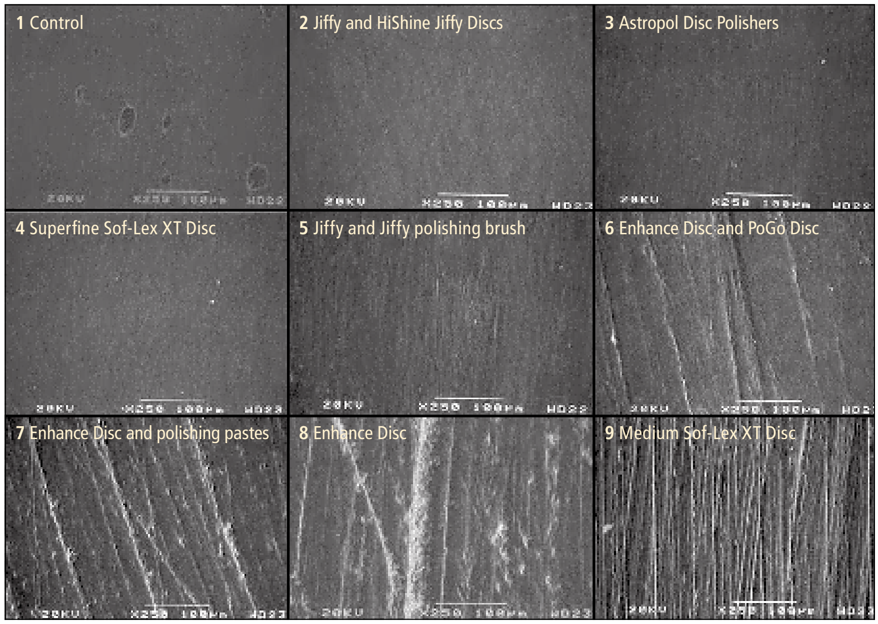


Fig. 1. SEM photomicrographs of the Durafill VS polishing procedures numbered in order of increasing surface roughness (R_a) values (magnification 250X).

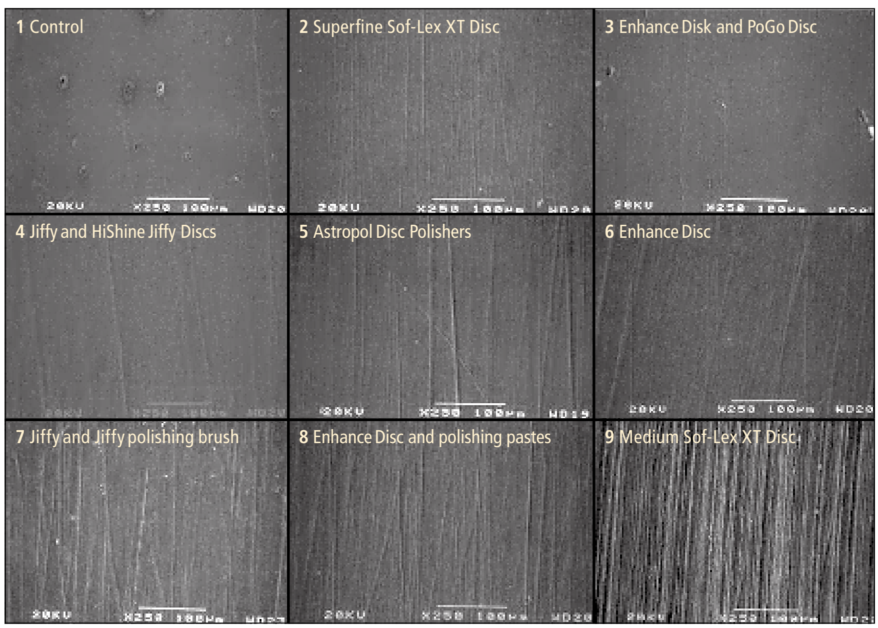
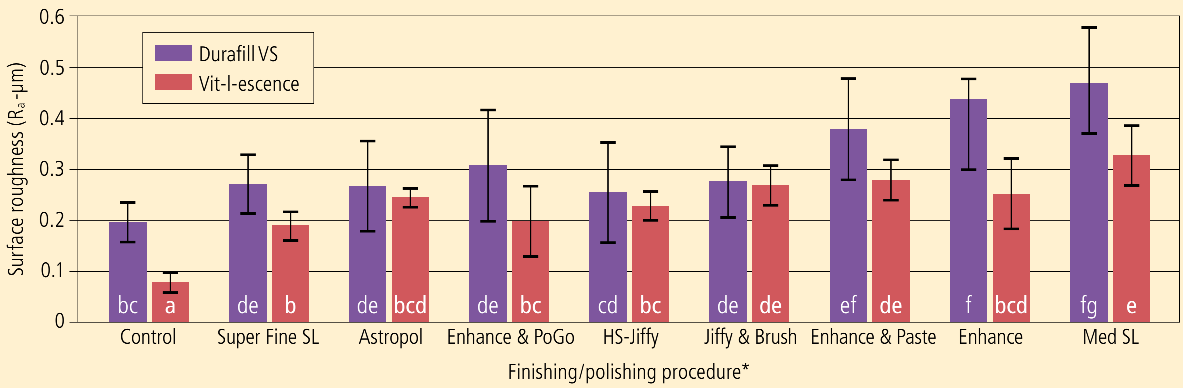


Fig. 2. SEM photomicrographs of the Vit-l-escence polishing procedures numbered in order of increasing surface roughness (R_a) values (magnification 250X).

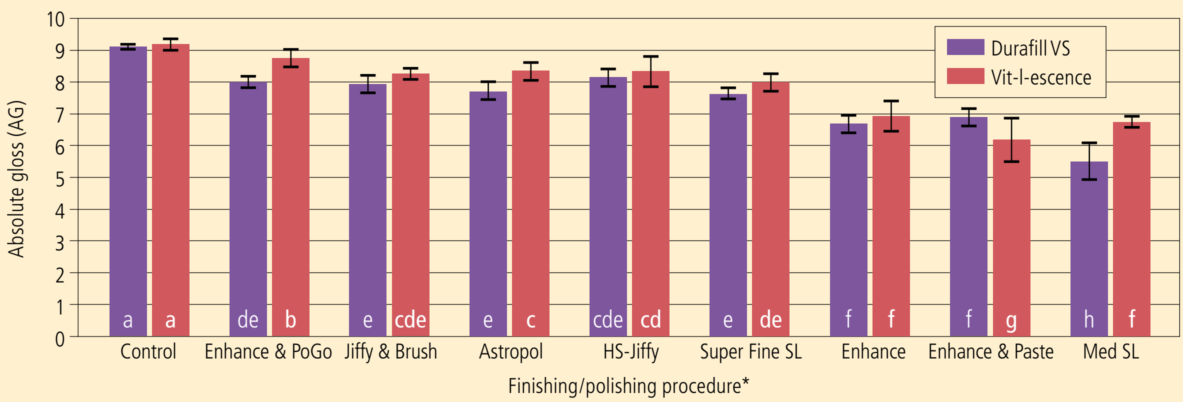
As illustrated in Chart 2, the AG values for the control group were the highest for each respective material. For the Vit-l-escence resin composite specimens—in addition to the control group—the AG values were >8 for 4 of the 8 finishing/polishing procedures. The AG value ranking (high to low) for these 4 finishing/polishing procedures was Enhance disc and PoGo disc > Medium Astropol P through

Chart 1. Surface roughness (R_a) comparisons for Durafill VS and Vit-l-escence.



*Finishing/polishing procedures with the same letter are not significantly different ($p \leq 0.05$). Abbreviations: SL, Sof-Lex XT; HS, HiShine; Med, Medium.

Chart 2. Absolute gloss (AG) comparisons for Durafill VS and Vit-l-escence.



*Finishing/polishing procedures with the same letter are not significantly different ($p \leq 0.05$). Abbreviations: HS, HiShine; SL, Sof-Lex XT; Med, Medium.

Astropol HP polishing discs > Medium through HiShine Jiffy discs > Medium Jiffy disc and Jiffy polishing brush. Chart 2 also illustrates that the AG values for the Durafill VS resin composite specimens—in addition to the control group—were >8 for 2 of the 8 finishing/polishing procedures. The AG value ranking (high to low) for these 2 finishing/polishing procedures was Medium through HiShine Jiffy discs > Enhance disc and Pogo disc.

For both Durafill VS and Vit-l-escence materials, the Medium Sof-Lex XT, Enhance disc, and Enhance disc and Prisma polishing pastes finishing/polishing procedures all recorded mean AG values <7.0.

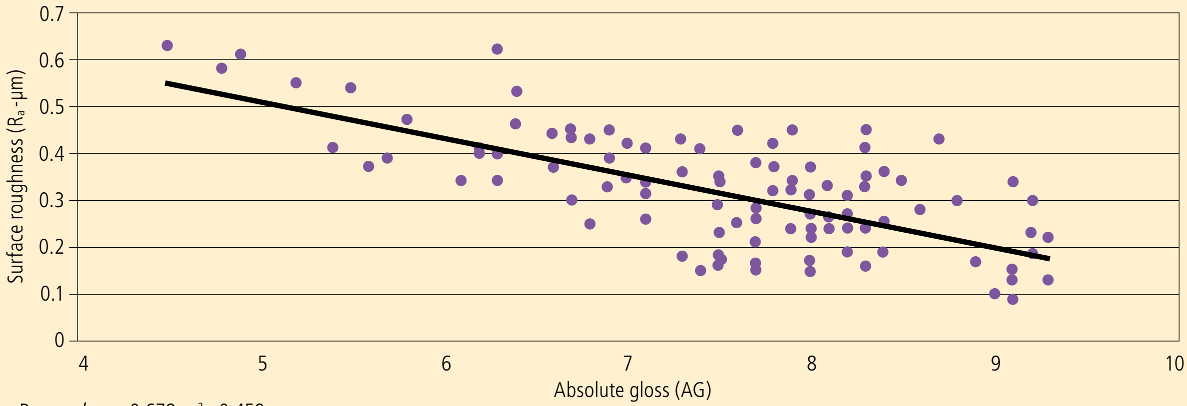
Figures 1 and 2 illustrate SEM photomicrographs (magnification 250X) for each resin composite and each finishing/polishing procedure (including the control) in numerical order of increasing R_a. Using a 55 degree tilt for the photomicrographs, qualitative differences in surface topography were observed when comparing the control with other finishing/polishing procedures. Direct visual examination of the specimens revealed relatively smooth surfaces with different degrees of surface gloss for the control and finishing/polishing procedures with the exception of the medium Sof-Lex XT disc, which appeared to have a matte surface.

As illustrated in Charts 3 and 4, the r value for Durafill VS had a greater negative value (-0.678) than that calculated for Vit-l-escence (-0.548). The coefficient of determination (r^2) value was 0.459 for Durafill VS and 0.300 for Vit-l-escence.

Discussion

Recommendations for finishing and polishing of resin composite materials are often generic, provide numerous options, or suggest use of the manufacturer's proprietary products. For the microhybrid resin composite Vit-l-escence, multifluted carbide burs followed by polishing with Jiffy rubber polishing discs, cups, or points are suggested by the manufacturer.[14] For the microfill resin composite Durafill VS, the manufacturer suggests using diamond burs and multifluted carbide burs for finishing, followed by polishing with silicone rubber polishing discs, cups, or points and elective use of polishing pastes.[13] Many articles are available on a variety of polishing procedures with resin composites because new materials and polishing instrumentation

Chart 3. Linear regression plot of surface roughness (R_a) and absolute gloss (AG) values for Durafill VS.



Pearson's r=-0.678, r^2=0.459

are continually evolving.[4,5,9,10] This research is unique in that it investigated the performance of 2 differently formulated resin composites subjected to a variety of different finishing/polishing procedures and is designed to provide guidance for the restorative dentist in the selection of optimal materials and techniques. It is important to note for comparison with other similar research that, for this in vitro research, the gloss meter in this study used 45 and 90 degree reflectance data to record the gloss value as AG units on a scale of 0.0-10.0. The AG values in this research are specific for this particular gloss meter and are different from other laboratory research using a 60 degree reflectance (or other reflectance angles) and with other commercially available gloss meters expressing gloss in gloss units (GU) with values that can range from 1-2000.[16]

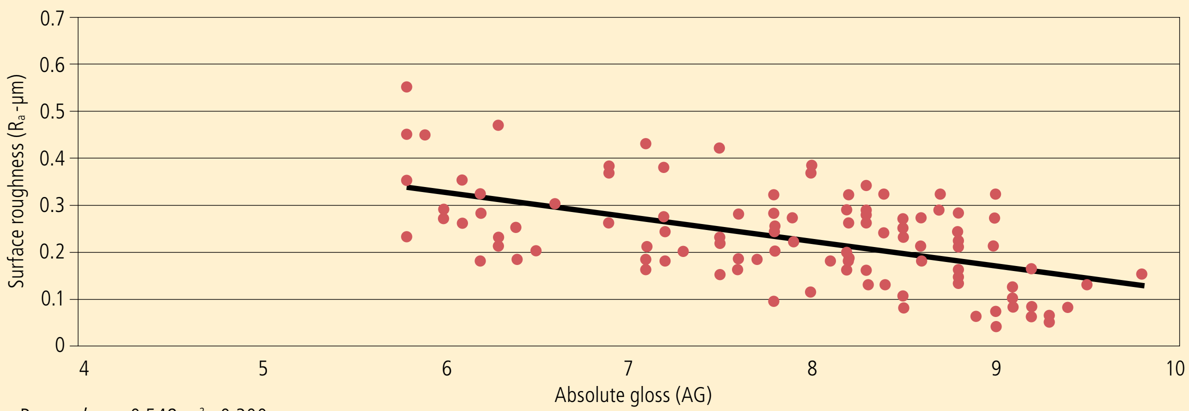
Surface irregularities of resin composite restorative materials before and after polishing procedures can be quantitatively assessed by recording R_a using a profilometer. These results have been correlated qualitatively in the dental literature using SEM to reveal surface topography and subjective comparative smoothness produced on the respective resin composite surfaces.[17] Profilometry and SEM evaluations at high magnification, however, cannot characterize surface gloss. Furthermore, the relationship between surface roughness and surface gloss may not be correlated with the resin composite materials available today in that a smooth surface will not always have a high gloss.

The results of this study indicate that an inverse correlation existed between R_a and AG, that is, when the R_a is lower, the AG is higher. However, the coefficient of determination (r^2) values of 0.459 for Durafill VS and 0.300 for Vit-l-escence indicate that this relationship is relatively weak. In other words, the percentage variations (45.9% and 30.0% for Durafill VS and Vit-l-escence, respectively) was explained by the direct relationship between R_a and AG. Durafill VS displayed a stronger correlation between R_a and AG than did Vit-l-escence. This finding is in agreement with previous research and suggests that finishing/polishing procedures attaining a low R_a is coincident with the presence of a glossy surface.[4-6,18,19] It is reasonable to assume that the multistep, fine particle, rubber abrasive systems used in this research are primarily designed to produce a surface gloss.

The control group produced the lowest R_a and highest AG values for both resin composites, a finding which is consistent with results from other investigations.[20,21] The higher mean R_a values for the control with the Durafill VS resin composite material were perhaps due to relatively larger surface porosities illustrated on the SEM photomicrographs for the control specimens. The resin composite materials were dispensed from a syringe container, light-activated under a Mylar strip to prevent oxygen inhibition, and had light pressure applied with the light tip directly on top of the Mylar strip. Although careful procedural techniques were followed to minimize air porosity, porosity was problematic, especially with the Durafill VS resin composite specimens. Although the authors were able to record R_a values on nonporous areas of the specimens, it took additional time to avoid porosities which, when present, would have skewed the data. It is the authors' opinion that the microscopic porosities did not adversely impact the R_a or AG values.

No specific finishing/polishing procedure consistently produced lower R_a and higher AG values for both of the resin composites tested. In vivo research of R_a has shown that there was a substantial increase in bacterial retention above a threshold of 0.2 µm.[22] It has also been proposed by Bollen et al that R_a values ≤0.3 µm cannot be discriminated by the patient.[22,23] Using R_a values ≤0.3 µm as a threshold criterion, 4 of the 8 finishing/polishing procedures (excluding control) for Durafill VS had R_a values ≤0.3 µm. The HiShine Jiffy disc had the second lowest mean R_a value (after control) for the Durafill VS material; however, this value was not significantly different ($P \le 0.05$) from the other 4 finishing/polishing procedures with R_a values ≤0.3 µm. With the exception of the medium Sof-Lex XT disc, all of the other finishing/polishing procedures (excluding control) for the Vit-l-escence material had R_a values ≤0.3 µm. In a similar fashion, the Vit-l-escence material had 4 of the 8 polishing/finishing procedures (excluding the control) with AG values

Chart 4. Linear regression plot of surface roughness (R_a) and absolute gloss (AG) values for Vit-l-escence.



Pearson's r=-0.548, r^2=0.300

≥8.0, while the Durafill VS material only had 2 out of the 8 finishing/polishing procedures (excluding the control) capable of producing an AG ≥8.0. Although the Durafill VS was unable to achieve a gloss with as many finishing/polishing procedures as did the Vit-l-escence in this study, other research has shown that microfilled resin composites will maintain a gloss finish after simulated tooth brushing better than other types of resin composites.[24] The polishing procedures Medium Sof-Lex XT, Enhance disc, and Enhance disc with Prisma polishing paste had AG values ≤7.0 for both resin composites. These observations regarding the R_a and AG of the resin composites are consistent with the known ability of fine-grit rubber abrasives and polishing brushes containing diamond, silicon carbide, and/or aluminum oxide to produce a smooth surface and concurrent high surface gloss, especially when used on microhybrid resin composites.[5,17]

Polishing procedures that included the Enhance disc or the Enhance disc and Prisma polishing pastes generally demonstrated higher R_a and lower AG values for both resin composites. This may be because the aluminum oxide abrasive particle size in the Enhance polisher is relatively large (45 µm) compared to the other finishing/polishing techniques, which use sequentially smaller-sized (1-8 µm) abrasive particles. Although the Enhance abrasives are frequently used as a final polisher by clinicians—because they are a "use and dispose" item—according to the manufacturer, the Enhance abrasive is suggested for use only as a finisher; the PoGo abrasive is suggested for final polishing to achieve a high gloss.[25]

Qualitative differences were evident when the SEM photomicrographs are compared between the resin composites and finishing/polishing procedures. Although the control specimens appeared smoother, they demonstrated surface porosity, likely due to air incorporation inherent with bulk-filling techniques. In order to simulate direct clinical observation, visual examination (loupe with 2.5X magnification) of the specimens categorized the surface appearance of the materials as relatively smooth and glossy for all finishing/polishing methods, except for the medium Sof-Lex XT disc, which appeared to lack surface gloss and had a matte surface. This finding suggests that the clinician may not be able to discriminate smoothness and gloss similar to profilometry and gloss meter measurements.

Conclusion

Smooth surfaces on resin composite restorations are critical for clinical success; the finished/polished surface should ideally resemble the relative gloss of the adjacent tooth structure. Rubber abrasives containing fine particles (1-8 µm) separately or in various combinations of diamond, aluminum oxide, and silicon carbide performed better or in a similar manner as the superfine (8 µm) aluminum oxide-impregnated Sof-Lex discs on these flat-surfaced specimens.

The results of this research suggest that the silicon oxide-containing brush (Jiffy polishing brush) was capable of producing a favorable level of surface gloss with relatively low surface roughness for both Durafill VS and Vit-l-escence. Use of the Enhance disc (with or without Prisma polishing pastes) without subsequent use of the Pogo disc for final polishing is not recommended for the representative resin composites used in this study.

Additional research is needed to quantify smoothness and gloss of nanofill and submicron resin composites, as this evidence needs to be supplemented.[26] Identification of finishing/polishing procedures that result in a smooth surface with a corresponding high degree of gloss appropriate for a particular resin composite material will aid the clinician in achieving optimal restorative outcomes.

Author information

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Manufacturers

Beta Industries, Carlstadt, NJ
800.272.7336, www.betascreen.com

DENTSPLY International, York, PA
800.877.0020, www.dentsply.com

Heraeus Kulzer, South Bend, IN
800.435.1785, www.heraeus-dental-us.com

Ivoclar Vivadent, Inc., Amherst, NY
800.533.6825, www.ivoclarvivadent.us

JEOL Ltd., Welwyn Garden City, England
44.170.7377.117, www.jeol.com

Kerr Corporation, Orange, CA
800.537.7123, www.kerrdental.com

Mitutoyo America Corporation, Aurora, IL
888.648.8869, www.mitutoyo.com

Ultradent Products, Inc., South Jordan, UT
888.230.1420, www.ultradent.com

3M ESPE, St. Paul, MN
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