Effects of air polishing powders on the surface roughness of composite resins

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Background/purpose: Although new composites are being introduced into clinical practice to achieve better polishability and wear resistance, their properties and the surface changes that occur after air polishing are still unknown. The aim of this study was to investigate the effects of different air polishing powders on the surface roughness of different types of composite resin restorative materials.

Materials and methods: Thirty cylindrical specimens (15 × 2 mm) were prepared for each of seven composite resin restorative materials. All specimens were polished with a series of aluminum oxide polishing discs (Sof-Lex). Prepared specimens of each composite resin were randomly divided into three groups of 10 specimens each, including a control (Group C) and two different air-powder applications (Group CP, Cavition Prophy-Jet; and Group PS, Sirona ProSmile prophylaxis powder). A standard air polishing unit (ProSmileHandly) was used. All specimens were air-polished for 10 seconds at a pressure of 4 bar. The distance of the spray nozzle from the specimens was approximately 10 mm, and the angle of the nozzle was 90º. Surface roughness measurements (Ra, μm) were performed using a profilometer (Perthometer M2). Data were analyzed by two-way analysis of variance (ANOVA), and mean values were compared by Tukey’s honestly significant difference test (α = 0.05).

Results: According to the two-way ANOVA, composite resins, air polishing powders, and their interactions were statistically significant (P < 0.05). For the CeramXMono, Grandio, Filtek Silorane, and Quixfil composite resin restorative material groups, the highest Ra values were observed in Group PS. No significant difference was observed between Group PS and Group CP (P > 0.05), and these groups demonstrated the highest Ra values for the Aelite Aesthetic Enamel, FiltekZ250, and IntenS composite resin restorative materials. The lowest Ra values for the composite resin groups were observed in Group C (P < 0.05). When comparing composite resins, FiltekZ250 demonstrated statistically significantly lower Ra values than the other composite resins tested (P < 0.05). No significant difference was observed between the IntenS and Quixfil composite resin groups; these groups also demonstrated the highest Ra values.

Conclusion: Air polishing applications increased the surface roughness of all composite resin restorative materials tested. Composite restorations may require re-polishing after air polishing.
Introduction

Resin composites are widely used for the direct restoration of both anterior and posterior teeth because of the esthetic, physical, and mechanical properties of these materials. A resin composite is composed of four major components: an organic polymer matrix, inorganic filler particles, coupling agents, and an initiator-accelerator system. The organic polymer matrix in most commercial composites today is either an aromatic or urethane diacrylate oligomer. The three most common oligomers used in dental composites are bisphenol A diglycidyl ether methacrylate (bis-GMA), urethane dimethacrilate (UDMA), and triethylene glycol dimethacrylate (TEGDMA).\(^1\) In addition, siloranes were suggested as alternatives to methacrylates as matrix resin components for dental composites because of their physical properties.\(^2\) Resin composites are classified according to various characteristics such as filler type, filler distribution, average particle size of the filler, and the physical and mechanical properties of the materials. Currently, three categories are proposed for widely used resin composites: microfilled, microhybrid, and nanocomposite.\(^3\)

Proper finishing and polishing are important steps in clinical restorative dentistry that enhance both the esthetics and longevity of restorations.\(^4\) The surface roughness of a resin composite is related to the composition and porosity of the material and the instruments and procedures used for polishing.\(^5\)−\(^8\) Residual surface roughness may result in excessive plaque accumulation, gingival inflammation, and increased surface staining.\(^9\)−\(^11\)

Hygiene maintenance therapy is an integral part of restorative and periodontal treatment. The removal of stains and plaque from all accessible tooth surfaces is a routine part of the maintenance appointment.\(^12\)−\(^13\) The conventional rubber cup prophylaxis and air-powder polishing system are both effective professional techniques for plaque and stain removal, without detrimental effects to the tooth structure or gingival tissues when correctly used.\(^14\)−\(^18\)

Since its introduction to the dental marketplace in 1977, air-powder polishing systems have been effective at removing stains and plaque.\(^19\) The designs of various air-powder polishing systems, such as Sirona ProSmile Handly, use a mixture of air, water and sodium bicarbonate to deliver a controlled stream of sodium bicarbonate particles to the tooth surface. Advantages of air polishers are rapid removal of tooth deposits, less invoked hypersensitivity,\(^20\)−\(^21\) lower operator fatigue,\(^15\) and improved access to pits and fissures.\(^22\)

To the best of our knowledge, no study has evaluated the effects of different air polishing powders on the surface roughness of actual commonly used composite resin restorative materials. The purpose of this study was to investigate the effects of different air polishing powders on the surface roughness of different types of composite resin restorative materials. The research hypothesis was that the surface roughness of the composite resins would be affected by the type of composite and air polishing powder.

Materials and methods

In the present study, seven different composite resin restorative materials were investigated. The composite resins used in this study are shown in Table 1. Thirty cylindrical specimens (15×2 mm) were prepared for each of seven composite resin restorative materials using a brass mold. The materials were manipulated and polymerized according to the manufacturers’ instructions. Light-polymerized specimens were polymerized using a halogen lamp (Astralis 3; Ivoclar Vivadent AG, Schaan, Principality of Liechtenstein) with a light intensity of 400 mW/cm\(^2\) for 20 seconds with the light tip approximately 1 mm away from the specimens on both sides. Both sides of the specimens were wet-ground with 1000-grit silicon carbide abrasive paper for 10 seconds on a grinding machine (Metaserv; Buehler GmbH, Düsseldorf, Germany) at 300 rpm. All specimens were polished with a series of 12.7-mm-diameter aluminum oxide polishing discs (Sof-Lex; 3M ESPE, St. Paul, MN, USA) with an electric handpiece (K10; KaVo, Biberach, Germany) at a speed of 10,000 rpm for 10 seconds with coarse and medium discs, and at a speed of 30,000 rpm for 10 seconds with fine and superfine discs according to the manufacturer’s directions. The specimens were stored for 24 hours in distilled water at 37°C prior to subjecting them to air-powder application.

The prepared specimens of each composite resin were randomly divided into three groups of 10 specimens each. The three groups comprised a control group (Group C), and two different air-powder applications: Group CP (Cavitron Prophy-Jet; Dentsply Detrey GmbH, Konstanz, Germany) and Group PS (ProSmile prophylaxis powder; Sirona Dental Systems GmbH, Bensheim, Germany). In Group C, no air polishing was applied to the specimens. A standard air polishing unit (ProSmile Handly; Sirona Dental Systems GmbH) was used for this investigation and was installed according to the manufacturer’s instructions. In Group CP, the powder chamber of the air polishing unit was filled to the top with Cavitron Prophy-Jet containing sodium bicarbonate, and specimens were polished for 10 seconds at 4 bars of pressure. The distance of the spray nozzle from the composite resin surface was approximately 10 mm,
<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Lot number</th>
<th>Matrix</th>
<th>Filler size (μm)</th>
<th>Filler weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aelite Aesthetic Enamel (reinforced nanofill composite)</td>
<td>Bisco Inc., Schaumburg, IL, USA</td>
<td>0800002171</td>
<td>Ethoxylated Bis-GMA, Bis-GMA</td>
<td>Glass filler amorphous silica 0.04–5.0 μm</td>
<td>73</td>
</tr>
<tr>
<td>Filtek Silorane (Silorane resin)</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td>7AJ</td>
<td>Silorane (3,4-epoxycyclohexylethylcyclo-polymethylsiloxane, bis-3,4-epoxycyclohexylethyl-phenylmethylsilane)</td>
<td>Silicon dioxide, ytterbium trifluoride 0.1–2.0 μm</td>
<td>76</td>
</tr>
<tr>
<td>Filtek Z250 (microhybrid/hybrid)</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td>7AK</td>
<td>Bis-GMA, UDMA, Bis-EMA</td>
<td>Zirconia/silica 0.01–3.5 μm</td>
<td>78</td>
</tr>
<tr>
<td>Quixfil (microhybrid/hybrid)</td>
<td>Dentsply Detrey GmbH, Konstanz, Germany</td>
<td>0611000259</td>
<td>Ethoxylated bisphenol-A-dimethacrylate (Bis-EMA), UDMA, TEGDMA,trimethylolpropane trimethacrylate (TMPTMA)</td>
<td>Glass 1–10 μm</td>
<td>86</td>
</tr>
<tr>
<td>CeramX mono (nanohybrid)</td>
<td>Dentsply Detrey GmbH, Konstanz, Germany</td>
<td>0708000501</td>
<td>Bis-GMA, TGDMA, UDMA</td>
<td>Glass filler size (mean) 1.1–1.5 μm; nanofiller size (mean) 10 nm; nanoparticle size (mean) 2.3 nm</td>
<td>76</td>
</tr>
<tr>
<td>Grandio (nanohybrid)</td>
<td>VOCO GmbH, Cuxhaven, Germany</td>
<td>771060</td>
<td>Bis-GMA, TGDMA, UDMA</td>
<td>Glass ceramic microfillers (1 μm) SiO₂ nanofillers (20–60 nm)</td>
<td>87</td>
</tr>
<tr>
<td>IntenS (microhybrid/hybrid)</td>
<td>Ivoclar Vivadent AG, Schaan, Principality of Liechtenstein</td>
<td>H29977</td>
<td>Bis-GMA, UDMA, Bis-EMA</td>
<td>Barium glass, ytterbium trifluoride 0.2–7.0 μm</td>
<td>74</td>
</tr>
</tbody>
</table>
Surface roughness of composite resins

and the angle of the nozzle to the specimens was 90º. For Group PS, specimens were polished with ProSmile prophylaxis powder containing sodium bicarbonate, calcium phosphate, and colloidal anhydrous silica, under the same polishing conditions as described for Group CP. All specimens were washed with tap water for 1 minute, ultrasonically cleaned in a water bath for 10 minutes, and then air dried.

Specimens were stabilized with silicone impression material into a brass mold, and three roughness measurements (Ra, μm) were taken on each sample using a profilometer (Perthometer M2; Mahr GmbH, Göttingen, Germany). A cutoff value of 0.25 mm allowed detection of only those irregularities.23,24 A diamond stylus (NHT-6) of 2-μm radius with a stylus angle of 90º was traversed at a constant speed across each of the finished ceramic samples with a force of 0.7 N. Before measurements in each group, the profilometer was calibrated. All profilometer records were made as close as possible to the sample center. For each specimen, three measurements were made, and the mean was calculated to obtain the general surface characteristics of the specimens. The Ra value describes the average value for a surface that has been traced by the profilometer.23 A lower Ra value indicates a smoother surface.

Two-way analysis of variance (ANOVA) using SPSS version 12.0.1 (SPSS Inc., Chicago, IL, USA) for Windows was performed to evaluate the effect of the composite material and air polishing powder on the surface roughness, including the possibility of interactions between the two factors. The means were then compared with Tukey’s honestly significant difference test (α=0.05).

After performing the surface roughness test, the surface irregularity of specimens was observed under a scanning electron microscope (JSM-6400; JEOL Ltd., Tokyo, Japan) at a magnification of 1000×.

Results

According to the two-way ANOVA results, composite resin restorative materials, air polishing powders, and their interaction were statistically significant (P<0.05) (Table 2). Mean Ra values, standard deviations of the surface roughness, and group differences of the composite resin restorative materials are listed in Table 3.

For the CeramX Mono, Grandio, Filtek Silorane, and Quixfil composite resin restorative material groups, the highest Ra values were observed in Group PS. Group CP was found to have statistically significantly lower Ra values than Group PS and higher Ra values than Group C. The lowest Ra values for these composite resin groups were observed in Group C (P<0.05).

For the Aelite Aesthetic Enamel, Filtek Z250, and IntenS composite resin restorative materials, no significant difference was observed between

### Table 2. Two-way ANOVA for composite resin restorative materials and different air polishing powders

<table>
<thead>
<tr>
<th>Variable (source)</th>
<th>df</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite resin</td>
<td>6</td>
<td>1.778</td>
<td>0.296</td>
<td>30.764</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Air powder</td>
<td>2</td>
<td>4.056</td>
<td>2.028</td>
<td>210.596</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Interaction</td>
<td>12</td>
<td>0.974</td>
<td>0.081</td>
<td>8.424</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Error</td>
<td>189</td>
<td>1.820</td>
<td>0.010</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3. Mean values (μm) and standard deviations (SDs) of the surface roughnesses (Ra) and differences among groups*

<table>
<thead>
<tr>
<th>Composite resin</th>
<th>Filtek Z250</th>
<th>Filtek Silorane</th>
<th>CeramX Mono</th>
<th>Aelite</th>
<th>Grandio</th>
<th>IntenS</th>
<th>Quixfil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group C</td>
<td>0.160</td>
<td>0.170</td>
<td>0.213</td>
<td>0.127</td>
<td>0.241</td>
<td>0.159</td>
<td>0.307</td>
</tr>
<tr>
<td>(0.05)</td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.06)</td>
<td></td>
</tr>
<tr>
<td>Group CP</td>
<td>0.258</td>
<td>0.325</td>
<td>0.308</td>
<td>0.453</td>
<td>0.408</td>
<td>0.635</td>
<td>0.457</td>
</tr>
<tr>
<td>(0.07)</td>
<td>(0.09)</td>
<td>(0.04)</td>
<td>(0.16)</td>
<td>(0.08)</td>
<td>(0.20)</td>
<td>(0.09)</td>
<td></td>
</tr>
<tr>
<td>Group PS</td>
<td>0.288</td>
<td>0.433</td>
<td>0.525</td>
<td>0.490</td>
<td>0.524</td>
<td>0.721</td>
<td>0.756</td>
</tr>
<tr>
<td>(0.03)</td>
<td>(0.12)</td>
<td>(0.09)</td>
<td>(0.14)</td>
<td>(0.11)</td>
<td>(0.17)</td>
<td>(0.10)</td>
<td></td>
</tr>
</tbody>
</table>

*Different superscript letters in the same column indicate a statistically significant difference (P<0.05). C = control (no air polishing application); CP = Cavitron Prophy-Jet; PS = Sirona ProSmile prophylaxis powder.
Groups PS and CP (P > 0.05), and these groups demonstrated higher Ra values than Group C. The lowest Ra values were observed in Group C for each of the composite resin groups above.

When comparing the seven different composite resin restorative materials, Filtek Z250 demonstrated statistically significantly smaller Ra values than the other composite resins tested (P < 0.05). No significant difference was observed between the IntenS and Quixfil composite resin groups, and these groups also demonstrated the highest Ra values.

The scanning electron microscope studies revealed that the surface irregularities of the composite resins corresponded to the results of the surface roughness study (Fig. 1).

Discussion

On the basis of these data, the hypothesis stated as the premise of this study is accepted. Different air polishing powders do affect the surface roughness of composite resin restorative materials differently. Although new composites integrating nanofiller technology are being introduced into clinical practice to achieve better polishability and wear resistance, their properties and the surface changes that occur after air polishing are still unknown.

The surface roughness (Ra) refers to fine irregularities of the surface texture that usually result from the action of the production process or material conditions and is measured in micrometers (μm). The critical surface roughness threshold established for bacterial adhesion is 0.2 μm. Whereas no reduction in bacterial accumulation is expected below this threshold, any increase in surface roughness above 0.2 μm results in simultaneous increases in plaque accumulation, superficial staining, and the risk of caries and periodontal inflammation, and the esthetics and longevity of the restoration are in jeopardy.

To describe the surface texture of the composite resin specimens, an Ra parameter was selected that could be obtained with a profilometer. This parameter describes the overall roughness of the surface and can be defined as the arithmetic average value of all absolute distances of the roughness profile from the center line within the measuring length.

Smother composite resin surfaces are obtained when the material is cured against a polyester matrix. Despite careful placement of the matrix, removing excess material and recontouring restorations are often clinically necessary. This requires some degree of finishing and polishing, which may alter the smoothness obtained with the matrix. Finishing instruments are designed to produce a smooth surface on dental restorative materials. Instruments commonly used for finishing and polishing tooth-colored restorative materials include carbide burs, 25–50-mm diamond rotary cutting instruments, abrasive-impregnated rubber cups and points, and abrasive discs, strips, and polishing pastes. Aluminum oxide discs were shown to produce better surface smoothness because they do not displace the composite fillers. Berastegui et al. reported that the fillers in microfilled composite resins are so small that their stiffness is reduced, and therefore aluminum oxide discs are most often recommended because their malleability promotes a homogeneous abrasion of the fillers and resin matrix. Findings of a previous study showed that flexible aluminum oxide discs (Sof-Lex) yielded the lowest Ra values for microfilled, hybrid, and packable composite resins. For these reasons, all specimens were polished with a series of Sof-Lex aluminum oxide polishing discs in the present study. Except for Quixfil and Grandio, surface roughness values of the control groups that were polished with Sof-Lex were observed to be below or near the critical surface roughness threshold. Bayne and Taylor stated that increasing the filler contents of composite resins generally improves the physical, chemical, and mechanical properties such as water absorption, color stability, and wear resistance. To be an effective finishing system for composite resins, the abrasive particles must be relatively harder than the filler materials. Otherwise, the polishing agent will only remove the soft resin matrix and leave the filler particles protruding from the surface. In control groups of Quixfil and Grandio, Ra values were > 0.2 μm in the present study. The reason for this might have been that the filler weights (%) of these composites were greater than those of the other composite resins tested (Table 1).

As heavy plaque depositions and stains are common near gingival tissues, cervical restorations are inevitably exposed to prophylactic procedures during maintenance therapy. Different types of prophylactic regimens are available. These procedures are usually performed using a variety of prophylactic agents with varying extents of abrasiveness and rotary rubber cups or brushes as carriers. Air-powered devices were also introduced into clinical practice. With these devices, sodium bicarbonate particles are propelled by an air jet combined with a small stream of water, creating a slurry that is directed onto the tooth surface. Air polishers were shown to remove extrinsic stains faster than hand scalers, abrasives in rubber cups, and strips without causing significant changes in the surface of the enamel or dentin.

The effects of hygiene procedures on surface roughness are material-dependent. Composites are biphasic, with fillers embedded in a resin/polymer matrix. During hygiene procedures, the matrix
<table>
<thead>
<tr>
<th>Material</th>
<th>Group C</th>
<th>Group CP</th>
<th>Group PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtek Z250</td>
<td>![Image](Fillet Z250)</td>
<td>![Image](Fillet Z250 CP)</td>
<td>![Image](Fillet Z250 PS)</td>
</tr>
<tr>
<td>Filtek Silorane</td>
<td>![Image](Fillet Silorane)</td>
<td>![Image](Fillet Silorane CP)</td>
<td>![Image](Fillet Silorane PS)</td>
</tr>
<tr>
<td>CeramX mono</td>
<td>![Image](CeramX mono)</td>
<td>![Image](CeramX mono CP)</td>
<td>![Image](CeramX mono PS)</td>
</tr>
<tr>
<td>Aelite</td>
<td><img src="Aelite" alt="Image" /></td>
<td>![Image](Aelite CP)</td>
<td>![Image](Aelite PS)</td>
</tr>
<tr>
<td>Grandio</td>
<td><img src="Grandio" alt="Image" /></td>
<td>![Image](Grandio CP)</td>
<td>![Image](Grandio PS)</td>
</tr>
<tr>
<td>IntenS</td>
<td><img src="IntenS" alt="Image" /></td>
<td>![Image](IntenS CP)</td>
<td>![Image](IntenS PS)</td>
</tr>
<tr>
<td>Quixfil</td>
<td><img src="Quixfil" alt="Image" /></td>
<td>![Image](Quixfil CP)</td>
<td>![Image](Quixfil PS)</td>
</tr>
</tbody>
</table>

**Fig. 1** Scanning electron microscope photographs of study groups tested at 1000× magnification. C = control (no air polishing application); CP = Cavitron Prophy-Jet; PS = Sirona ProSmile prophylaxis powder.
phase is preferentially removed as the abrasives employed in prophylactic agents are harder than the resin matrix. These abrasives can even be similar in hardness to the fillers of some composite materials. As the resin matrix is selectively removed, filler particles are exposed, resulting in a rough surface. Johnson et al. stated that regardless of the polishing agent used, whether sodium bicarbonate or aluminum trihydroxide, the use of these agents should be avoided on dental restorative materials. Cooley et al. and Lubow and Cooley evaluated the effect of an air polishing system that utilized sodium bicarbonate powder on the surface characteristics of various restorative materials. They found that the composite resins underwent the greatest change in roughness. In the present study, air polishing applications increased the surface roughness of all the composite resin restorative materials tested. Surface roughness values of Groups CP and PS for all composite resin restorative materials tested were observed to be above the critical surface roughness threshold. When comparing two different air polishing powders, ProSmile prophylactic powder exhibited higher Ra values than Cavitron Prophy-Jet. The reason for this may have been the difference in content of these two different air polishing powders. While Cavitron Prophy-Jet contains sodium bicarbonate, ProSmile prophylactic powder contains calcium phosphate and colloidal anhydrous silica in addition to sodium bicarbonate.

Composite surface roughness is basically dictated by the size, hardness and amount of filler, which influence the mechanical properties of the resin composites. It is also influenced by the flexibility of the finishing material, the hardness of the abrasive systems, and the grit size. In composite resins, in which the fillers are markedly harder than the resin matrix, the resin phase may suffer preferential losses during finishing and polishing, leaving the filler phase in positive surface relief. Use of composite resins with a higher small-sized filler-particle content has increased in recent years, due to difficulties in producing smooth surfaces such as enamel with composite resins with larger filler particles. An increase in the amount of filler content results in smoother surfaces because of the decreased particle size and better distribution within the resin matrix. Differences in the surface topography among conventional composite resins tested in this study can be attributed to differences in their interparticle spacing and filler particle size. For conventional composite resins tested, the highest surface roughness averages were recorded for the larger particle composite resins, IntenS and Quixfil, while the smoothest surfaces were recorded for Filtek Z250. According to the results of this study, there were no statistically significant differences among the nanofil, nanohybrid, and silorane resin restorative materials. These groups exhibited lower Ra values than the IntenS and Quixfil composite resins.

The present study has several limitations. The specimen surfaces were flat, whereas clinically, composite resin restorations have an irregular shape with convex and concave surfaces. Furthermore, the application of the surface finishing procedure used in this study may be difficult to perform clinically. In the present study, two different air polishing powders with different contents were evaluated, and specimens were air-polished for 10 seconds at 4 bars of pressure. The distance of the spray nozzle from the composite resin surface was approximately 10 mm, and the angle of the nozzle to the specimens was 90°. In future studies, the effects of different application times, pressures, and nozzle distances and angles to the surface roughness of different restorative materials will be carried out.

Within the limitations of the current study, the following findings are noted: (1) the highest surface roughness averages were seen for IntenS and Quixfil, while the smoothest surfaces were seen for Filtek Z250; (2) when comparing the two air polishing powders tested, ProSmile prophylactic powder exhibited higher Ra values than Cavitron Prophy-Jet; and (3) air polishing applications increased the surface roughness of all of the composite resin restorative materials tested. Composite restorations may require re-polishing after air polishing.

References

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