Influence of Polishing System on the Surface Roughness of Flowable and Regular-Viscosity Bulk Fill Composites

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This study evaluated the influence of polishing protocols on the surface roughness of flowable and regular bulk fill composites. Five bulk fill composites were tested: SureFil SDR Flow (SDR), Tetric EvoFlow Bulk fill (TEF), Filtek Bulk Fill Flowable (FIF), Tetric EvoCeram Bulk Fill (TEC), and Filtek Bulk Fill Posterior (FIP). Two polishing protocols were tested: Sof-Lex and Astropol. Astropol created a smoother surface for FIP (P < .05); however, the polishing protocol did not influence surface roughness on TEC (P > .05). SDR, TEF, and FIF exhibited rougher surfaces when polished. Sof-Lex created rougher surfaces for bulk fill composites. It was concluded that surface roughness was related to material composition rather than the polishing system. Int J Periodontics Restorative Dent 2018;38:e79–e86. doi: 10.11607/prd.3033

Composites are widely used for anterior and posterior restorations due to their ability to closely mimic the natural tooth in terms of color, strength, shape, and texture.1,2 Superficial texture is an important factor in the longevity of composite restorations.3 Long-term follow-up studies have demonstrated that a rough composite surface can compromise color and gloss,4–6 lead to increased plaque accumulation,2,4–7 and favor development of secondary caries.2,7–9 Secondary caries are one of the main reasons for failure of a composite restoration (around 38% in 30 years).8,9

In addition to their beneficial effect on patient comfort, finishing and polishing procedures are required to achieve restoration esthetics and increase longevity.2,4 Finishing is the primary contouring of a restoration to reach a desirable anatomy and occlusion. Polishing reduces roughness and removes scratches created in previous steps.2 Many polishing systems (with one or multiple steps) have been introduced over the years, including diamond burs, multifluted carbide finishing burs, and aluminum oxide–coated abrasive discs/wheels.2,3 The goal for manufacturers and clinicians is to create the smoothest surface in the shortest amount of time.2 A clinically acceptable surface roughness will have values close to enamel-to-enamel contact in occlusal areas (0.64 μm).10
Previous studies suggest that surface roughness and polishing efficiency are dependent on the composite resin formulation. Flowable conventional composites (37% to 53% of the filler’s volume) allow for easier insertion, better adaptation, and improved polishing results. However, regular conventional composites (50% to 70% of the filler’s volume) are generally more difficult to polish and adaptation might be compromised due to their higher viscosity. Filler size has also proven to influence the surface roughness of composite materials. For example, nanoparticles (smaller than 100 nm) exhibit better polishing, improved optical characteristics, and better gloss maintenance relative to composites with coarser fillers.

Bulk fill composites were developed to fill cavities in one increment. Matrix and filler content and size have been modified to improve the clinical performance of materials. They are commercially available in two viscosities, flowable and regular, which have different indications in clinical practice. Flowable bulk fill composites are recommended as a base in Class I and II restorations, which should subsequently be capped with a conventional composite to withstand occlusal loading. Regular-viscosity bulk fill composites are recommended for bulk filling the entire caries lesion and do not require a regular composite layer.

Further investigations are warranted considering that few studies have assessed the different surface textures produced after polishing bulk fill composites. This in vitro study evaluated the efficiency of polishing protocols and the surface roughness of flowable and regular-viscosity bulk fill composites. The following two hypotheses were tested: (1) flowable and regular-viscosity bulk fill composites will present different surface roughness after polishing protocols, and (2) different polishing systems will provide different surface roughness.

Materials and Methods

Specimen Preparation

A total of 126 composite discs (5 × 2 mm) were prepared according to the seven composites tested. Three flowable bulk fill composites (SureFill SDR Flow [SDR], Tetric EvoFlow Bulk Fill [TEF], and Filtek Bulk fill Flowable [FIF]) and two regular-viscosity bulk fill materials (Tetric EvoCeram Bulk fill [TEC] and Filtek Bulk Fill Posterior [FIF]) were tested, and two conventional composites (IPS Empress Direct [EMD] and Filtek Supreme Ultra [FIS]) were used as control materials (n = 18). Materials, manufacturers, and composition are shown in Table 1. For each material, composite was inserted into a rubber mold and pressed between two glass microscope slides covered by polyester strips. Constant standardized mild pressure was applied on the top to remove excess material and produce a flat surface. Specimens were polymerized from the top for 20 seconds with a polywave LED light-curing unit (1,200 mW/cm², Bluephase, Ivoclar Vivadent). All samples were stored in distilled water at 37°C for 24 hours before polishing procedures.

The samples were subdivided into three groups (n = 6) according to the polishing protocol used. In the control group, no polishing was performed; the polyester strip provided the surface finishing. The other groups were polished using either Sof-Lex discs or Astropol rubber polishers, following manufacturers’ recommendations (Table 2). A metal mold was used to hold the sample during polishing procedures, which were performed by a single operator (L.C.R.). The abrasive discs were used once and discarded. After polishing, samples were ultrasonically cleaned with deionized water for 10 minutes to remove any surface debris. All samples were stored under water at 37°C prior to surface roughness evaluation.

Surface Roughness Evaluation

The average surface roughness (Sa) of each specimen was measured in five different areas using optical topometry (OTM) (PhaseView ZeeScan, attached to a Zeiss Axio Imager M1m) for extended depth of field imaging. An x-y cutoff of 425 μm was used with a ×50 (NA = 0.70) magnification objective lens providing submicron vertical resolution. ZeeScan software (GetPhase) provided z-depth measurement and three-dimensional reconstruction of the surface for calculating surface roughness (Sa) as well as two-dimensional images from the surface for qualitative analysis.

The data was statistically analyzed by two-way analysis of variance (ANOVA) considering material and polishing protocols. Post hoc
comparisons were carried out using Tukey test ($\alpha = .05$).

### Results

Table 3 presents the $S_a$ values and standard deviation for the different groups. Two-way ANOVA revealed significant differences for the factors composite resin ($P = .00001$) and polishing technique ($P = .00001$) and for the interaction between factors ($P = .00001$).

Regarding polishing protocols, no significant difference was observed for the conventional composites (FIS and EMD) ($P > .05$). With the exception of TEC, Sof-Lex increased surface roughness for all bulk fill composites. Astropol created a smoother surface for the regular bulk fill composites FIP and TEC; however, no significant difference was observed with respect to TEC in terms of polishing protocol ($P > .05$). Both polishing protocols created rougher surfaces than the control (polyester strip) for all bulk fill flowable composites (FIF, TEF, and SDR) ($P > .05$). Regarding FIF and SDR, no significant difference was observed between Sof-Lex and Astropol. However, regarding TEF, Astropol produced the highest surface roughness values ($P < .05$). Consider-

### Table 1 Materials, Manufacturers, Batch Numbers, Composition, and Filler Loading of the Materials Studied

<table>
<thead>
<tr>
<th>Material (abbreviation)</th>
<th>Composition</th>
<th>Batch number</th>
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<tbody>
<tr>
<td><strong>Regular conventional composite</strong></td>
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<tr>
<td>Filtek Supreme Ultra Universal Restorative, 3M ESPE (FIS)</td>
<td>Matrix: bisphenol a diglycidyl ether dimethacrylate (Bis-GMA), modified urethane dimethacrylate resin (UDMA), triethylene glycol dimethacrylate (TEGDMA), ethoxylated bisphenol A dimethacrylate (bis-EMA), and polyethylene glycol dimethacrylate (PEGDMA); Fillers: nonagglomerated silica filler (20 nm), nonagglomerated zirconia filler (4–11 nm), and aggregated zirconia/silica cluster fillers (filler content 78.5% wt/63.3% vol, filler average size = 0.6–1.4 μm)</td>
<td>N709034</td>
</tr>
<tr>
<td>IPS Empress Direct, Ivoclar Vivadent (EMD)</td>
<td>Matrix: UDMA, Bis-GMA, tricyclodecane dimethanol dimethacrylate (TCDD); Fillers: barium-alumina-fluorosilicate glass, barium glass filler (0.4 μm), mixed oxide (150 nm), prepolymer (1–10 μm) (filler content 81.2% wt/59% vol)</td>
<td>U26969</td>
</tr>
<tr>
<td><strong>Regular bulk fill composite</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetric EvoCeram Bulk Fill, Ivoclar Vivadent (TEC)</td>
<td>Matrix: Bis-GMA, UDMA, bis-EMA; Fillers: Ba-Al-Si glass (0.4–0.7 μm), ytterbium trifluoride (200 nm), and an Isofilm (prepolymer) (filler content 79%–81% wt/60%–61% vol)</td>
<td>U24443</td>
</tr>
<tr>
<td>Filtek Bulk Fill Posterior Restorative, 3M ESPE (FIP)</td>
<td>Matrix: AUDMA, UDMA, 12-dodecanedimethylamine dimethacrylate (DDDMA); Fillers: nonagglomerated silica filler (20 nm), nonagglomerated zirconia filler (4–11 nm), aggregated zirconia/silica cluster filler (20 nm silica/4–11 nm zirconia), and an agglomerate ytterbium trifluoride filler (100 nm) (filler content 76.5% wt/58.4% vol)</td>
<td>N710947</td>
</tr>
<tr>
<td><strong>Flowable bulk fill composite</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filtek Bulk Fill Flowable Restorative, 3M ESPE (FIF)</td>
<td>Matrix: Bis-GMA, UDMA, substituted dimethacrylate, (BisEMA-6), and Procrylat resins; Fillers: zirconia/silica particles (0.01–3.5 μm) and ytterbium trifluoride fillers (0.01–5.0 μm) (filler content 64.5% wt/42.5% vol)</td>
<td>N721690</td>
</tr>
<tr>
<td>Tetric EvoFlow Bulk Fill, Ivoclar Vivadent (TEF)</td>
<td>Matrix: Bis-GMA, Bis-EMA, TCDD; Fillers: barium glass, ytterbium trifluoride, copolymers (filler content 68.2% wt/46.4% vol)</td>
<td>U27609</td>
</tr>
<tr>
<td>SureFil SDR Flow, Dentsply Caulk, Milford (SDR)</td>
<td>Matrix: UDMA, EBPDMA, TEGDMA; Fillers: barium-alumino-fluoro-borosilicate glass fillers (4.2 μm) (filler content 68% wt/45% vol)</td>
<td>1410000822</td>
</tr>
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In qualitative analysis, OTM two-dimensional surface images (Fig 1) demonstrated that polishing systems created scratches on composite surface depending on the materials and polishing technique used. Three-dimensional reconstructions (Fig 2) revealed that for conventional composites (FIS and EMD), a similar surface was obtained for all polishing groups. A change in the reconstruction pattern between the polished composites and the control was observed for the rest of the composites. Overall, qualitative texture was similar for all polishing protocols.

### Discussion

The present study evaluated surface roughness of bulk fill composite materials using OTM. OTM is a three-dimensional optical profilometry analysis that provides qualitative and quantitative representations, making it a useful method to evaluate surface roughness.1,2,4,15 OTM is a nondestructive method for sensitive samples that allows general and detailed visualization without mechanical contact.16 Three-dimensional optics captures specular light reflection from the material. The apparatus measures topographic relief on the surface with submicron resolution to detect microscale roughness.4

This investigation assessed the surface roughness of flowable and regular-viscosity bulk fill composites

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**Table 2** Composition and Application Directions of the Polishing Systems Used

<table>
<thead>
<tr>
<th>Finishing/ polishing material</th>
<th>Composition</th>
<th>Application directions</th>
<th>Batch number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sof-Lex, 3M ESPE</td>
<td>Extra-thin contouring and polishing discs; aluminum oxide discs (coarse 92–98 μm, medium 25–29 μm, fine 16–21 μm, and superfine 2–5 μm); followed by spiral finishing and polishing wheels—thermoplastic elastomer impregnated with aluminum oxide particles (beige and white)</td>
<td>20 s each, using a low-speed handpiece in circular movements and without water cooling</td>
<td>Coarse N723925; medium N719256; fine N712257; superfine N723924; spiral beige N715950 and white N717535</td>
</tr>
<tr>
<td>Astropol, Ivoclar Vivadent</td>
<td>Silicon carbide–coated polishing discs (coarse grey [F] 45 μm; fine green [P] 1 μm; and extra-fine pink [HP] 0.3 μm)</td>
<td>15 s each, using a low-speed handpiece in circular movements and with continuous water cooling (50 mL/min)</td>
<td>Grey (F) UL0368; green (P) TL0806; pink (HP) TL0809</td>
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</table>

**Table 3** Mean ± SD Surface Roughness $S_a$ (μm) for the Composite Resins After Different Polishing Protocols

<table>
<thead>
<tr>
<th>Composite</th>
<th>Control (polyester strip)</th>
<th>Sof-Lex</th>
<th>Astropol</th>
</tr>
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<tbody>
<tr>
<td>Filtek Supreme Ultra (FIS)</td>
<td>0.36 ± 0.02$^{Aa}$</td>
<td>0.44 ± 0.07$^{Aa}$</td>
<td>0.37 ± 0.04$^{Aa}$</td>
</tr>
<tr>
<td>Empress Direct (EMD)</td>
<td>0.39 ± 0.06$^{Aa}$</td>
<td>0.40 ± 0.06$^{Aa}$</td>
<td>0.35 ± 0.04$^{Aa}$</td>
</tr>
<tr>
<td>Tetric Evoceram Bulk Fill (TEC)</td>
<td>0.37 ± 0.06$^{Aa}$</td>
<td>0.38 ± 0.05$^{Aa}$</td>
<td>0.37 ± 0.03$^{Aa}$</td>
</tr>
<tr>
<td>Filtek Bulk Fill Posterior (FIP)</td>
<td>0.35 ± 0.06$^{Aa}$</td>
<td>0.52 ± 0.16$^{Aa}$</td>
<td>0.41 ± 0.08$^{Aa}$</td>
</tr>
<tr>
<td>Filtek Bulk Fill Flowable (FIF)</td>
<td>0.35 ± 0.05$^{Aa}$</td>
<td>0.48 ± 0.09$^{Aa}$</td>
<td>0.42 ± 0.05$^{Aa}$</td>
</tr>
<tr>
<td>Tetric Evoflow Bulk Fill (TEF)</td>
<td>0.29 ± 0.03$^{Aa}$</td>
<td>0.58 ± 0.05$^{Aa}$</td>
<td>0.68 ± 0.07$^{Aa}$</td>
</tr>
<tr>
<td>Surefil SDR Flow (SDR)</td>
<td>0.27 ± 0.02$^{Aa}$</td>
<td>0.56 ± 0.11$^{Aa}$</td>
<td>0.55 ± 0.12$^{Aa}$</td>
</tr>
</tbody>
</table>

Different superscript letters (uppercase: material; lowercase: polishing) are significantly different by Tukey test at the .05 confidence level.
Flowable bulk fill composites are indicated to fill Class I cavities as a base, as a Class II box liner, or as a stand-alone restorative material in nonocclusal-contact areas. A conventional composite should be applied on the top following the incremental technique. Clinical studies have polished with different protocols. The first postulated hypothesis was accepted because different $S_a$ values were observed for the different materials. For flowable bulk fill composites (FIF, TEF, and SDR), Sof-Lex and Astropol produced higher $S_a$ values. This observation differs from previous studies regarding conventional flowable composites, which demonstrated a smoother surface when compared to regular-viscosity conventional materials because of their lower filler rate. The filler size for the three flowable bulk fill composites tested in this study was increased by the manufacturers, which modified the surface characteristics of the materials. Manufacturers followed different strategies to increase the depth of cure of bulk fill composites, allowing an adequate degree of conversion in increments $\geq 4$ mm thick (ie, reducing the filler amount, increasing filler size, changing the photoinitiator, increasing material translucency). This study revealed that the $S_a$ of these materials increased after polishing.

Fig 1 Two-dimensional images showing composites’ surfaces obtained by optical topometry. Field width = 196 $\mu$m, with a $\times 50$ (NA = 0.70) magnification. Unpolished surfaces (left column) exhibited few air voids (white arrows) and reproductions of matrix imperfections (black arrows). Polished samples displayed a rougher and scratchier surface, Sof-Lex (middle) and Astropol (right).
Fig 2  Three-dimensional surface reconstructions obtained by optical profilometry. Spikes appearing at borders are edge artifacts and were not included in surface roughness measurements.
demonstrated acceptable performance after a 3- to 5-year follow-up period when applied according to the manufacturer’s instructions.\cite{18,19}

Although flowable bulk fill composites are not subject to polishing or exposed to occlusal wear resistance, their roughness and polishing behavior is an important characteristic on the proximal surfaces. In nonstress areas (ie, proximal areas), flowable bulk fill composites tend to be exposed to environmental degradation and plaque accumulation. According to the results of this study, FIF, TEF, and SDR revealed smoother surfaces with both polishing systems. However, low $S_a$ values, not significantly different from regular composites, were obtained when the polyester strip was used as control. A polyester strip represents the clinical result when a matrix is used,\cite{2,22} and it is considered the smoothest surface obtained on a restoration.\cite{2,4} Accordingly, when these materials are used, proximal polishing (file strips) should be avoided, if possible.

With respect to regular bulk fill composites, no significant difference was observed among the polishing protocols for the TEC group. Sof-Lex and Astropol revealed smoother surfaces compared to the control polyester strip. Previous studies suggested that TEC exhibits higher Vickers microhardness due to modifications of its composition. The modifications were focused on the substitution of camphorquinone for a more efficient photoinitiator (Ivocerin, Ivoclar Vivadent), the increase in the material’s translucency, and the addition of smaller-size round fillers. These modifications are related to a deeper and more efficient degree of polymerization and a better polishing performance because of the size and shape of the fillers.\cite{24}

With respect to FIP, Sof-Lex created the roughest surface. According to the manufacturer, FIP has the same filler composition as the conventional regular composite FIS. Nevertheless, FIS presented no difference between polishing protocols. This may be explained by the modifications made to the FIP matrix content. Four monomers were introduced: two low-viscosity monomers (DDDMA and UDMA) and two new monomers (AUDMA and AFM). DDMA and UDMA reduce reactive groups in the material to moderate the shrinkage, while AUDMA and AFM react with any methacrylate. This mechanism relaxes the developing material, relieving stress. Previous studies suggested that UDMA elution on Filtek Bulk Fill was considerably higher and its degree of cure was lower compared to other bulk fill composites.\cite{21} These properties may contribute to a higher abrasion of the matrices during polishing and exposure of superficial fillers, resulting in increased roughness.\cite{20,22}

The second postulated hypothesis, that polishing systems would provide different surface roughness, was partially accepted. Except for TEC, Sof-Lex increased the surface roughness of all bulk fill materials tested. A possible explanation lies with the smooth surface provided by the polyester strip used as a control.\cite{22} The Sof-Lex system created a more abrasive surface because it consists of four gradual files (starting from 92 to 98 μm and progressing to 2 to 5 μm) to first finish and then polish the surface, with two additional silicon wheels impregnated with aluminum oxide particles used at the end of the procedure. Previous studies described the Sof-Lex system as providing a smooth surface when a rougher starting surface was evaluated (ie, silicon paper files, diamond or carbide burs).\cite{2,11,22,25}

In this study, the control was smoother than the last polishing disc, which may have increased the $S_a$.\cite{26} In contrast to Sof-Lex, the Astropol system polishes the surface with a sequence of three silicon carbide–coated discs,\cite{2,11} which are less abrasive (from 45 to 0.3 μm) and have fewer steps than Sof-Lex. The result was a more uniform and regular surface.

Only discs and rubber polishers were tested in this study. From a clinical practice perspective, other finishing protocols (ie, diamond burs, carbide burs) are usually used before finishing and polishing discs or rubber, likely changing the roughness results obtained.\cite{22} In addition, other factors can influence polishing efficiency, such as pressure, time, abrasive particles hardness, and attachment of such particles to the base material.\cite{20} The abrasive particles should be harder than the composite filler and should not detach during polishing.\cite{2,22} The polishing choice should ultimately be based on the finishing/polishing need of each specific clinical case.

Final composite roughness should be similar to enamel-to-enamel contact in occlusal areas (0.64 μm).\cite{10} The results obtained from the OTM analysis range from
0.29 to 0.68 μm, which according to Kakaboura et al15 indicate that all composites presented clinically acceptable results with both polishing systems. Additional studies are needed to determine the long-term roughness of these materials.

Conclusions

Flowable bulk fill composites exhibited rougher surfaces when polished. The Sof-Lex disc system created rougher surfaces for bulk fill composites. Surface roughness was more closely related to material composition than to the polishing system used.

Acknowledgments

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