Surface roughness of aesthetic restorative materials: An \textit{in vitro} comparison

\textbf{SUMMARY}
The purpose of this study was to compare the surface roughness of three types of aesthetic restorative material. Six standard samples of two brands of each type of material were prepared namely: hybrid composites (Prodigy, Z100), comomers (Compoglass F, Hytac Aplitip) and glass ionomer cements (Photac-Fil, Vitremer) in a perspex mould \((N = 36)\). Upper and lower surfaces were covered with Mylar strips which, in turn, were covered with glass slides and compressed to express excess material. After light curing, specimens were stored in distilled water for 14 days. Thereafter, one side of each specimen was polished sequentially with medium, fine and superfine Soflex discs (treatment). Untreated surfaces served as controls. All surfaces were examined with Talysurf and the surface roughness \((R_{a})\) of each specimen was recorded. Three measurements were made of each specimen. A 4-way ANOVA and Tukey’s Studentised range test were used to analyse the data. Statistically significant effects were found for both type of material \((P = 0.0001)\) and for treatment process \((P = 0.0065)\). Among unpolished specimens: Compoglass F is significantly rougher than Vitremer, Z100, Prodigy and Hytac Aplitip, and comomers are significantly rougher than hybrids. Among polished specimens: Photac-Fil is significantly rougher than Z100 but does not differ from Compoglass F, Vitremer, Prodigy and Hytac Aplitip, and glass ionomers are also significantly rougher than hybrids. The smoothest surface is obtained when curing materials against a Mylar strip.

\textbf{Introduction}
The establishment of a smooth surface has always been a prime objective for composite resin restorations

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because of the biologic consequence of plaque accumulation (Berastegui \textit{et al.}, 1992). Composite restorative surfaces appear to accumulate more plaque than enamel and plaque accumulation has been related to surface roughness (Larato, 1972). Therefore, a smooth composite restoration surface is necessary to promote a plaque-free environment (Shintani \textit{et al.}, 1985) thereby improving the lifespan of the restoration (Chandler, Bowen and Paffenbarger, 1971; Heath and Wilson, 1976).

The smoothest surface is obtained when curing composite against a Mylar strip (Chung, 1994; Saito, Lovadino and Kroll, 1999). Unfortunately most restora-
tions need to be finished and polished to ensure contour and marginal integrity. The quality of the polish depends on the ability of the abrasive to polish yet not damage the surface of the composite. Diamond finishing burs have been found to cause extensive damage to surface areas of enamel and composites finished with diamond burs appear rough and uneven [Quiroz and Lentz, 1985; Hoelscher et al., 1998]. Different types of restorative composite resin finished with Soflex discs had a smoother surface than those finished by other finishing methods (Van Dijken and Ruyter, 1987; Berastegui et al., 1992; Wilson, Heath and Watts, 1990; Bouvier, Duprez and Lissac, 1997; Hoelscher et al., 1998). Little advantage appeared to be gained by prior smoothing of the surface with stones or points (Wilson, et al., 1990). This smooth surface may be due to the ability of the Soflex discs to cut or abrade filler particles and resin matrix equally (Kaplan, et al., 1996). However, Soflex discs also seemed to cause cracks, caused by frictional heat on the polymer matrix (Kaplan, et al., 1996), emphasising the need to prevent overheating of a restoration during polishing.

Many types of aesthetic restorative materials, each having unique physical properties, are available on the market. As surface roughness of composite restorative resins has been associated with failure and plaque retention and subsequent biological complications, the purpose of this study was to compare the surface roughness of different types and brands of aesthetic restorative material which have recently come on the market.

Materials and methods

The surface roughness of three types of aesthetic material was compared, using two brands of each, namely: hybrid composites, Prodigy and Z100; compomers, Compoglass F, and Hytac Aplitip; and resin modified glass ionomers, Photac-Fil and Vitremer. Details of the materials tested are given in Table 1.

Six discs (5 mm in diameter and 1.5 mm thick) of each brand were prepared in clear perspex moulds giving 6 test surfaces and 6 control surfaces per brand of material making a total of 36 specimens with 72 test surfaces. After placement of the material, upper and lower surfaces were covered with mylar strips which in turn were cov-

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**Table 1. Details of materials tested**

<table>
<thead>
<tr>
<th>Brand name and type</th>
<th>Manufacturers</th>
<th>Batch number</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass ionomer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photac-Fil</td>
<td>ESPE, Norristown, PA</td>
<td>Liquid 035</td>
<td>Copolymers of maleic acid, camphoroquinone monomers, oligomers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Powder 007, Liquid 3303L, Powder 3303A3</td>
<td>Na-Ca-Al-La fluorosilicate glass, Polyalkenoic acid, Fluoroaluminosilicate glass</td>
</tr>
<tr>
<td>Vitremer</td>
<td>3M, St Paul, MN</td>
<td>CE0086</td>
<td>Filler: fumed silicon dioxide, zinc oxide, barium aluminoorthosilicate, titaniaoxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3022A2</td>
<td>Matrix: Bis GMA, TEGDMA, EDADM</td>
</tr>
<tr>
<td>Hybrid composite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prodigy</td>
<td>Kerr, Orange, CA 92867</td>
<td></td>
<td>Filler: yttrium trifluoride, Ba-Al-fluorosilicate glass &amp; spheroidal mixed oxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Matrix: urethane dimethacrylate, cycloaliphatic dicarboxylic acid, dimethacrylate</td>
</tr>
<tr>
<td>Z100</td>
<td>3M, St Paul, MN</td>
<td>909411</td>
<td>Filler: yttrium fluoride, Ca-Al-Zn fluoroglass</td>
</tr>
<tr>
<td>Compomer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compoglass F</td>
<td>Vivadent, FL9494,</td>
<td>Schaan</td>
<td>Filler: yttrium trifluoride, Ba-Al-fluorosilicate glass &amp; spheroidal mixed oxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>004</td>
<td>Matrix: urethane dimethacrylate, cycloaliphatic dicarboxylic acid, dimethacrylate</td>
</tr>
<tr>
<td>Hytac Aplitip</td>
<td>ESPE, Norristown, PA</td>
<td></td>
<td>Filler: yttrium fluoride, Ca-Al-Zn fluoroglass</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Matrix: methacrylate &amp; carboxyl groups</td>
</tr>
</tbody>
</table>

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1. Buffalo Dental Manufacturing, Co, Brooklyn, USA
2. Dentsply Caulk, Milford, USA
3. 3M, St Paul, USA
4. Taylor Hobson, Leicester, UK
ered with glass microscope slides and compressed with finger pressure to express excess material. Each specimen was light cured for 40 seconds on each side, using a Dentsply QHL75 curing light and then stored in distilled water for 14 days. Thereafter one side of each specimen was polished sequentially with medium, fine and super fine Soflex discs. Each disc was used for 30 seconds in a slow handpiece and new discs were used for each specimen. Unpolished surfaces served as controls. Thereafter, the specimens were returned to distilled water for a further 7 days until surface profiles were recorded. Surface profiles were recorded using a Rank Taylor Hobson Ltd., Form Talysurf Series 2 instrument. Three replicate R

Statistical analysis
The results were subjected to a 4-way analysis of variance (ANOVA) (SAS Institute Inc., 1989), with roughness as the dependent variable and type and brand of material (6), treatment (2), replication (3) and specimen (6) as the independent variables. Where the ANOVA showed any statistically significant effects Tukey’s Studentized range test was used to establish where these differences lay. The critical level of statistical significance was set at \( P = 0.05 \).

Results
The ANOVA showed statistically significant effects on surface roughness of the independent variables, namely, materials (df = 5, \( F = 7.23, P = 0.0001 \)) and treatments (df = 1, \( F = 7.56, P = 0.0065 \)) but not replication and specimen. Unpolished surfaces were significantly smoother than polished surfaces as indicated by the lower R\(_a\) measurements listed in Table II.

The absence of statistically significant effects of replication and specimen indicate a consistency in the production of the specimens and laboratory procedures employed to record the Talysurf profiles.

In Table III mean surface roughness values of unpolished material are arranged in descending order. Compoglass F has the roughest surface and does not significantly differ from Photac-Fil but is significantly rougher than all the other materials, of which Prodigy is the smoothest.

Examples of the surface tracings of Compoglass F and Prodigy are shown in Fig. 1. A comparison within each type of material indicates that Compoglass F is significantly 7.5 times rougher than Hytac Aplitip but there are no significant differences within the hybrids and glass ionomers.

In Table IV mean surface roughness values of polished material are arranged in descending order. The only significant difference observed is between Photac-Fil and Z100, where Photac-Fil is rougher by a factor of 4.2. The difference between these two materials is illustrated graphically in Fig. 2. No significant differences were observed between the brands within each type of material.

<table>
<thead>
<tr>
<th>Material</th>
<th>Unpolished</th>
<th>95% CI</th>
<th>Polished</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid</td>
<td>0.21</td>
<td>0.04-0.39</td>
<td>0.36</td>
<td>0.17-0.55</td>
</tr>
<tr>
<td>Z100</td>
<td>0.15</td>
<td>0.10-0.20</td>
<td>0.47</td>
<td>0.30-0.64</td>
</tr>
<tr>
<td>Group mean</td>
<td>0.18</td>
<td>0.10-0.27</td>
<td>0.41</td>
<td>0.29-0.54</td>
</tr>
<tr>
<td>Compomer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compoglass F</td>
<td>1.15</td>
<td>0.42-1.89</td>
<td>1.34</td>
<td>0.36-2.32</td>
</tr>
<tr>
<td>Hytac Aplitip</td>
<td>0.15</td>
<td>0.05-0.25</td>
<td>0.61</td>
<td>0.05-1.17</td>
</tr>
<tr>
<td>Group mean</td>
<td>0.65</td>
<td>0.26-1.04</td>
<td>0.97</td>
<td>0.42-1.52</td>
</tr>
</tbody>
</table>

| Glass ionomer     |            |            |          |            |
| Photac-Fil        | 0.72       | 0.20-0.30  | 1.52     | 0.79-2.24  |
| Vitremer          | 0.43       | 0.30-0.55  | 0.66     | 0.41-0.90  |
| Group mean        | 0.57       | 0.36-0.79  | 1.09     | 0.69-1.48  |

![Fig. 1. Tracings of unpolished materials comparing the surface roughness profiles of Prodigy (R\(_a\)0.0.0382) and Compoglass F (R\(_a\)1.8369). Note that the magnification differs for the two tracings.](image)
Comparison between material types

The surface roughness between types of material for unpolished specimens was compared. The ANOVA for the 108 records is similar to previous results shown on page 319 and indicates statistically significant effects on surface roughness of the independent variable material (df = 2, F = 3.87, P = 0.0241). No significant differences were found between replication and specimen. The results of Tukey’s Studentised range test, where N = 36 per group of two brands, indicate that compomer (Ra 0.6531) is significantly rougher than hybrid (Ra 0.1807) but not significantly different from glass ionomer (Ra 0.5719); glass ionomer does not differ significantly from hybrid.

Similarly, the surface roughness between types of material for polished specimens was analysed. The ANOVA for the 108 records indicates statistically significant effects on surface roughness of the independent variable material (df = 2, F = 3.43, P = 0.0364). No significant differences were found between replication and specimen. The results of Tukey’s Studentized range test, where N = 36 per group of two brands, indicate that when the materials are polished glass ionomer (Ra 1.0864) is significantly rougher than hybrid (Ra 0.4145) but not significantly different from compomer (Ra 0.9720); compomer does not differ significantly from hybrid.

Discussion

A summary of the comparison of the surface roughness of the different types and brands shows that there is a trend for compomers and glass ionomer cements to have a rougher surface than hybrid composites. The restorative material cured against a mylar strip gives the smoothest surface. Unfortunately required finishing of the restoration destroys this surface. Differences in surface roughness between the unpolished materials could be due to differences in the composition of the materials, method of polymerisation and the curing instrument (Youssef et al., 1998). However, in the polished state, differences previously apparent disappear. This is seen in the current study where, in the unpolished state, Compoglass F was significantly rougher than Vitremer, Z100, Hytac Aplitip and Prodigy. However, when these materials were polished there were no significant differences in surface roughness between the above mentioned materials. A possible explanation is that the surface roughness is now dictated by the coarseness of the abrasive used and not by the composition of the material. Evidence suggests that there is no connection between different types of matrix and polishing behaviour and no correlation between filler content and surface roughness (Behr et al., 1998).

Results from the current study cannot be directly compared to other studies because of the paucity of comparable information. Most research in this field has con-
centrated on comparing polishing techniques on surface roughness and not on the polishability of materials. However, in the broader context of comparing types rather than brands some comparisons can be made. We found that unpolished compomer was rougher than hybrid composite and no different to glass ionomer, whereas polished glass ionomer became rougher than composite but remained as smooth as compomer. Gladys et al. (1997) showed that polished composite and compomer were smoother than resin modified glass ionomer and Tate and Powers (1996) found that polished composite was smoother than hybrid glass ionomer (Vitremer included). Bouvier et al. (1997) found both unpolished composite and compomer of similar smoothness and smoother than glass ionomer. However, when polished, compomer was found to be smoother than both composite and glass ionomer.

The results of this study show that when finished against a Mylar strip there is no significant difference in the surface roughness of Prodigy, Vitremer and Photac-Fil. However, St. Germain and Meiers (1995) found that Vitremer was significantly rougher than Photac-Fil while Dörter et al. (1998) found Prodigy was statistically smoother than Vitremer. The current study found no significant differences between the composites Z100 and Prodigy in either the unpolished and polished states, while both materials became significantly rougher when polished. These results were confirmed by the findings of Youssef et al., (1998).

Obtaining a smooth surface has been held to be important when finishing composite restorations and an association between failure and surface roughness has been established (Smales and Webster, 1993). However, a degree of roughness appears to be tolerable as $R_a$ values of less than 10 $\mu$m are clinically undetectable, and hence any system that delivered a surface roughness of less than 10 $\mu$m would be acceptable (Kaplan et al., 1996). In this study significant differences were found between the roughnesses of the materials tested. The clinical significance of these discrepancies may not be important. According to Kaplan et al., 1996, they would be clinically acceptable as all $R_a$ values recorded in this study were less than 10 $\mu$m. However, there is a need to define unsatisfactory restorations more clearly in terms of actual adverse effects on oral health, rather than merely in terms of restoration deterioration (Smales and Webster, 1993).

**Conclusion**

It is concluded that the smoothest surface is obtained when curing materials against a Mylar strip. Unpolished specimens: Compoglass F is significantly rougher than Vitremer, Z100, Prodigy and Hytac Aplitip; compomer is significantly rougher than hybrid composite. Polished specimens: Photac-Fil is significantly rougher than Z100 but does not differ from Compoglass F, Vitremer, Prodigy and Hytac Aplitip; glass ionomer cement is significantly rougher than hybrid composite.

**REFERENCES**


