Consistency of resin composites for posterior use


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ABSTRACT
Objectives. The aim of this study was to compare a large set of resin composites suitable for application in stress-bearing areas on the basis of their consistency.

Methods. A variety of posterior resin composites were tested using an apparatus that was originally designed for determination of the consistency of elastomeric impression materials (ISO 4823, 1992). The consistency of a standardized volume of resin composite was tested in a dark room at 23°C by loading the samples during 60 s with 1625 g. After loading, the circumference of each sample was determined by a digitizer. Results were analyzed using Tukey-HSD multiple comparisons test and Student's t-tests.

Results. The consistency of different brands of composites varied considerably. P50 was the material with the thinnest consistency. Significant differences (p < 0.05) in consistency were found between the same brands of material which were applied directly out of the syringe or out of a preloaded tip. Loading a Centrix tip with one composite out of a syringe resulted in a thinner consistency of the material than when taken directly from the syringe.

Significance. A ranking of posterior resin composites is presented to enable a material selection based on consistency.

INTRODUCTION
Classification of resin composites is often based on morphological properties. Although the size and distribution of filler particles and the filler amount are important factors, mechanical properties should also be included in a classification (Willems et al., 1992). However, for a successful restorative procedure, the handling characteristics of a material are important as well. Dentists often have a preference for a composite with a specific consistency, as this parameter will affect the application and manipulation of the material. However, the consistencies of resin composites for posterior restorations have not been previously compared. In a study by Van Meerbeek et al. (1994), resin composite cements were compared. This study reported a large variation in consistency among materials.

The current processes of inserting a composite into a cavity can sometimes lead to voids and porosities in the restoration. In a clinical study by Kreulen et al. (1992) on the performance of posterior composites, the presence of voids in restorations was frequently demonstrated using radiographic evaluation. In that study, 52.9% of the restorations had voids, and a significant difference was found between various brands of composites. Nordbø et al. (1993) also reported the detection of voids on radiographs in a clinical study on posterior composites. In the clinical situation, the presence of voids and porosities can lead to discoloration, decreased wear resistance (O'Brien and Yee, 1980; Leinfelder and Roberson, 1983) and even replacement of the restoration (Nordbø et al., 1993). One of the important factors that influences the introduction of voids is the consistency of the material when inserted and manipulated during the restorative procedure. During clinical application, the currently available composites show a large variation in consistency. Some authors recommend the use of "high-viscosity" or "condensable" composites in posterior restorations but provide no objective criteria to compare consistency (Jordan and Suzuki, 1992).

In a proper restorative procedure, the composite is placed and cured in layers. The influence of manipulation of a resin composite on the adaptation to the cavity wall was investigated by Hansen and Asmussen (1989). They found that extensive manipulation of composites in the cavity resulted in increased marginal porosity. At the same time, the width and extent of the contraction gap increased. Therefore, the authors recommended careful manipulation of a resin composite when the material is applied in the cavity. The consistency of the composite will certainly influence the manipulation required for correctly shaping the material. A composite can be applied in the cavity either by injecting the composite or by application with a hand instrument. Resin composites can be injected in a tip preloaded by the manufacturer, or in a Centrix tip (Hawe Neos, Bioggio, Switzerland) which can be filled in the dental office. A study by Gjerdet and Hegdahl (1978) found that
injection of a paste-paste composite decreased the number of pores in the composite restoration. Gotfredsen et al. (1983) found that the injection technique with a one-component light-cured composite also led to a reduction of pores in the restoration. Whether a composite material is "syringable" depends on the consistency of the material.

Until now, the relation between consistency of composites, their filler content, application techniques, and the appearance of voids has not been demonstrated. Therefore, a comparison of resin composites according to their consistencies would be valuable. The aim of this study was to compare the consistencies of a large set of resin composites. Moreover, the influence on consistency of the filler content, particle size and the application mode (syringe or preloaded tip) of a composite was investigated.

**MATERIALS AND METHODS**

An apparatus, originally designed for determination of the consistency of elastomeric impression materials (ISO 4823, 1992), was used to test the consistency of a standardized volume of resin composite. A large number of resin composites, delivered in syringes or preloaded tips and intended for application in posterior stress-bearing restorations, were tested (Table 1).

All experiments were performed in a dark room. Ten samples from single batches of the uncured composites were prepared in a specially-designed Perspex mold (volume: 70 mm³) which could be divided in order to remove the composite sample (Fig 1). The mold was coated with a thin layer of cocoa butter to

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**TABLE 1: RESIN COMPOSITES TESTED IN THIS STUDY**

<table>
<thead>
<tr>
<th>Products*</th>
<th>Manufacturer</th>
<th>Type/Batch/Shade-</th>
<th>VM</th>
<th>VW</th>
<th>MPS (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrafine compact filled composites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P50</td>
<td>3M Dental Products, St. Paul, MN, USA</td>
<td>Pre-loaded tip</td>
<td>77.0</td>
<td>70.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Z100</td>
<td>3M</td>
<td>Syringe</td>
<td>64.3</td>
<td>71.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Tetric</td>
<td>Vivadent, Schaan, Liechtenstein</td>
<td></td>
<td>62.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrafine midway filled composites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pekafill</td>
<td>Bayer Dental, Leverkusen, Germany</td>
<td></td>
<td>675143/L</td>
<td>0915G/G</td>
<td>55.2</td>
</tr>
<tr>
<td>Brilliant</td>
<td>Coltene AG, Altstätten, Switzerland</td>
<td></td>
<td>9209296/A2</td>
<td>9209247/A2</td>
<td>55.2</td>
</tr>
<tr>
<td>Prisma APH</td>
<td>DeTrey - Dentsply, Konstanz, Germany</td>
<td></td>
<td>921009/A2</td>
<td></td>
<td>57.0</td>
</tr>
<tr>
<td>Prisma TPH</td>
<td>DeTrey - Dentsply</td>
<td></td>
<td>930210/A2</td>
<td></td>
<td>57.0</td>
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<tr>
<td>Graft LC</td>
<td>GC Corporation, Tokyo, Japan</td>
<td></td>
<td>910718/A2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charisma</td>
<td>Heraeus Kulzer, Wehrheim, Germany</td>
<td></td>
<td>45/A2</td>
<td></td>
<td>59.4</td>
</tr>
<tr>
<td>Herculite XRV</td>
<td>Kerr, Romulus, MI, USA</td>
<td></td>
<td>2/3069/1/A3</td>
<td>3604-22861/A3</td>
<td>57.0</td>
</tr>
<tr>
<td>Fine compact-filled composites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visiomolar</td>
<td>ESPE, Seefeld, Germany</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Estilux Posterior</td>
<td>Heraeus Kulzer</td>
<td></td>
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<tr>
<td>Clearfill Ray-Posterior</td>
<td>Kuraray Corporation, Osaka, Japan</td>
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<tr>
<td>Fine midway-filled composites</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pertac-Hybrid</td>
<td>ESPE</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Miscellaneous composites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heliomolar radiopaque</td>
<td>Vivadent, Schaan</td>
<td></td>
<td>460136/U</td>
<td>460321/U</td>
<td>49.1</td>
</tr>
</tbody>
</table>

* Composite classification according to Willems et al., 1992

VM: Inorganic filler volume percentage as obtained from the manufacturers

VW: Inorganic filler volume percentage according to Willems et al., 1992

MPS: Mean Particle Size (μm)

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**Fig. 1. Mold used in the study.**
prevent the resin composite from sticking. After removal from the mold, the measured specimen weights had a standard deviation of 2%. After removal, the samples were stored for 24 h in a dark room at 23°C. They were subsequently put between plastic sheets and placed under a constant load of 1625 g for 60 s. After loading, the circumference of each sample was determined and marked by means of a digitizer (Hitachi, HDG1111B, Hitachi Seiko Ltd., Japan). The digitized surface area defined the consistency of each resin composite specimen.

The influence of insertion from a Hawe-Centrix tip was also investigated for one material (P50). In one group, prefilled Centrix tips (Hawe-Centrix nr. 449, Hawe-Neos Dental, Bioggio, Switzerland) were used to prepare the samples in the Perspex mold. Another group was prepared in the same way, but the Centrix tips were internally coated with a thin film of unfilled resin (Silux Enamel Bond, 3M Dental Products, St. Paul, MN, USA, Batch no. 2R) to minimize the surface resistance inside the tip. In order to make the film as thin as possible, a stream of air was blown into the tip before the composite was inserted.

A Tukey-HSD multiple comparisons test at p < 0.05 was carried out to estimate the significance of the differences found among different materials. Student's t-tests for a pooled estimate of $\sigma^2$ (p<0.05) were carried out to estimate the significance of the results among different application modes of the same material. A Pearson correlation test was carried out between the results and the values for volume percentage and mean particle size of the filler for each composite. The values of filler volume percentage obtained from the manufacturers were used as well as the values reported by Willems et al. (1992).

**RESULTS**

The surface area of each sample was calculated from the circumference. Mean surface areas and standard deviations for all resin composites investigated as well as the statistical significant differences among the materials are presented in Fig. 2. According to these results, a large variation in consistency is present. Brilliant pre-loaded tips showed the thickest consistency (mean surface area 69 mm²) and P50 out of the syringe, the thinnest consistency (mean surface area 392 mm²). A comparison between identical composites delivered by the manufacturer in syringes and pre-loaded tips as well as the results of P50 measured directly out of the syringe or injected from a Centrix tip are presented in Fig. 3. The differences in surface area of the samples between the syringes and pre-loaded tips for each material were significant at p < 0.01. Also, the differences between the surface areas of the samples of P50 out of the syringe, P50 from a Centrix tip and P50 from a centrix tip coated with enamel bond were significant (p < 0.05).

No correlation was found between the mean particle size of the composites tested and their consistency ($r = 0.151$). A positive correlation was found between the filler volume and the consistency of the composites ($r = 0.659$ for values provided by the manufacturers and 0.558 for values reported by Willems et al. (1992)).

**DISCUSSION**

The results demonstrate a large variation in consistency among posterior resin composites. Based on the results, composites can be roughly categorized into materials with a thick consistency, medium consistency and thin consistency. From this comparison, dentists can select a composite with the consistency of their choice. Jordan and Suzuki (1992) suggest the use of "high-viscosity, no slump" materials which can be shaped, molded and condensed. However, they characterized materials with large differences in consistency such as Herculite XRV and P50, as high-viscosity materials. The present results indicate that their classification is based on subjective impressions and does not match experimental findings. Apparently there is need for an international standard for consistency of composite materials so that a dentist can select a material based on this handling characteristic. This study may be a first step in formulating such a standard.
According to this study, delivery of a composite (P50) with the help of a Centrix tip resulted in a thinner consistency. Viscoelastic shear thinning as a rheological explanation for this phenomenon is not likely because the samples were stored before the experiments were carried out, and the test method was the same for different application modes. It is more likely that the thinner consistency of the injected composite is due to the pressure built up inside the tip, resulting in a lower filled composite extruding from the tip. Braem et al. (1993) found that the pressure inside a composite syringe caused the resin and filler particles of the composite to separate and thus, a lower filled material was extruded. P50 was also placed into a Centrix tip coated with a thin film of unfilled resin in order to minimize the surface resistance inside the tip (Jørgensen and Hisamitsu, 1983). This coating also decreased the consistency of the composite. This may be the result of dilution of the composite by the unfilled resin or better wetting of the plastic sheets.

In the present study, identical composites marketed by the manufacturer in both syringes and preloaded tips appeared to have different consistencies. Samples of Z100, Heliomolar, Pekafil and Brilliant that were prepared from pre-loaded tips, demonstrated a thicker consistency than samples of the same composite directly out of the syringe. However, Herculite XRV showed the opposite behavior: a thinner consistency of the composite injected out of the pre-loaded tips. Differences in the geometry, resulting in a variation of surface resistance and pressure inside the various tips and syringes, could be an explanation for these findings. Another explanation might be that the manufacturer produces different formulations of the same composite for preloaded tips and syringes.

No correlation could be found between the mean particle size of a composite and its consistency whereas a positive correlation was demonstrated between the filler volume content and surface area of the samples. However, due to the fact that a highly filled material should provide a thicker consistency, a negative correlation between filler volume content and consistency would be expected. Therefore, a more likely explanation for the variations in consistency among the different brands of composites found in this study is that manufacturers have their own criteria for the preferred consistency of their composites and thus provide the material with additional viscosity controllers. Van Meerbeek et al. (1994) also could not demonstrate a correlation between the filler amount, mean particle size and the consistency of several composite cements.

This study emphasizes that posterior resin composites demonstrate a large variation in consistency, not only among different brands but also among composites of the same brand with different delivery modes, such as preloaded tips, filled Centrix tips or syringes. There is a need for standardization of consistency of composites.

Further research will focus on the influence of the consistency of resin composites on the technique of insertion and the presence of voids and pores in the final restoration.

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