Effect of polyvinyl siloxane impression material on the polymerization of composite resin

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The excellent properties of polyvinyl siloxane impression material, such as working time, detail reproduction, and dimensional accuracy, make it the most widely used impression material in prosthodontic treatment. 1,2 Despite its advantages, many studies have shown that, during the setting time, the polymerization of the polyvinyl siloxane impression material could be influenced by contact with different dental materials. 3-8 For instance, some latex products, including latex gloves and rubber dam, have an inhibitory effect on the polymerization of the polyvinyl siloxane impression material. The mechanism of this inhibition may be related to the interaction between the chloroplatinic acid catalyst in the impression material and the sulfur compounds in the latex products. In addition, resin-based materials may also adversely affect the polymerization of polyvinyl siloxane impression material. Some authors 9,10 have proposed that the oxygen-inhibited layer formed on resin-based materials may interact with polyvinyl siloxane impression material, leading to inhibition. However, some contradictory results 11,12 also indicate that the inhibitory effect still exits

ABSTRACT

Statement of problem. Polyvinyl siloxane impression material has been widely used as a lingual matrix for rebuilding missing tooth structure with composite resin. The composite resin is light polymerized in contact with the polyvinyl siloxane impression material. However, polyvinyl siloxane impression material has been shown to interact with other dental materials. 3-8 For instance, some latex products, including latex gloves and rubber dam, have an inhibitory effect on the polymerization of the polyvinyl siloxane impression material. The mechanism of this inhibition may be related to the interaction between the chloroplatinic acid catalyst in the impression material and the sulfur compounds in the latex products. In addition, resin-based materials may also adversely affect the polymerization of polyvinyl siloxane impression material. Some authors 9,10 have proposed that the oxygen-inhibited layer formed on resin-based materials may interact with polyvinyl siloxane impression material, leading to inhibition. However, some contradictory results 11,12 also indicate that the inhibitory effect still exists

Purpose. The purpose of this study was to assess the effect of polyvinyl siloxane impression materials on the polymerization of composite resins by assessing the Vickers microhardness and degree of conversion of polyvinyl siloxane.

Material and methods. The composite resins were light polymerized in contact with 3 polyvinyl siloxane impression materials (Flexitime Easy Putty; President Light Body; Xantopren L Blue) (n=8) and in contact with a matrix strip as the control group (n=8). Vickers microhardness and degree of conversion on contact surfaces were measured to evaluate the polymerization of composite resins. The depth of the effect was assessed by Vickers microhardness on section surfaces and observed with scanning electron microscopy. The results were analyzed by 1-way analysis of variance and the post hoc Tukey honest significant differences test (α=.05).

Results. The Vickers microhardness and degree of conversion values on the contact surfaces of the experiment groups were significantly lower than those of the control group (P<.05); the Vickers microhardness values on the section surfaces indicated that there was no significant difference at the same depth of different groups (P>.05). The scanning electron microscope observation showed that an approximately 10-µm deep unpolymerized layer was found in the experimental group.

Conclusions. Polyvinyl siloxane impression materials have an inhibitory effect on the polymerization of the composite resins, but just limited to within approximately 10 µm from the surface in contact with the impression material. (J Prosthet Dent 2017;117:552-558)
Clinical Implications
The inhibitory effect of polyvinyl siloxane impression material on composite resin was limited to an approximately 10-μm layer, which can be easily removed by finishing and polishing. Therefore, a polyvinyl siloxane lingual matrix should be a suitable technique.

even after the oxygen-inhibited layer is removed. Although these inhibitions are minimal and limited to the contact surface, most of them have been adopted as precautions in the manufacturers’ instructions because insufficiently polymerized impression material is more likely to produce unacceptable inaccuracy and distortion.

Published reports also describe silicone contamination on the bonding surface due to the silicone fit-indicator13,14 or silicone impression material,15 which has a negative influence on the bond strength and durability of the restorations; this may be caused by the interaction of Si-C bonds among the organic groups in cements containing C-H and the main component of silicone materials containing Si-O.16 The bonding surface should be carefully cleaned before the bonding procedure.

Recently, dentists and manufacturers have advocated a technique that uses impression materials to provide a lingual matrix for rebuilding missing tooth structure with esthetic composite resin.17 Briefly, in the lingual matrix technique, a trial restoration is first created directly on the fractured tooth or on the diagnostic waxing to establish the incisal length and lingual contour. The lingual matrix is fabricated with polyvinyl siloxane from the trial restoration or diagnostic waxing. Once the matrix is created, it should be trimmed properly to cover only the lingual surface, incisal edge, and facial incisal margin to provide a template and guidance for the esthetic composite resin. As a result, this technique can easily facilitate the reproduction of the lingual contour and translucent characteristics of the incisal edge. It also allows a dentist to quickly reconstruct the missing structure and reproduce a tooth-like restoration.18,19

However, in this situation, the composite resin is light polymerized in contact with the polyvinyl siloxane impression material. As mentioned, polyvinyl siloxane impression material is susceptible to interaction with other dental materials. Moreover, in daily clinical practice, dentists often find a tacky layer on the lingual surface of the composite resin restoration after light polymerization and removal of the lingual matrix. Whether polyvinyl siloxane impression material has an adverse impact on the polymerization of composite resin is unknown.

These authors know of no research concerning this problem. The purpose of this study was to assess the polymerization of composite resins which were light polymerized in contact with polyvinyl siloxane impressions by assessing the Vickers microhardness (VMH) and degree of conversion (DC) of the composite resin. The null hypothesis tested was that polyvinyl siloxane impression materials would have no inhibitory effect on the polymerization of composite resins.

MATERIAL AND METHODS
One translucent composite resin (Filtex Supreme XTE; 3M ESPE), 3 types of polyvinyl siloxane impression materials (Table 1), and 1 matrix strip (DirectaStrips; Directa AB) were used in this study. The specimens were prepared as previously described.20,21 All the impression materials were mixed and manipulated according to the manufacturers’ instructions and then put on a glass slide to obtain a smooth surface. Before contact with the composite resins, the impressions were stored at room temperature for 24 hours to ensure complete polymerization.

The composite resin specimens were prepared in 2-mm-thick plastic rings with a 3-mm-diameter internal hole. First, the ring mold was positioned on the smooth surface of the impression specimen and then the unpolymerized composite resin was directly filled into the ring mold. A matrix strip and a glass slide were then placed on top of the composite resin specimen and pressed to squeeze out extra material (Fig. 1).

Under pressure, the composite resin specimen was light polymerized for 20 seconds through the upper glass slide and matrix strip with a light intensity of 1200 mW/cm² (Elipar S10; 3M ESPE). After 20 seconds of light polymerization, the composite resin specimen was removed from the mold, and the contact surface was additionally light polymerized for 20 seconds.

The specimens were divided into 4 groups (n=8). In the control group (specimens with Matrix Strips [SM]), the composite resin specimens were prepared by the same method but were polymerized in contact with the matrix strips. In groups SF (specimens with Flexitime Easy Putty), SP (specimens with President Light Body), and SX (specimens with Xantopren L Blue), the composite resin specimens were light polymerized in contact with Flexitime Easy Putty (Heraeus Kulzer GmbH), President Light Body (Coltène/Whaledent), or Xantopren L Blue (Heraeus Kulzer GmbH). Fourier transform infrared (FTIR) spectroscopy (FTS 40; Bio-Rad Laboratories, Inc) with an attenuated total reflection attachment was used to measure the DC of the composite resin specimens.
reflectance (ATR) element (Golden Gate; Specac Ltd) was used to assess the contact surface of the composite resins. The FTIR spectra were recorded with 16 scans per spectrum and 4 cm\(^{-1}\) resolution. The wave number ranged from 3000 cm\(^{-1}\) to 650 cm\(^{-1}\) in the absorbance mode. Additionally, the prepared polyvinyl siloxane impressions were also measured using the same method to locate their characteristic bands for the subsequent compositional analysis.

The DC value was calculated by the ratio of the peak height at 1608 cm\(^{-1}\) (aromatic carbon double bond) to the peak height at 1638 cm\(^{-1}\) (aliphatic carbon double bond) as follows\(^{22,23}\):

\[
\text{DC\%} = \left[ 1 - \left( \frac{\text{peak height after polymerization}}{\text{peak height before polymerization}} \right) \right] \times 100
\]

The peaks before polymerization were measured by putting the unpolymerized composite resin with the ring mold directly onto the ATR crystal. The composite resin specimens were then stored in a dark incubator at 37°C and remeasured using the same method at 1 day and 7 days after specimen preparation.

The VMH was measured using a microhardness tester with a Vickers indenter (HM-124; Mitutoyo Asia Pacific Pte Ltd) after each DC measurement. Five measuring points starting from the central area (Fig. 1) were made on the contact surface with a 0.98-N force for 30 seconds, and the average hardness was calculated for each specimen. The indentation depth (h) was approximately calculated according to the formula\(^{24}\):

\[ h = d / 7.0006, \]

where d is the average length of the diagonal left by pyramidal indentation in millimeters.

When the DC and VMH measurements on the contact surfaces were complete, the specimens were sectioned in the middle under water by using a low-speed diamond saw (Isomet 1000; Buehler), and the section surfaces were polished using 800-grit SiC wet paper. Subsequently, the VMH was measured on the sectioned surface, starting from 100 μm under the contact surface. For each section surface, 3×10 indentation arrays were made with intervals of 100 μm.

Finally, both the contact and the section surfaces of each specimen were sputter coated with Au and observed by scanning electron microscopy (SEM) (Inspect F50; FEI).

Statistical analysis was performed with software (IBM SPSS Statistics v21; IBM Corp). One-way analysis of variance (ANOVA) and the post hoc Tukey honest significant difference test were used to compare VMH and DC values of the different groups at each time interval and the VMH values of the different groups at each depth (\(\alpha = 0.05\)).

**RESULTS**

Immediately after light polymerization, tacky substances were found on the contact surfaces between composite resins and polyvinyl siloxane impressions (Fig. 3).

The mean (±SD) DC values of different groups are shown in Table 2. For the composite resins in groups SF,
SP, and SX, the DC values were significantly lower than those of group SM at 0, 1, and 7 days after light polymerization \((P<.05)\). After 7 days, the DC value of groups SF, SP, and SX were still approximately 50.6%, 43.1%, and 44.2%, respectively, of the control group (Fig. 4).

The IR spectra of each experimental group indicated a higher peak at 1638 cm\(^{-1}\) of aliphatic carbon double bond relative to the reference peak at 1608 cm\(^{-1}\) of aromatic carbon double bond, compared with the control group. The characteristic band of the Si-CH\(_3\) group in polyvinyl siloxane at 1275 cm\(^{-1}\) was also detected on all the impression materials but could not be found on the contact surfaces of composite resin specimens which were light polymerized in contact with impression materials (Fig. 5).

The mean indentation depths of groups SM, SF, SP, and SX were 8.43, 9.51, 10.11, and 9.89 \(\mu\)m, respectively. The mean ±SD VMH values on the contact surfaces of different groups are shown in Table 3, which shows that for the composite resins in groups SF, SP, and SX, the VMH values were significantly lower than those of group SM at 0, 1, and 7 days after light polymerization \((P<.05)\). After 7 days, the VMH values of groups SF, SP, and SX remained at approximately 72.%, 71.5%, and 72.6%, respectively.

### Table 2. Mean (±SD) DC of composite resins after light polymerization

<table>
<thead>
<tr>
<th>Group</th>
<th>0 Day</th>
<th>1 Day</th>
<th>7 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>59.10 (1.74) (^a)</td>
<td>58.21 (1.34) (^a)</td>
<td>57.89 (2.00) (^a)</td>
</tr>
<tr>
<td>SF</td>
<td>22.15 (4.44) (^b)</td>
<td>26.74 (4.02) (^b)</td>
<td>29.29 (3.87) (^b)</td>
</tr>
<tr>
<td>SP</td>
<td>22.05 (2.80) (^b)</td>
<td>26.19 (6.35) (^b)</td>
<td>24.96 (8.40) (^b)</td>
</tr>
<tr>
<td>SX</td>
<td>21.38 (6.11) (^b)</td>
<td>26.75 (7.47) (^b)</td>
<td>25.60 (3.57) (^b)</td>
</tr>
</tbody>
</table>

DC, degree of conversion; Within each column, different superscript letters showed significant difference \((P<.001)\). Values between each column not compared.

### Table 3. Mean (±SD) VMH of composite resins after light polymerization

<table>
<thead>
<tr>
<th>Group</th>
<th>0 Day</th>
<th>1 Day</th>
<th>7 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>52.33 (2.49) (^a)</td>
<td>63.48 (3.21) (^a)</td>
<td>63.09 (5.61) (^a)</td>
</tr>
<tr>
<td>SF</td>
<td>38.20 (2.77) (^b)</td>
<td>41.17 (2.24) (^b,c)</td>
<td>45.43 (2.98) (^b)</td>
</tr>
<tr>
<td>SP</td>
<td>34.85 (2.30) (^b)</td>
<td>39.30 (3.11) (^b)</td>
<td>45.13 (1.63) (^b)</td>
</tr>
<tr>
<td>SX</td>
<td>36.35 (4.07) (^b)</td>
<td>43.88 (4.15) (^c)</td>
<td>45.78 (2.79) (^b)</td>
</tr>
</tbody>
</table>

Vickers microhardness. Within each column, different superscript letters showed significant difference \((P<.001)\). Values between each column not compared.
respectively, of the control group (Fig. 4). The result of the VMH on the section surface indicated no significant difference between the experimental groups and the control group at each depth (Table 4).

The SEM results showed an unstructured layer at a depth of approximately 10 μm near the contact interface in each experimental group. However, no such layer was noted in the composite resin of the control group (Fig. 6).

**DISCUSSION**

According to the results of this study, the null hypothesis was rejected. The 3 tested polyvinyl siloxane impression materials adversely affected the polymerization of the tested composite resin, albeit superficially.

For the lingual matrix technique, the most commonly recommended materials for the lingual matrix were the putty polyvinyl siloxane impression material, although some dentists also use the injectable material with low viscosity. Also, to reproduce the esthetics of the incisal edge, the translucent composite resin is used as the first layer and light polymerized in contact with impression materials. Therefore, 1 translucent composite resin and 3 types of polyvinyl siloxane impression materials with different viscosities were tested in this study.

In previous studies of the interaction between polyvinyl siloxane impression materials and other dental materials, the polyvinyl siloxane impression materials were allowed to polymerize in contact with the restorative material. This leaves an oily substance on the restoration from the unpolymerized polyvinyl siloxane. Conversely, in this study, the polyvinyl siloxane impression materials were stored at room temperature for 24 hours to ensure complete polymerization before contact with the unpolymerized composite resin. The IR spectra detected no characteristic band at 1275 cm⁻¹ resulting from the Si-CH₃ group in polyvinyl siloxane on the contact surfaces of the tested composite resins, which were light polymerized in contact with matrix strip, Flexitime, President, Xantopren. Therefore, in this study, the tacky substances left on the composite resin were considered the result of unpolymerized composite resins, rather than contaminants left by the impression materials.
The results of the VMH and DC values in this study indicated that the 3 tested polyvinyl siloxane impression materials might adversely affect the polymerization of the tested composite resins, but the VMH values on the section surface indicated only superficial influence. Considering the length of the diagonal left by pyramidal indentation, which was approximately 0.07 mm, the influence may be limited to within approximately 10 μm of the contact surface. This result was consistent with the SEM observation. However, it may be much less than the inhibitory effect of zinc oxide eugenol on the polymerization of composite resin, which may be limited to within 100 μm of the influenced surface.26 For the esthetic restoration of fractured anterior teeth, such a thin layer of imperfect composite resin should not present a problem because it can be easily removed with finishing and polishing procedures.

Finishing with a matrix strip can produce a smooth composite resin surface.20 In this study, SEM revealed a similar surface on the composite resin surface which was light polymerized in contact with a matrix strip. However, an unstructured surface formed on the composite resin surface which was light polymerized in contact with the 3 tested impression materials even though the polyvinyl siloxane impressions were set on a glass slide to obtain a surface as smooth as the matrix strip. This suggested that

Figure 6. SEM images. A, Control group. Insufficiently polymerized layer with depth of approximately 10 μm from contact interfaces found in groups B, SF; C, SP; and D, SX. However, no such layer seen in composite resin in control group. Control, SF, SP, and SX showed composite resin specimens light polymerized in contact with matrix strip, Flexitime, President, and Xantopren. Original magnification ×2000.
the difference on the surfaces may result from the interaction between the composite resins and the polyvinyl siloxane impression material.

Although the inhibitory mechanism of polyvinyl siloxane impression is not yet fully understood, we presume that the interaction between the free radicals generated by the photoinitiators in composite resins and the components in polyvinyl siloxane impression material may inhibit the polymerization reaction during the induction stage. In this study, the contact surface of each composite specimen was directly irradiated for 20 seconds after it was removed from the impression materials. However, compared with the control group, the composite resin specimens of the 3 experimental groups were still incompletely polymerized. This implies that the photoinitiators in the contact surface of the composite resin were totally occupied and absorbed on the impression materials during the induction period. As a result, not enough photoinitiators remained to initiate repolymerization when the contact surface was removed from the impression materials and again directly irradiated.

As only a few materials were tested in this study, further investigations should involve more materials in an effort to identify the mechanism that inhibits polymerization.

CONCLUSIONS

Within the limits of this in vitro study, the following conclusions were drawn:

1. The 3 tested polyvinyl siloxane impression materials could significantly inhibit the polymerization of the tested composite resin, albeit limited to the contact surface.

2. A lingual matrix made of polyvinyl siloxane impression material should be a suitable and reliable technique for esthetic restorations with composite resin.

REFERENCES


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