Effects of Lining Materials on the Composite Resins Shrinkage Stresses

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Recently, three types of lining materials have been used in dental clinics, conventional powder-liquid glass ionomer cement, light-cured powder-liquid glass ionomer cement and a light-cured single paste type. This study compared the effects of these lining materials on the shrinkage stress of light-cured composite resins during the early setting stage, when polymerization shrinkage occurs. After the second irradiation, the shrinkage stress of composite resins lined with light-cured powder-liquid type cements was approximately 1.0 to 2.2 MPa when the lining application was 1.5 mm and 0.5 mm thick, respectively, demonstrating that a thicker lining application decreased shrinkage stress. The single paste type was only slightly effective in reducing shrinkage stress in composite resins. Although the sample lined with conventional powder-liquid type showed that stresses were less affected by the thickness of the lining, and had the lowest shrinkage stress of all conditions tested, greater exfoliation from the composite resin or the cavity occurred compared to that occurring with other materials.

Key words: Composite resin, Lining material, Shrinkage stress

INTRODUCTION

Glass ionomer cement is generally used as a lining material under composite resin for esthetic reasons, reduced irritation to the pulp and increased adhesion to the dentin in comparison with that obtained using other lining materials. Furthermore, glass ionomer cement shows almost the same thermal expansion as a tooth and volumetric change during hardening is slight. Some reports indicate that microleakage is prevented by using glass ionomer cement as a lining for composite resins. From another perspective, it could be assumed that the glass ionomer cement lining affects the shrinkage or shrinkage stress in composite resins.

Glass ionomer cement, light-cured as well as conventional glass ionomer cements, is in widespread clinical use. Light-cured cement is more readily used as a lining material because of it can be efficiently manipulated. Recently, a single paste type lining material, light-cured without mixing the powder and liquid, has been marketed. This study investigated the effects of these three types of lining materials on the shrinkage stress in composite resins during the early setting stage, during which polymerization shrinkage occurs.

MATERIALS AND METHODS

In this study, the following materials were used for the lining: light-cured powder-liquid...
type, Vit* and LC**; single paste type, Cava# and Iono##; conventional powder-liquid type, Den@; and light-cured composite resin@@ (shade US) as a control. An apparatus for measuring stress, designed by Nemoto", was used in this experiment. The apparatus, shown in Fig. 1, consisted of 1) sample tester, 2) load cell for measuring shrinkage force, 3) strain gauge UL type transducer for measuring distance, 4) clamp, 5) limit switch for the distance between the upper and lower rods, 6) servomotor and 7) specimen. The specimen was placed in the sample tester while the upper rod was down. When the distance between the upper and lower rods was decreased by shrinkage, the developing current was amplified by the UL transducer and drove the servomotor to maintain a constant distance between the rods and the developing force was measured by the load cell.

As the cavity walls, brass rings were prepared 4.5 mm, 5.0 mm, and 5.5 mm in depth, and 6.0 mm in inner diameter. The cavity floor was made of a brass rod connected to the servomotor. The inner cavity surfaces were frosted with an aqueous slurry of No. 400 carborundum particles to adhere tightly to the cement or composite resin. The test lining

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* Vitrabond, 3M Co., USA.
** Lining LC, G-C Co., Tokyo, Japan.
# Cavalite, Kerr Co., USA.
## Ionosit, DMG, Hamburg, German.
@ Dentin Cement, G-C Co., Tokyo, Japan.
@@ Photo Clearfil A, Kuraray Co., Okayama, Japan.

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Fig. 1 Schema of the apparatus for measuring shrinkage stress.
material was placed on the cavity floor, in a thickness of 0.5 mm, 1.0 mm or 1.5 mm, after applying a dual-cured bonding agent$. The specimen was then irradiated by CureMaster A$$ for 40 sec. The composite resin, shade US, 4 mm thick, was then placed on top of the cement lining, and irradiated twice for 40 sec at an interval of 40 sec. For Den, the composite resin was added 4 min after the start of mixing, and irradiated in the same manner.

Three specimens of each lining material as well as the control were evaluated and the means and standard deviations of the maximum shrinkage stresses during the hardening of the lining materials in the first, and second irradiation periods were obtained.

RESULTS

The shrinkage stresses over time are represented in Fig. 2 a-f. The bonding agent was applied and irradiated for 10 sec during the first stage and there were no stresses at this stage in any specimen. The second stage lasted 40 sec during which various thicknesses of lining materials were placed in the cavities and irradiated for 40 sec except for the Den samples (Table 1). Shrinkage stresses of lining materials were measured during this stage. In the third stage, the bonding agent was applied over the lining material and irradiated for 10 sec. Some specimens showed increased stress during this stage. During the fourth stage, the cavity was filled with a 4 mm layer of composite resin and irradiated for 40 sec (first irradiation). In the fifth stage, the specimen was again irradiated for 40 sec (second irradiation). For the Den sample, the irradiation in the second stage was omitted and the specimen was allowed to set for 240 sec.

The means and standard deviations of the maximum shrinkage stresses during the irradiation of the lining and those of Den (Table 1), and during the first and second irradiations of the composite resins are shown in Table 2. The effects of the lining thickness on the shrinkage stress in composite resins are shown in Fig. 3 a-f.

During the irradiation of the lining material before composite resin filling, all specimens showed increased shrinkage stresses relative to thicker lining application except for Den which showed no stress during 240 sec (Table 1). During the first irradiation, shrinkage stresses in samples lined with Vit, LC and Den were decreased by thicker application, while stresses in samples lined with Cava and Iono showed increases, as did the control (Table 2). During the second irradiation, all samples showed maximum stress values at each thickness except for Den which showed maximum stresses during the first irradiation (Table 2). The highest values for stress measurements were: Vit, 1.90 MPa; LC, 2.18 MPa (second irradiation); and Den, 0.65 MPa (first irradiation) at 0.5 mm thick, and Cava, 3.62 MPa; Iono, 3.65 MPa, and the control, 4.74 MPa at 1.5 mm thick (second irradiation). In the samples lined with Den, the stress was less affected by the thickness of the linings, and showed the lowest shrinkage stress of all conditions in this study, however, stress rapidly decreased at the end of the first irradiation.

$ Clearfil Photo Bond, Kuraray Co., Okayama, Japan.
$$ CureMaster A, 3M Co., USA.
DISCUSSION

The advent of the acid etch technique\(^3\) and bonding systems\(^4\) has improved the bond strength to tooth, but this has resulted in greater shrinkage stress in the structure surrounding the cavity\(^5\)–\(^8\). Jøgensen et al.\(^9\) reported that cracks developed in the enamel surface surrounding the cavity, when the composite resin hardened in the cavity after etching and bonding. Pearson et al.\(^10\) reported the adhesive composite resin caused cusp movement in molar teeth. Bowen et al.\(^11\) reported that shrinkage stress in chemical-cured composite resins was 5 to 6
MPa using an open type cavity made of aluminum. Using different experimental approaches, Davidson et al.\cite{12} and Feilzer et al.\cite{13} also reported that polymerization shrinkage stresses were 2 MPa and 7 MPa, respectively. It is considered that such shrinkage stress will induce some damage to pulp tissues. For example, microleakage may occur from an enamel crack and then microorganisms will penetrate the pulp.

Currently, glass ionomer lining materials are applied under the composite resin to protect the pulp tissue. Although an important role of this lining material is inhibiting the penetration of irritating substances from composite resins into the pulp, it has also reduced shrinkage stress during the composite resin hardening.

The thickness of lining material as well as the type of cement used should be factors in reducing stress. For the light-cured powder-liquid type, it was presumed that a deformation might occur after the cement was hardened by irradiation, because it contained a polyacrylic solution and resin components\cite{14}. As a result, samples lined with this type of cement showed less shrinkage stress in the composite resins than that in the single paste type, and relatively similar to the shrinkage stress in the conventional type.

Single paste type lining materials, contain components similar to those of composite resin\cite{15}, so composite resin shrinkage stress at each thickness demonstrated higher values, although not higher than those of the controls.

**Table 1** Shrinkage stresses of lining materials

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>l.c. powder-liquid</th>
<th>l.c. single paste</th>
<th>powder-liquid cont.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vit</td>
<td>LC</td>
<td>Cava</td>
</tr>
<tr>
<td>0.5</td>
<td>0.05(0.01)</td>
<td>0.06(0.02)</td>
<td>0.14(0.02)</td>
</tr>
<tr>
<td>1.0</td>
<td>0.05(0.01)</td>
<td>0.11(0.01)</td>
<td>0.15(0.05)</td>
</tr>
<tr>
<td>1.5</td>
<td>0.06(0.01)</td>
<td>0.13(0.01)</td>
<td>0.30(0.06)</td>
</tr>
</tbody>
</table>

* values of 4 min after mixing (without irradiation) ( ) : SD

**Table 2** Comparison of shrinkage stresses in composite resins at the end of first and second irradiations by thickness of the liner application.
(for Den, the maximum values in each irradiation period.)

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>l.c. powder-liquid</th>
<th>l.c. single paste</th>
<th>powder-liquid cont.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vit</td>
<td>LC</td>
<td>Cava</td>
</tr>
<tr>
<td>first irradiation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1.43(0.09)</td>
<td>1.40(0.23)</td>
<td>1.10(0.07)</td>
</tr>
<tr>
<td>1.0</td>
<td>1.12(0.15)</td>
<td>1.04(0.02)</td>
<td>1.44(0.15)</td>
</tr>
<tr>
<td>1.5</td>
<td>0.91(0.10)</td>
<td>0.93(0.02)</td>
<td>1.56(0.06)</td>
</tr>
<tr>
<td>second irradiation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1.90(0.03)</td>
<td>2.18(0.12)</td>
<td>2.92(0.04)</td>
</tr>
<tr>
<td>1.0</td>
<td>1.46(0.20)</td>
<td>1.85(0.09)</td>
<td>3.56(0.06)</td>
</tr>
<tr>
<td>1.5</td>
<td>1.02(0.08)</td>
<td>1.41(0.11)</td>
<td>3.62(0.09)</td>
</tr>
</tbody>
</table>

( ) : SD
Fig. 3 Shrinkage stresses of various thickness of lining materials, alone and with composite resins during each irradiation period.

a, Vit; b, LC; c, Cava; d, Iono; e, Den; f, Composite resin (control).

Samples lined with the conventional type demonstrated the least shrinkage stress. It was presumed that the maximum shrinkage stress developed approximately 15 to 30 min after lining, according to our report\textsuperscript{16}, while the stress in the composite resin developed within the irradiation period, so that the lag in setting time of this cement decreased shrinkage stress. That is, slow setting of this material may permit stress relief while the composite resin hardens\textsuperscript{17}. Previous reports\textsuperscript{18} also suggested that the stresses of light-cured composite resin lined with conventional powder-liquid glass ionomer cement\textsuperscript{+} 1.5 mm and 0.5

\textsuperscript{+} Lining Cement, G-C Co., Tokyo, Japan.
mm thick were 1.0 to 1.4 MPa, respectively, 10 min after this material was applied. Even if the experimental period was prolonged, the maximum stresses showed no more than 2.5 MPa in our preliminary study.

Regarding the thickness of lining material, samples lined with powder-liquid type cement showed that the shrinkage stresses of composite resins were decreased by thicker applications (Table 2), however the shrinkage stress of lining materials were increased with irradiation to thicker lining applications (Table 1). In the samples lined with Den, such stress was less affected by the thickness, and showed the lowest shrinkage stress of all conditions studied. When the composite resin 4 mm thick was placed on the lining material, greater shrinkage stress in the composite resin induced lining material deformation particularly in the polycarboxylate-containing powder-liquid type cements. Then the amount of shrinkage stress was decreased by a thicker lining application. However, in samples using the single paste type, stress was increased by thicker application, possibly because it contained composite resin components, with a shrinkage stress pattern similar to the control during each irradiation period (Fig. 2). Therefore, less deformation should arise in the single paste type material than in the powder-liquid type during composite resin shrinkage.

The buffer effect of the lining material during the composite resin polymerizing process was clarified by measuring the stresses during the first and second irradiations. The samples lined with light-cured powder-liquid type showed smaller differences between the first and second irradiations compared to that of those lined with the single paste type or the control. This indicates that the buffer effects of the light-cured powder-liquid type are higher than those of other materials.

For the samples lined with Den, stresses decreased rapidly at the end of the first irradiation as shown in Fig. 2-e, then the stresses of the first and second irradiation turned were reversed in Fig. 3-e. It was supposed that greater exfoliation occurred at the junction of the cement and composite resin or the cavity surface just after the first irradiation. Although lower shrinkage stress may be preferable in clinical practice, whether this phenomenon provides physical properties for restorations and lining materials has not been determined.

In this study, the shrinkage stresses measured may not reflect all stresses caused by gross shrinkage away from the cavity wall or floor. The stress values obtained might be factors of flow deformations, exfoliations and micro cracks in the material.

These results imply that lining material can effectively reduce shrinkage stresses in composite resins. Especially, powder-liquid type cements might be suitable lining materials for a deep cavity and a thicker lining application could improve shrinkage stress.

**CONCLUSION**

Lining materials clearly reduced shrinkage stress in composite resins. The shrinkage stresses of composite resins applied over light-cured powder-liquid type cement bases were approximately 1.0 to 2.2 MPa at 1.5 mm and 0.5 mm thick, respectively, after the second irradiation and were decreased by thicker lining applications. The single paste type was only slightly effective in reducing shrinkage stress in composite resins. Although the
samples lined with conventional powder-liquid type showed that stresses were less affected by application thickness, and had the lowest shrinkage stresses of all conditions in this study, it should be noted that greater exfoliation may occur between the sample and the composite resin or the cavity than with the other lining materials.

REFERENCES

本号掲載論文の和文抄録

コンポジットレジンの収縮応力に対する裏層材の効果

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今日，従来型粉液タイプと，光重合型粉液タイプのグラシアイオンマーセメント，および1ペーストタイプの裏層材が歯科臨床で用いられている。本研究は，それらのセメントが光重合型コンポジットレジンの重合時に生じる収縮応力に与える影響を比較検討する目的で行われた，光重合型粉液タイプで裏層したものは，2回目の照射によって1.5mmの厚さで約1.0MPaから0.5mmの厚さで2.2MPaまでの収縮応力を示し，厚く裏層するとほど収縮応力が減少した。1ペーストタイプのものはコンポジットレジンの収縮応力を減少させるのに効果的ではなかった。従来型粉液タイプのものは，厚さによる影響は少なく，本実験条件中で最も収縮応力は小さかったが，これはコンポジットレジンあるいは窩洞からより大きな剥離が生じたものと思われた。

スピロオルトエステルを側鎖に持つアクリレートおよびメタクリレートの加熱および光重合と重合体の性質

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スピロオルトエステルを側鎖に持つアクリレート（ASOE）およびメタクリレート（MASEOE）を合成し，その重合と得られた重合体の性質について検討した，スピロオルトエステルはイオン重合開始剤（BSS，HPSS）による加熱重合によって良好重合重合した。しかし，得られた重合体には少量の未反応の二重結合が見られた。また，ラジカル重合開始剤（BPO，AIBN，DTBおよびCQ）による重合ではビニール基の重合のみならず開環重合も低調であつた。BSS，AIBNおよびBPO/BSSによる加熱重合によって得られたMASOE重合体はプラスチックス状であった。ASOEおよびMASEOEのイオン重合開始剤による加熱重合や紫外線重合における重合収縮は汎用のモノメタクリレートに比べて有効に小さかった。

象牙質接着性コンポジットレジン修復における重合収縮応力と窩壁適合性

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コンポジットレジンの重合収縮応力が象牙質に対する接着力ならびに窩壁適合性に及ぼす影響について，3種市販象牙質接着修復システムを用い検討した。モールドとしてテフロンモールド(TF)あるいは内面を粗造にし