Relationship among visible light source, composite resin polymerization shrinkage, and hygroscopic expansion

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Composite resins contract during polymerization, and studies have shown that light-cured composite resins shrink toward the polymerizing light source. The purpose of this study was to investigate differences in the adaptation of composite resin to the axial wall in Class V restorations following light curing from the lingual or facial aspects. Polymerization contraction in relation to hygroscopic expansion of the restoration was also investigated. Results showed no statistically significant differences (P < .05) in the adaptation of composite resin to the axial wall, regardless of the polymerization technique, the composite resin, or the effects of hygroscopic expansion.

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Introduction

Visible light-polymerizing composite resins have become the treatment of choice for the restoration of cosmetically prominent teeth. Prior to the introduction of composite resins, other materials, such as gold foil, silver amalgam, and silicate cement, were used to restore anterior teeth. Composite resin has replaced such materials because of its unprecedented color match, easy handling, strength, stability, and enamel surface luster when it has been finished and polished.

Composite resins, however, have one deficiency: They all contract, causing dimensional changes, during photopolymerization. Such contraction is termed polymerization shrinkage. Contraction shrinkage of composite resin is important because of its effect on cavosurface margins. Polymerization shrinkage causes separation between a composite resin mass and adjacent tooth structure. Marginal adaptation of composite resin is dependent on several factors, such as polymerization shrinkage, hygroscopic properties, bonding between restorative material and the cavity walls, coefficient of thermal expansion of the material, and composite resin finishing methods. It has been demonstrated that, despite acid etching of enamel walls, hygroscopic expansion of composite resin, careful finishing procedures, and use of materials with thermal expansion-contraction properties similar to that of enamel, marginal gaps still result from polymerization shrinkage. Such resin shrinkage not only causes marginal gap formation, but also, when the enamel-resin bond remains intact, may cause damage within the composite resin in the form of microcracks, which cause premature failure of the restoration.

Polymerization shrinkage of composite resin materials has been measured to be 1.67% to 5.68%; most materials shrink about 2% to 3%. Macrofilled composite resins exhibit less polymerization shrinkage and hygroscopic expansion than do composite resins with low filler contents, but resin contraction of any extent is of concern to the clinician.
Methods designed to reduce polymerization contraction and microgap formation have been investigated. Incremental filling techniques and the influence of the direction of the visible light beam have been evaluated. Studies have shown that light-cured composite resins shrink in the direction of the polymerization light source. In addition, contraction towards the light source causes the resin to shrink from margins of the preparation, even when resin is applied and cured in small increments.

The purpose of this study was to investigate the adaptation of composite resin to the axial wall following light curing of anterior Class V restorations. Composite resin cavity wall adaptation after initial light polymerization from the lingual aspect of the tooth was compared to adaptation after polymerization from the labial aspect. Both hybrid and microfilled composite resins were evaluated, because these are the resins used in Class V restorations. Polymerization contraction in relation to hygroscopic expansion of the restoration was also investigated.

**Method and materials**

Thirty-two maxillary permanent incisors and 32 mandibular permanent incisors with intact clinical crowns were obtained from the University of Texas Dental Branch Clinic. There were equal numbers of maxillary central and lateral incisors. The teeth were stored in a 0.1% thymol solution until the study was initiated.

Each tooth was placed in a 2.5-cm retention tube and stabilized by acrylic resin, but the crown was left exposed. A Class V preparation was cut with a water-cooled, high-speed carbide bur on the labial surface of each tooth. The axial wall was 1.5 mm in depth. Maxillary incisor preparations were standardized so that the mesiodistal dimension was 6 mm and the incisogingival dimension was 4 mm. Mandibular incisor preparations were standardized so that the mesiodistal dimension was 4 mm and the incisogingival dimension was 3 mm. A 45-degree, 0.5-mm bevel was prepared on the cavosurface enamel margins.

Following preparation, the teeth were randomly assigned to four groups of 16 each. Eight teeth in each group were maxillary incisors and eight were mandibular incisors. Enamel margins on each tooth were acid-etched with 37% phosphoric acid gel, then restored as follows:

**Group I.** A fine-tipped brush was used to apply unfilled dentinal bonding resin (Scotchbond, 3M Dental Products Division) to the dentinal walls and etched enamel. The bonding resin was light cured for 20 seconds from the facial aspect. A microfilled composite resin (Visio-Dispers, ESPE GmbH) was placed and the visible light was applied from the facial direction for 60 seconds.

**Group II.** Unfilled dentinal bonding resin was applied by brush to the dentinal walls and etched enamel and was light cured for 20 seconds, through the tooth, with the beam directed from the lingual aspect. Microfilled composite resin was placed and was initially polymerized from the lingual aspect for 60 seconds, followed by 30 seconds of polymerization from the facial direction. The duration of polymerization was evaluated for appropriateness by testing the microhardness of the composite resin. The hardness tester demonstrated that the polymerization time values used in this experimental protocol provided equal facial and lingual polymerization hardness.

**Group III.** Unfilled dentinal bonding resin was applied to dentinal walls and etched enamel, and was light cured for 20 seconds from the facial aspect. A hybrid composite resin (Visio-Fil, ESPE GmbH) was then placed and polymerized from the facial direction for 60 seconds (Fig 1).

**Group IV.** Unfilled dentinal bonding resin was applied to the dentinal walls and etched enamel and was light cured for 20 seconds from the lingual direction, through the tooth. A hybrid composite resin was placed and was initially polymerized from the lingual direction for 60 seconds, followed by 30 seconds of polymerization from the facial aspect.

Excess composite resin was removed with carbide finishing burs, and then the restoration was polished with composite resin finishing disks.

One half of the maxillary and mandibular incisors in each group were placed into distilled water, in which they were maintained at 37 °C for 4 weeks. Four weeks was chosen because composite resin approaches its maximal water sorption at that time.

The teeth that were not stored in water were sectioned incisogingivally, and the cavity axial wall/composite resin junction was photographed at × 40 magnification (Fig 2). The photographic slides were processed, projected, and magnified ten times, and the resulting photograph was displayed on a digitizer pad. Slides were projected at random onto the digitizer pad, and measurements between the axial wall and composite resin were recorded.

After storage in water for 4 weeks, the remaining samples were sectioned, photomicrographed, and measured in the same way (Fig 3).
Measurements were made by two independent investigators, and the means were used for statistical analysis.

Results

Mean measurements of the microgap at the composite resin/axial wall junction were calculated. The first mean given is that of the teeth not exposed to water and the second mean is that of the teeth exposed to water. Results are also presented graphically in Fig 4. The group I means were 2.6 µm and 3.7 µm; the group II means were 1.8 µm and 1.6 µm; the group III means were 3.3 µm and 4.1 µm; and the group IV means were 3.7 µm and 4.7 µm. The means indicated that lingual polymerization of microfilled composite resin produced minimal gap at the composite resin/axial wall, but the difference in gap between facial and lingual polymerization was less than 3 µm. Application of Scheffé’s test revealed that there was no statistical significance in these differences ($P < .05$).

Discussion

Initial lingual polymerization requires more clinical time. By polymerizing a Class V restoration from the
facial aspect the clinician saves time and can produce a restoration with optimal polymerization. However, the low volume of composite resin used in Class V restorations, particularly in the mandibular teeth, may have resulted in the small difference in resin adaptation between labial and lingual polymerization. Polymerization shrinkage would be greater if the volume of composite resin restorative material was increased. The volumetric shrinkage from polymerization increases with increased bulk of composite resin. In larger and thicker anterior restorations, a greater amount of polymerization shrinkage would occur, and that could affect the adaptation of the composite resin to the cavity wall. Lutz et al. and Krejci et al. demonstrated improved adaptation of composite resin at the cementoenamel junction of a Class II restoration by controlling the direction of the polymerizing light source.

Conclusion

The experimental design in this study included polymerization of the dentinal bonding agent before the filled composite resin was applied to the preparation, as recommended by manufacturers. Polymerization of the dentinal bonding agent and composite resin restoration simultaneously may result in different findings in restoration adaptation.

Although the present results were not statistically significant, it is not known at this time what sized difference would result in a clinical difference that would affect the long-term success of the restoration. Further research is required to determine the effects of initial through-the-tooth light beam positioning on the polymerization of variously sized resin masses. In addition, the present findings as well as those in the future should be evaluated in relation to their influence on in vivo microleakage of composite resin restorations at the cavosurface dentinal and enamel margins.

References