

Posterior composite polymerization shrinkage in primary teeth: an in vitro comparison of three techniques

Kevin J. Donly, DDS Mark E. Jensen, DDS, PhD

Abstract

This in vitro study investigated strain produced in the placement and polymerization of Class II posterior composite resin restorations in primary teeth. Mesio-occlusodistal preparations were placed in primary teeth, followed by posterior composite resin restoration placement, using 3 different application techniques (technique I—placement and polymerization in 1 complete unit; technique II—placement and polymerization in gingivo-occlusal increments; and technique III—placement and polymerization in buccolingual increments). A precision strain gage was attached to the buccal surface of each tooth, balanced at 0, and after each increment was polymerized, the strain appearing on the strain gage indicator was recorded. Each tooth was restored using all 3 techniques. Results demonstrated the mean microstrain units to be 60.3 for technique I, 46.5 for technique II, and 38.5 for technique III.

Scheffe's test indicated that the buccolingual incremental polymerization produced a statistically significant lower amount of strain on the tooth than polymerizing the restoration as 1 complete unit ($P < 0.05$).

The utilization of composite resin is becoming more popular for the restoration of posterior primary teeth. Use of composite resin has many advantages: esthetics, relatively low thermal conductivity, and most importantly, the preservation of tooth structure in cavity preparation.

Researchers have demonstrated the volumetric polymerization shrinkage of composite resin and discussed techniques to measure accurately this shrinkage quantitatively.¹⁻³ A study by Goldman analyzed the polymerization shrinkage of various chemical and photopolymerized composite resins using a volumetric shrinkage measuring method. The values of the polymerization shrinkage ranged from 1.67 to 5.68%, light-activated materials showing the least.⁴ Bowen et al. reported measurements showing significant tensile stresses developed during the polymerization of composite resins.^{5,6} The bond of the com-

posite resin to the enamel and dentin walls must be stronger than the polymerization shrinkage tensile strength, therefore preventing the shrinkage contraction from breaking the composite-tooth interface bond.⁷ Although studies have shown that polymerization shrinkage can produce a force powerful enough to create separation at the enamel-composite junction, thereby allowing for marginal leakage,⁸⁻¹² the significance of this occurrence remains a controversial issue. Davidson and deGee suggest that the flow in the composite can compensate for the contraction stresses created by polymerization.¹³ A study by Hegdahl and Gjerdet indicated that the stresses produced on the enamel by polymerization shrinkage were low compared to the tensile strength of the enamel, providing minimal force on the enamel.¹⁴

Bowen et al. observed that placement of composite resin in numerous increments could create less polymerization shrinkage, whereas placement by the bulk method demonstrated more shrinkage and less hygroscopic expansion.¹⁵ This study also demonstrated that hygroscopic expansion infrequently is sufficient to compensate completely for the polymerization shrinkage.

Composite restorations are becoming more widely accepted as a posterior restoration in primary teeth. Several studies report that composite is a reasonable restoration for Class II preparations in primary teeth.¹⁶⁻¹⁹ The purpose of this study is to quantify the stresses created by 3 different techniques in the placement and polymerization of Class II posterior composite resin restorations.

Methods and Materials

Ten primary second molars were obtained from patients treated in the University of Iowa Pediatric Dentistry Clinic. Five teeth were maxillary second primary molars and 5 teeth were mandibular second primary molars. None of these teeth were affected by

caries—each was extracted for orthodontic treatment. The teeth were placed in a 0.1% Thymol®^a solution immediately after extraction, and retained in this preservative until the study was initiated.

One at a time, each tooth was taken from the preservative solution, rinsed with distilled water, and air dried. A precision strain gage^b was attached to the buccal surface of each tooth with a cyanoacrylate ester bonding cement.^c The tooth was situated in a 1-in. retention tube, the tooth roots being retained within the tube by acrylic,^d leaving the crown and strain gage exposed. The mounted tooth had 2 stabilized leads from the strain gage connected to the digital strain gage indicator.^e

The baseline strain indicator was balanced at 0 and recorded. A mesio-occlusodistal preparation was placed in the tooth, the isthmus being approximately one-half of the intercuspal width and a 45°, 0.5 mm bevel placed on all enamel margins. The standardized preparation was essentially the same as that used for conventional amalgam preparations in primary molars.²⁰ The tooth was acid etched with 37% phosphoric acid^f for 60 sec, then thoroughly rinsed for 30 sec and air dried. Each tooth then was restored, using 3 different techniques described as follows:

Technique I. Scotchbond®^g unfilled resin was applied to the etched surface, followed by P-30®^h being condensed into the preparation and polymerizedⁱ (2 min) as 1 complete unit.

Technique II. Scotchbond® unfilled resin was applied to the etched surface, followed by a gingivo-occlusal incremental placement of P-30®. The first increment was condensed to the gingival half of the cavity preparation and polymerized (1 min). The second increment, filling the remainder of the preparation, was polymerized (1 min).

Technique III. Scotchbond® unfilled resin was applied to the etched surface, followed by a buccolingual incremental placement of P-30®. The first increment was placed against the buccal wall and extended lingually to an imaginary plane approximately 1.5 mm from the lingual wall. This increment was polymerized (1 min), followed by the

placement and polymerization (1 min) of P-30® in the remainder of the preparation.

After each increment was polymerized, the strain appearing on the strain gage indicator was recorded. Each tooth was restored using all 3 techniques. After 1 technique was completed and findings recorded, the restoration was cut from the preparation and the next technique initiated. Three teeth were started with technique I, 4 teeth were started with technique II, and 3 teeth were started with technique III.

After each tooth had been restored using the 3 techniques, the strain gage was removed and the tooth was disengaged from the acrylic. The roots were cut from the tooth at the cemento-enamel junction leaving the entire crown intact. This portion of each tooth was weighed.^j The composite resin then was cut from the teeth and the teeth were weighed again. The mass of the composite restoration was calculated by subtracting the weight of the crown, in which the restoration had been removed, from the weight of the crown with the restoration intact. By multiplying this mass by the density of the composite, the actual volume of composite resin was determined. The percentage of the total crown weight that was composite resin then was calculated (Table 1).

Results

The microstrain data in Table 1 show complete unit polymerization to result in the highest strain, buccolingual incremental polymerization to result in the least strain, and gingivo-occlusal incremental polymerization to fall between these other 2 techniques. Maxillary and mandibular teeth were divided into separate groups and no difference in polymerization shrinkage stress was noted; therefore, the teeth were grouped together for analysis. The analysis of variance (ANOVA) demonstrated that significant differences in polymerization stress are associated with different techniques of composite application ($P < 0.05$).

The Scheffé's test was chosen to analyze all possible contrasts while ensuring that the level of significance did not exceed that used in the randomized block design. The test demonstrates that the buccolingual incremental polymerization created significantly less stress on the tooth than polymerizing the restoration as 1 complete unit. The analysis shows no statistically significant difference between gingivo-occlusal incremental polymerization and buccolingual incremental polymerization.

Discussion

The results demonstrated the technique which created the greatest amount of strain was the placement

^a Thymol®—Mallinckrodt Inc: St Louis, MO.

^b CEA-09-032UW-/20 Precision Strain Gages—Measurement Group Inc: Raleigh, NC.

^c Permabond, 910 Adhesive—Permabond International Corp: Englewood, NJ.

^d Fastray—Harry J. Bosworth Co: Skokie, IL.

^e V/E-20A Strain Gage Indicator—Measurements Group Inc: Raleigh, NC.

^f Etching Liquid—3M Dental Products: St Paul, MN.

^g Scotchbond®—3M Dental Products: St Paul, MN.

^h P-30®—3M Dental Products: St Paul, MN.

ⁱ Visilux® Visible Light Curing Unit—3M Dental Products: St Paul, MN.

^j Scientech 3300—Scientech: Boulder, CO.

Table 1.

Tooth #	Max or Man	Complete Set*	G-O Set*	B-L Set* (grams)	Crown Weight w/ Composite (grams)	Crown Weight w/o Composite (grams)	Composite Weight	% Comp of Total Crown Weight (cm ³)	Volume of Composite**
1	Man	45	35	33	0.912	0.820	0.092	10.088	0.202
2	Max	53	46	43	0.717	0.610	0.107	14.923	0.235
3	Man	83	51	43	0.956	0.792	0.164	17.154	0.361
4	Max	53	49	35	0.697	0.591	0.106	15.208	0.233
5	Max	58	51	41	0.852	0.719	0.133	15.610	0.293
6	Max	41	33	24	0.865	0.746	0.199	13.757	0.262
7	Man	73	52	38	0.982	0.828	0.154	15.682	0.339
8	Man	51	45	41	0.693	0.595	0.098	14.141	0.216
9	Max	85	55	48	0.889	0.731	0.158	17.773	0.348
10	Man	61	48	39	0.853	0.748	0.105	12.309	0.231

Mean: 60.30, 46.50, 38.50; SD: 14.46, 6.84, 6.30.

* Micro strain units. ** Volume derived by multiplying mass by density: density of P-30 is 2.2 g/cm³ (supplied by 3M).

and polymerization of the composite resin as 1 complete unit. This finding is certainly what was expected because the technique has the largest volume of composite when polymerized. The shrinkage of this composite causes strain on the buccal and lingual walls being held fast by the dentin bonding agent (Scotchbond®) and the strong acid-etched enamel bond.

As expected, placement and polymerization of the composite resin in gingivo-occlusal increments caused less strain than placement of the composite in 1 complete unit, yet this strain is not shown statistically to create a less significant strain. Since there is less volume in each polymerization step, less shrinkage would be expected.

The buccolingual placement created the least amount of stress. This can be due to 2 factors: (1) as with the gingivo-occlusal incremental placement, there is less volume, therefore less shrinkage; (2) the bond that creates the most stress occurs when the enamel and dentin of both the buccal and lingual walls have composite adapted against them before polymerization. As shrinkage occurs, the walls are pulled together. Using the buccolingual technique avoids this phenomenon, since the first increment is in contact with only the buccal wall. With no composite touching the lingual wall, there is no possibility of shrinkage of the composite to pull the lingual wall centrally, therefore eliminating that possibility of stress. The final incremental placement allows shrinkage of only a thin buccolingual layer to pull the buccal and lingual walls together, therefore causing less stress than the previous 2 techniques. To ensure that dehydration had minimal effect on the strain indicated, the composite was cut from the tooth following the experimental procedure while the strain gage was still in place. The strain gage indicator returned to 0 (± 3 strain gage units), thereby demonstrating that there was minimal strain caused by dehydration.

This study demonstrates that the placement of a composite resin produces stresses on the tooth, but are these stresses actually a factor in obtaining a successful restoration? Several authors believe that polymerization shrinkage indeed can be a possible cause for fractures at the enamel-composite margin. Other authors report that the forces created are so much less than the tensile strength of the enamel, that the forces are insignificant.

As a clinician, one should be concerned with these shrinkage stresses. The tensile strength of enamel may be much greater than the contraction forces of polymerization shrinkage, yet a technique that creates less stress would be more ideal, possibly alleviating pulpal responses due to the contraction of the composite in large restorations.

Absorption of water, after completing the restoration, has been shown to relieve strain created by the polymerization shrinkage, therefore relieving the concern of the initial stress created. The hygroscopic expansion properties of composite resin should not be expected to relieve the initial stress created upon polymerization of the restoration. Place the composite using the least traumatic technique possible, and do not rely on hygroscopic expansion to relieve the stress created by polymerization shrinkage.

There are many factors that may cause postoperative sensitivity in a tooth. One of these factors is polymerization shrinkage. It would seem that postoperative sensitivity could be reduced by applying the restorative material in a manner that induces the least amount of strain. Therefore, results from this study suggest buccolingual placement of posterior composite restorations in primary teeth.

Through this study, it is evident that the buccolingual incremental polymerization appears to be superior to polymerization as 1 complete unit. This study does not demonstrate a statistically significant difference between buccolingual incremental polymerization and gingivo-occlusal incremental poly-

merization. In the future, by eliminating the complete unit polymerization technique and securing a larger sample size, the buccolingual and gingivo-occlusal incremental polymerization technique may be compared more effectively.

Conclusion

A comparison of 3 application techniques of posterior Class II composite restorations led to the following conclusions:

1. Composite resin placement and polymerization as 1 complete unit creates the most stress of the 3 techniques.
2. Buccolingual incremental placement and polymerization of composite resin creates the least amount of stress of the 3 techniques.

Dr. Donly is an assistant professor of pedodontics at the University of Texas Dental Branch and Dr. Jensen is an assistant professor, Dept. of Family Dentistry and Dows Institute for Dental Research, University of Iowa. Reprint requests should be sent to: Dr. Mark E. Jensen, University of Iowa College of Dentistry, Dows Institute for Dental Research, Iowa City, IA 52242.

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Correction

Because of a printer's error in the June, 1986, issue, the first three paragraphs of the article *Influence of apicoectomy on the pulps of replanted monkey teeth* by David P. Durr and Odd B. Svein (*Pediatr Dent* 8:129) are actually the first three paragraphs of the article *A comparison of two dentin bonding agents in primary and permanent teeth* by Timothy Fagan et al. (8:144).