

## Posterior composite polymerization shrinkage in primary teeth: an in vivo comparison of three restorative techniques

Kevin James Donly, DDS, MS   Mark E. Jensen, DDS, PhD  
John Reinhardt, DDS, MS   Jerry D. Walker, DDS, MA

### Abstract

*The purpose of this study was to quantify the cuspal deflection produced by polymerization shrinkage, comparing 3 different techniques in the placement and polymerization of Class II posterior composite resin restorations in vivo. Thirty primary second molars in need of a Class II restoration were identified. An index, with a size ¼ carbide round bur, was placed on the buccal and lingual cusp tips of the tooth that was to receive the restoration. A standardized conventional Class II preparation was completed, then each tooth was restored with posterior composite resin, using 3 different application techniques (Technique I—placement and polymerization as one complete unit; Technique II—placement and polymerization in gingivo-occlusal increments; Technique III—placement and polymerization in buccolingual increments). Pre-operative and postoperative impressions were made, then poured with an epoxy resin die material. Photomicrographs were projected on a digitizing pad and measured by 3 independent investigators. Results demonstrated the mean cuspal deflection to be 19.7 µm for Technique I, 14.7 µm for Technique II, and 5.2 µm for Technique III.*

Advances in dental materials have progressively led to many changes in operative dental techniques. These advances are demonstrated by changes in preparation designs, restoration placement techniques, and improvements in the physical properties of restorative materials. Over the past 10 years composite resin has become more useful as a posterior restorative material. It has the advantages of excellent esthetics, relatively low thermal conductivity, and preservation of tooth structure in cavity preparation.

Composite resins have been shown to be successful as Class I and Class II posterior restorations.<sup>1</sup> When considering the placement of a Class II posterior composite restoration, the knowledge of an acceptable cavity preparation design is necessary. Pa-

quette et al. (1983), conducted a study in which a modified preparation was placed in primary teeth involving removal of only carious enamel and dentin. Although tooth structure was conserved, this technique was successful only with Class I restorations. Class II restorations, having a failure rate of approximately 25% when using this modified preparation technique, demonstrate that a conventional type of preparation is desired. A study of composite resin restorations by Oldenberg et al. (1985), demonstrated that conventional preparation design with a bevel had the greatest success, failure rate being 2.5% (3/119) compared to 4.5% (5/110) failure for conventional preparations and 11.7% (15/128) for modified preparations. A conventional preparation, with an enamel bevel, appears to be the most appropriate design for Class II composite resin restorations at this time.

Increased filler content, used in current posterior composite resins for wear resistance, reduces the amount of polymerization shrinkage compared to a conventional composite with a relatively large amount of unfilled resin matrix. Although polymerization shrinkage is decreased, a closer insight into the phenomena should be viewed. Goldman (1983) analyzed the polymerization shrinkage of various chemical and photopolymerized composite resins using a volumetric shrinkage measuring method. Shrinkage ranging from 1.67 to 5.68% was observed with light-activated, highly filled materials showing the least amount of shrinkage. Significant tensile stresses have been shown to develop during polymerization of composite resins, producing a force powerful enough to create separation at the enamel-composite junction.<sup>2</sup> Davidson and deGee (1984) suggest that the flow in composites compensates for the contraction

<sup>1</sup> Nelson et al. 1980; Oldenburg et al. 1985; Paquette et al. 1983; Tonn and Ryge 1985.

<sup>2</sup> Bowen and Cobb 1983; Jorgensen et al. 1975; Asmussen 1975; Hansen 1981; Ehrnfors and Derand 1984.

stresses created by polymerization shrinkage. Bowen et al. (1982), observed that placement and polymerization of composite resin in numerous increments could create less hardening shrinkage; whereas placement in one complete unit demonstrated more shrinkage and less hygroscopic expansion. Very infrequently was hygroscopic expansion sufficient to compensate completely for the polymerization shrinkage. Polymerization shrinkage stresses were found to be less when the composite resin was placed and polymerized in buccolingual increments rather than one complete unit (Donly and Jensen 1986).

A scanning electron microscope study of composite restorations showed large voids to be present in specimens restored using the bulk-pack method (Eick and Welch 1986). Gingivo-occlusal incremental polymerization showed cracks in the composite resin along the resin-adhesive-tooth interface on both the buccal and lingual surfaces of the proximal box. Buccolingual incremental polymerization showed the composite resin to produce a dense, tight bond to tooth structure with little evidence of porosity.

The purpose of this study was to evaluate any measurable dimensional change created by 3 techniques in the placement and polymerization of Class II posterior composite resin restorations in primary teeth.

## Methods and Materials

Thirty primary teeth were identified in the University of Iowa College of Dentistry Pediatric Dentistry Clinic. These teeth were fully erupted, in functional occlusion, and in need of a Class II restoration. Criteria used to assess the need for acceptance in this study included: (1) radiographic evidence of interproximal decay, (2) decay not encroaching on the pulp, (3) no evidence of tooth fracture, (4) asymptomatic status, and (5) restoration requiring a preparation design that did not extend to the buccal or lingual surfaces. The patients were appointed for a restorative appointment after the parents had consented for the patients to take part in the study.

The clinical treatment procedures were performed in the following manner:

1. The patient was seated and local anesthesia was administered.
2. The tooth and adjacent teeth were isolated with a rubber dam.
3. Indices, with a size  $\frac{1}{4}$  carbide round bur, were placed on the buccal and lingual cusp tips of the proximal surface of the tooth that was to receive the restoration.
4. A preoperative impression was made using a polyvinylsiloxane impression material.<sup>a</sup>

<sup>a</sup> Express®—3M Dental Products, St. Paul, MN.

5. A pretreatment color photograph was taken.
6. The tooth was prepared, removing all carious tooth structure and unsound enamel, following the usual preparation principles of operative dentistry (McDonald and Avery 1983). The isthmus of the preparation included approximately two-thirds the buccolingual width of the tooth, using cusp tip to cusp tip as reference points. A 45°, 0.5 mm bevel was placed in enamel around the entire preparation with a flame-shaped carbide finishing bur.
7. An impression of the preparation was made.
8. The tooth was rinsed and dried, then a calcium hydroxide base<sup>b</sup> was placed over the exposed dentin.
9. The tooth was acid etched with 37% phosphoric acid gel<sup>c</sup> for 60 sec, then thoroughly rinsed for 30 sec and air dried.
10. The entire calcium hydroxide base then was removed using an enamel hatchet, thereby exposing all dentinal surfaces for application of the dentin bonding agent.
11. A T-band matrix band was fit to the tooth and a wooden wedge driven interproximally to prevent overhangs and provide tooth separation to obtain postrestorative contact.
12. The 30 teeth were restored randomly, with 10 teeth being used for each of the following techniques:

*Technique I:* Scotchbond<sup>®d</sup> unfilled resin was applied to the etched surface, followed by P-30<sup>®e</sup> being placed into the preparation and polymerized<sup>f</sup> (2 min) as 1 complete unit.

*Technique II:* Scotchbond<sup>®</sup> unfilled resin was applied to the etched surface, followed by a gingivo-occlusal incremental placement of P-30. The first increment was placed into 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. The increment was polymerized (1 min), followed by the placement and polymeriza-

<sup>b</sup> Life Base<sup>®</sup>—Kerr, Romulus, MI.

<sup>c</sup> Etching Gel—3M Dental Products, St. Paul, MN.

<sup>d</sup> Scotchbond<sup>®</sup>—3M Dental Products, St. Paul, MN.

<sup>e</sup> P-30<sup>®</sup>—3M Dental Products, St. Paul, MN.

<sup>f</sup> Visilux<sup>®</sup>—Visible Light Curing Unit; 3M Dental Products, St. Paul, MN.

tion (1 min) of P-30 in the remainder of the preparation.

13. Excess composite was removed with carbide finishing burs followed by polishing of the restoration with composite finishing discs.
14. The rubber dam was removed and the restoration was evaluated for proper occlusion with articulating paper.
15. Any premature contact was relieved and the restoration polished.
16. A postoperative impression was made, using the same polyvinylsiloxane material as before, and a 2 × 2 color slide was taken.
17. The tooth, once again, was isolated with a rubber dam and the indices on the cusp tips were restored with composite resin following the accepted technique presented before. The impressions were taken to the laboratory and the following procedures completed.
  1. All impressions were poured with an epoxy resin die material<sup>g</sup> as suggested by the manufacturer.
  2. The epoxy resin dies were placed on a photomicroscope<sup>h</sup>, where the indices on the cusp tips were brought into focus under five times magnification, and a photograph exposed with Tungstun film.
  3. The 2 × 2 slides were developed, placed in a projector and magnified ten times, displaying the photograph on the digitizer pad.<sup>i</sup>
  4. The slides were projected at random onto the digitizer pad; measurements were made from the buccal index to the lingual index using the most interior edge of the indices for the reference points. All measurements were recorded.

The slides were arranged randomly and measured on the digitizer by 3 independent investigators. The 3 measurements of the independent investigators were averaged, and the means used for statistical analysis.

## Results

The data in Table 1 indicate the cuspal deflection determined for each tooth. Cuspal deflection is described relative to the Latin definition: to bend. Deflection in this study refers to the amount of cuspal bending toward the center of the tooth. Results dem-

<sup>g</sup> Cerestore Epoxy Resin—Cerestore System, Ceramco Inc., Johnson and Johnson Co., East Windsor, NJ.

<sup>h</sup> Nikon FX-35 Camera, Nikon SM2-10 Stereoscopic Microscope, Nikon Microflex AFX-II Photomicrographic Attachment—Nippon Kogaku K.K., Tokyo, Japan.

<sup>i</sup> Graf/Pen Sonic Digitizer—Science Accessories Corp., Southport, CT.

TABLE 1. In Vivo Cuspal Deflection

	Complete Set*	G - O Set*	B - L Set*
	6	16	3
	34	17	4
	36	4	2
	24	29	4
	15	9	1
	18	19	11
	28	7	8
	11	22	13
	14	18	1
	11	6	5
Mean	19.70	14.70	5.20
SD	± 9.77	± 7.59	± 3.94

\* Cuspal deflection in microns.

onstrated the mean cuspal deflection to be 19.7 microns for complete unit polymerization, 14.7 microns for gingivo-occlusal incremental polymerization and 5.2 microns for buccolingual incremental polymerization.

A randomized block design was used for data interpretation. Analysis of variance (Table 2) indicated significant differences occurred due to the different placement and polymerization techniques ( $P < 0.05$ ). Scheffe's Test indicated that the buccolingual incremental placement and polymerization created a statistically significant lower amount of cuspal deflection than polymerization of the restoration as one complete unit or in gingivo-occlusal increments ( $P < 0.05$ ). No statistically significant difference was noted between gingivo-occlusal incremental polymerization and polymerization as one complete unit.

## Discussion

The results demonstrated the technique that created the greatest amount of cuspal deflection was the placement and polymerization of the composite resin as one complete unit. This was a rational finding, the complete unit polymerization having the largest volume of composite when polymerized. The greater volume may allow the composite shrinkage to place strain on the buccal and lingual walls, therefore pulling these walls centrally as indicated by the cuspal deflection.

Placement and polymerization of the composite resin in gingivo-occlusal increments caused less mean cuspal deflection than placement and polymerization in one complete unit. Less volume, using this tech-

TABLE 2. Analysis of Variance Table for Cuspal Deflection Created During Polymerization

Source	SS	df	MS	F
1. B (restoration)	1085.00	k - 1 = 2	542.50	8.50
2. S (teeth)	537.60	n - 1 = 9	59.73	0.94
3. Residual	1148.20	(k - 1)(N - 1) = 18	63.79	
Total	2770.80	n - 1 = 29		

$P < 0.05$ , 3.55 critical value.

nique, would create less shrinkage; therefore less cuspal deflection than the polymerization as one complete unit. The results of this study do not demonstrate a statistically significant ( $P < 0.05$ ) difference between these 2 techniques, thereby indicating the gingivo-occlusal incremental polymerization is not necessarily preferable over the complete unit polymerization.

The buccolingual placement and polymerization created the least amount of cuspal deflection, which was shown statistically to create a significantly lower amount of cuspal deflection than the other two techniques. This finding may be due to the fact that there is less composite volume in each increment, therefore less total polymerization shrinkage. The buccolingual technique has no composite touching the lingual wall when polymerizing the first increment; this eliminates that possibility of stress and cuspal deflection. The lingual incremental placement allows the shrinkage of only a thin buccolingual layer to pull the buccal and lingual walls together, resulting in less strain and cuspal deflection than the other 2 techniques. In order to reduce the effects of dehydration on the cuspal deflection, the preparations were cut using a water spray. A previous study also has indicated that dehydration has minimal effect on this experimental restorative procedure (Donly and Jensen 1986).

This study demonstrated that polymerization shrinkage can have a significant effect on deformation of primary teeth. Several outcomes may result from shrinkage, including fractures at the enamel-composite margin as well as in the uncut tooth structure. It has been shown that hygroscopic expansion properties of composite resins cannot be expected to relieve the initial shrinkage upon polymerization. The relationship between postoperative sensitivity and stresses created by polymerization shrinkage is currently unknown. The use of a technique which may prevent traumatic forces to a tooth should be considered when practicing operative dentistry.

## Conclusion

An in vivo comparison of 3 application techniques of posterior Class II composite resin restorations found buccolingual incremental placement and polymerization of composite resin to create the least amount of cuspal deflection of the 3 techniques observed. Since cuspal deflection may relate to postoperative sensitivity or unnecessary stresses to tooth structure, results from the study suggest buccolingual incremental placement to be most favorable.

Dr. Donly is an assistant professor, pediatric dentistry, The University of Texas. Dr. Jensen is an associate professor, pediatric dentistry and the Dows Institute for Dental Research; Dr. Reinhardt is an associate professor, operative dentistry; and Dr. Walker is a professor, pediatric dentistry, the University of Iowa College of Dentistry. Reprint requests should be sent to: Dr. Kevin James Donly, Department of Pediatric Dentistry, The University of Texas, Health Science Center at Houston Dental Branch, Houston, TX 77030.

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