HOW CAVITY DIMENSION INFLUENCES IN THE COMPOSITE DEFORMATION DURING POLYMERIZATION SHRINKAGE

ABSTRACT

PURPOSE: To understand how the dimensions of the cavity made of a rigid substrate influences on displacement of the composite free surface during polymerization shrinkage. **MATERIAL AND METHODS:** Cylindrical cavities in 4 or 6mm diameter and 1 or 2mm depth were prepared in glass rods. These cavities were restored in bulk (Single Bond + Filtek Z250). Free surface displacement was monitored for 10 minutes with a probe. The data was analyzed 60 seconds and 10 minutes after photo-activation. Results were analyzed using two-way ANOVA/Tukey's test to evaluate the influence of diameter and depth, and Student's t-test to compare the periods ($\alpha=0.05$). **RESULTS:** The interaction between the factors diameter and depth was statistically significant ($p<0.05$ for both periods), but Tukey's test did not revealed this interaction. For the same diameter the higher the cavity depth, the higher was the displacement. Student's t-test showed that the displacement was significant higher at 10 minutes than at 60 seconds ($p<0.05$), even though this difference was not so evident numerically. It was not possible to determine any strong correlation with volume neither with C-factor. **CONCLUSIONS:** The displacement of free surface represents the stress state to which the composite is subjected. The variation in depth of the cavity seems to be a further factor that influences the displacement of free surface, more than variation in diameter.

BOARO, Leticia Cristina Cidreira*
XAVIER, Tathy Aparecida**
BRANDT, William Cunha*
BRAGA, Roberto Ruggiero**

KEYWORDS

Polymerization. Shrinkage. Dental resins. Dental bonding.

Department of Prosthodontics, School of Dentistry, University of Santo Amaro, Sao Paulo, SP, Brazil*
Department of Dental Materials, School of Dentistry, University of Sao Paulo, Sao Paulo, SP, Brazil**
Correspondence: leticiaboaro@usp.br (BOARO LCC)

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INTRODUCTION

After being initiated, the polymerization reaction of composite resins results in a volumetric shrinkage due to the approach of monomers to form chains. When the composite is adhered to the more rigid walls of remaining teeth, they will not fully follow the deformation and therefore, the polymerization shrinkage stresses can be developed.

Polymerization reaction is usually divided into two phases: pre and post-gel. In the pre-gel phase, the composite mass can still flow[1] and thus, the shrinkage resulting from the polymerization does not develop any stress, since the molecules are still able to slide and also rearrange into new positions to compensate the reduction in volume. However, in the post-gel phase, the resin has a flow capacity constrained by establishment of cross links between the polymer chains. At this stage, the polymerization shrinkage, associated with increased elastic modulus, causes development of stress, which may be transferred to the interface and cause the appearance of gaps[2]. The gaps generated compromise the marginal sealing of restoration, which is the major cause of clinical failures that we have nowadays regarding the composites [3, 4].

It is believed that cavity configuration can also interfere with development of stress during composite shrinkage. The cavity configuration is described by "configuration factor" or C-factor, defined as the ratio between the area of composite adhered to the tooth, and the free surface of composite (not adhered) [5]. According to this concept, free areas of the composite (not adhered to the rigid walls) allow the stress relief by viscous flow, particularly during the pre-gel phase [5, 6]. Therefore, the higher the free surface, in other words the lower the C-factor, the greater ability of material to deform and lower will be the stress developed [5, 6].

Based on this concept, flow of the composite from the free surface of restoration (not adhered) has been cited by several authors as the major mechanism of relieving stresses developed during polymerization in tooth/restoration interface [6, 7]. This concept is implicit even in the incremental technique, which aims to reduce stress development at interface by insertion of small increments and photo-activation with large free surfaces and small adhered areas [8, 9].

Considering the above, the aim of this study was to understand how the dimensions of cavity made of a rigid substrate influence on displacement of the composite free surface during polymerization shrinkage.

MATERIAL AND METHODS

Glass rods with 8 and 10 mm in diameter were cut to approximately 10 mm in length. To prepare the cavities with 4mm in diameter, the rods with 8 mm were used, and for the cavities with 6 mm in diameter the rods with 10 mm, in order to maintain the wall thickness of cavities similar in all the groups. The cavities were prepared using high-speed cylindrical diamond burs (ref. 1141, KG Sorensen, Cotia, SP, Brazil) and low-speed custom-made cylindrical diamond burs with dimensions of cavity (KG Sorensen, Cotia, SP, Brazil). Both of them under copious air-water spray cooling. Cavities dimensions (n = 10) and its respective volume, C-factor, free surface and adhered area are shown in Table 1.

Table 1: Dimensions and characterization of cavities used in this study.

Dimensions (d x h) (mm)	Volume (mm^3)	C factor	Adhered area (mm^2)	Free surface (mm^2)
4 x 1	13	2.0	25	13
4 x 2	25	3.0	38	13
6 x 1	28	1.7	47	28
6 x 2	57	2.3	66	28

The cavities were sandblasted with alumina (150-250 µm) to create an adhesive surface with micro-retentions. Then the surface was silanated (3M ESPE, St Paul, MN, USA), and its solvent was air-dried. Two layers of an one-bottle adhesive system (Single Bond, 3M ESPE, St Paul, MN, USA) were applied and phtoto-activated using a radiant exposure of 6J/ cm^2. A hybrid composite Filtek Z250 (3M ESPE, St Paul, MN, USA, shade A3) was used to restore the cavities in bulk. Before photo-activation, the specimen a probe (model p 80, Sylvac, Switzerland) was placed in contact with the free surface of restoration, perpendicularly.

The experimental set-up is presented on figures 1 and 2, this development of experimental design was based on the method by Loguercio *et al* 2004 [9]. The distance between the light unit tip and the composite surface was approximately 10 mm. Using a dental radiometer (model 100, Demetron Res. Corp., Orange, CA, EUA), the irradiance that effectively reached the composite was checked (200 mW/cm^2). Then the exposure of 60 s was used to photo-activate the composite, resulting in a radiant exposure of 12 J/cm^2.

Displacement values of free surface as a result of polymerization shrinkage was measured in µm in two different periods: right after photo-activation (60 seconds) and 10 minutes after photo-activation beginning. The data were analyzed separately for each period using two-way ANOVA (diameter and depth) and Tukey's test. To compare the periods Student's t-test was used for each group. For both tests the global significance level was 5%.

RESULTS

The interaction between the factors diameter and depth was statistically significant ($p<0.05$ for both periods), but Tukey's test did not revealed this interaction, as can be observe in tables 2 and 3. Student's t-test showed that displacement was significantly higher at 10 minutes than at 60 seconds ($p<0.05$), even though this difference was not so evident numerically.

The Figure 3 shows the linear regression between displacement of free surface at 10 minutes and volume or C-factor. It was not possible determining any strong correlation with volume neither with C-factor.

Table 2: Means and standard deviation of displacement of the free surface (μm) 60 seconds after photo-activation (means followed by the same letter are statistically similar, $p>0.05$).

		Diameter	
		4 mm	6 mm
Depth	1 mm	16 (3.7)b	11 (2.2)b
	2 mm	31 (6.9)a	34 (4.3)a

Table 3: Means and standard deviation of displacement of the free surface (μm) 10 minutes after photo-activation (means followed by the same letter are statistically similar, $p>0.05$).

		Diameter	
		4 mm	6 mm
Depth	1 mm	18 (3.9)b	13 (2.9)b
	2 mm	34 (7.6)a	37 (4.8)a

Figure 1: Experimental set-up - A: device that indicates the displacement of the free surface; B: light unit; C: specimen.

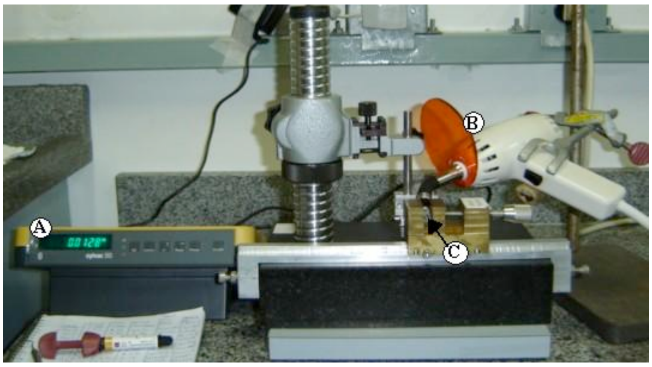


Figure 2: Side approximate view - A: probe (model p 80, Sylvac), which is in contact with free surface of the composite; B: light-unit tip.

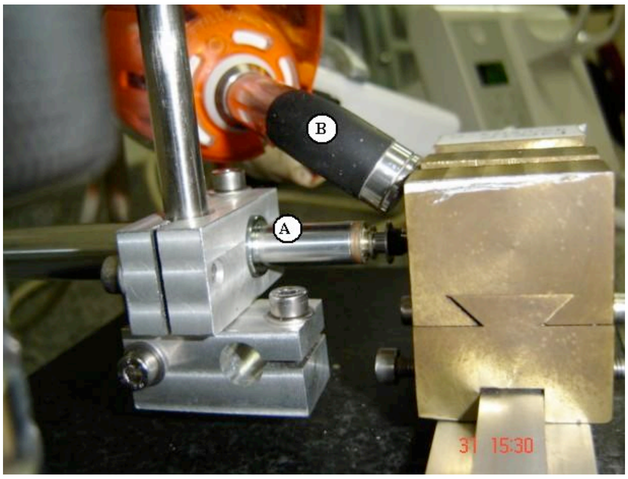
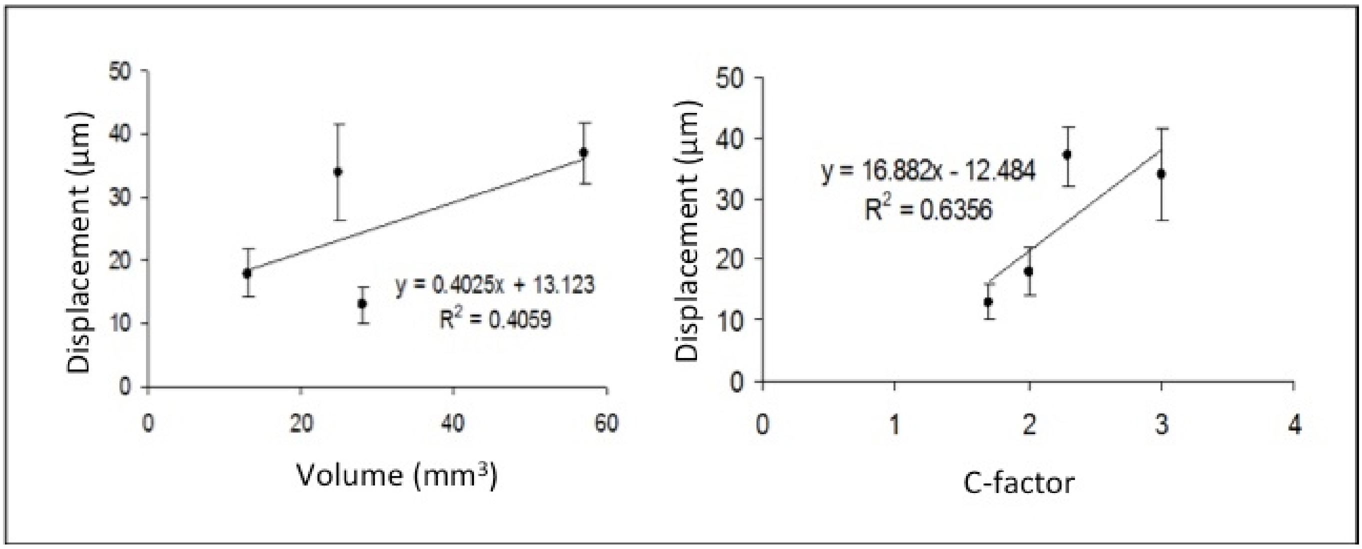


Figure 3: Graphs of linear regression between displacements of free surface at 10 minutes (μm), and volume (left) and C-factor (right).



DISCUSSION

For this study, the glass was chosen as bonding substrate as a way to eliminate the variability of quality bonding inherent of adhesion in dentin. Thus, the displacement can be attributed only to the volumetric shrinkage, and not under covered by interfacial debonding. Based on the results, it is possible observe that cavity depth presented a significant influence on displacement of the free surface. The higher values of displacement were observed for the higher depths for both diameter, and in both periods (60 second and 10 minutes after photo-activation).

Considering the same depth, the change in diameter was not enough to reveal significant differences for displacement of free surface.

In the present study, the majority of displacement occurred in the first 60 seconds of polymerization process, with only a slight (but significant $p<0.05$) increase in values on the following 9 minutes. This finding can be explained based on the high speed of polymerization for composites photo-activated, and the chance to occur viscous flow (as evidenced by displacement of free surface) is restricted to the first moments of polymerization reaction. In this study, the displacement of free surface measured represents a sum of the flow (plastic deformation) and the elastic deformation of composite. As cited before, polymerization reaction of composites photo-activated happens really fast. It is estimated that gel point of dimetacrylate copolymers occurs at a degree of conversion around 5% [10], which is achieved few seconds before photo-activation.

To be able to quantify the composite flow, it would be necessary an instrument with acquisition data as faster as the one used in the present study. A previous study showed that rigid shrinkage (post-gel shrinkage) for the composite Filtek Z250 (the same composite used in the present study) photo-activated with an irradiance of 200 mW/cm^2 for 40 s (radiant exposure of 8 J/cm^2) started to be registered at 1.5 seconds after photo-activation[11] beginning. Then, in practical terms we can assume that in the present study only de plastic deformation was measured.

Preliminary studies using finite element analysis indicates that a larger displacement of free surface of restoration corresponds to the stress state more pronounced [12]. Another study which evaluated microleakage as a function of cavity dimensions using bovine teeth found a higher microleakage in cavities with the same diameter and higher depths. In this way, it is possible assume that for a same diameter the higher depth results in higher stress in the cavity.

Other evidence that higher displacement represents a stress state more pronounced in some specimens with 2 mm in diameter was the development of cracks in the glass observed few hours after the test was finished.

Although, there was a trend observed to increase the displacement with volume and C-factor, but it was not observed statistically significant correlations between those variables. This weak correlation can be explained by correlation observed between displacements of free surface with the cavity depth for a same diameter. This finding suggests that displacement can be associated to the adhered surface, which leads to a concomitant increase, as the volume factor C.

CONCLUSION

Within the limitations of this study, it is possible concluded that displacement of free surface represents the stress state to which the composite is subjected. The variation in depth of cavity seems to be a further factor that influences the displacement of free surface, more than variation in diameter. So, it is possible assert, for the same diameter, the higher the depth, the greater displacement.

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