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Shrinkage Deformation of Three Different Light Cure Composite Resin Using Image Correlation Method

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Key words
polymerization Shrinkage, Composite resin, Image correlation method.

Abstract

The study performed were to measured the amount of shrinkage deformation of resin composites with and without bonding agent. The shrinkage deformation of three types of composite resin (Ecusphere, Densply, CHARISMA) in cavities was studied using image correlation method. The cylindrical cavity in extracted teeth (premolors) are to examine the shrinkage behavior on the top free surface. The cavities filled with resin after spreading a bonding agent are irradiated using LED unit, also performed on the cavities without bonding agent. One way analysis of variance and MOIRE analysis were used for statistical analysis. The shrinkage behavior was different in the cavities prepared with and without bonding agent. Polymerization of dental composites is characterized by heterogeneous deformation patterns with variable shrinkage values at different locations within the material.

Introduction

Light cure resin composite has been widely used as one of dental restoration materials mainly due to its handling ability in clinical practice and its esthetic appearance, as well as from a clinical view point on minimal invasion to healthy tooth tissue .The wide use of the resin composite has also been prompted by the introduction of new resin products with good physical and mechanical properties, and new bonding agents having highly-adherent to tooth tissue .However, the contraction stress due to the polymerization shrinkage can reportedly cause damage or defect in the resin restoration, tooth structure and at their interface [(1)]. Polymerization shrinkage remains one of the most important disadvantages of dental composites and leads to the loss of marginal integrity of the tooth-restoration interface. Shrinkage is caused by shortening the intra-molecular distances between monomer units in the polymer compared to intermolecular distances between free monomers. The formation of microgaps between the cavity walls and the restoration allows the penetration of salivary fluids and microorganisms which may lead to secondary caries. Attempts have been made to develop low-shrinkage composites based on the silorane technology. However, polymerization shrinkage has not been eliminated even in the most contemporary materials available on the market[(2-4)]. Adhesive systems have been used in dentistry for bonding of resin composite to enamel and dentin for more than 10 years . Adhesives were introduced to simplify the clinical application procedure as well as to improve bond strength and marginal seal of resin composite restorations Recently, self-etching primers containing a mixture of phosphoric acid esters were designed and manufactured on the basis of the formation of the hybrid layer at the enamel/ dentin–resin interfaces[(5)]. This study measured the shrinkage behavior of the resin composite in cavities of extracted teeth using image correlation method. The cavities with

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cylindrical shapes was used to study the shrinkage behaviors on the top free surface.

Materials and Method

Specimen Preparation

Experiments were performed on geometries of specimen with a cylindrical on an extracted tooth. The geometries were illustrated in Figure1. The cylindrical cavity was used to measure the shrinkage behaviors on its top free surface. The specimens were prepared using the following procedures; (i) an extracted tooth refrigerated was defrosted at room temperature and then wiped with soft paper to remove moisture from the surface, (ii) the lingual side of the tooth was embedded in cold cure acrylic resin to fix it tightly, (iii) a cylindrical cavity with 3 mm in diameter and 2 mm in depth was made on the labial side surface using a turbine with water cooling, and then the cavity was washed and cleaned with water(6). A resin composite used in this experiment are listed in Table 1. The resin was filled into the cylindrical cavities using the bonding agent(fifth generation) according to the manufacturer's instruction. The specimens prepared without the bonding agent were also made to study the influence of the agent.

Experimental Setups

These setups consisted of a conventional LED light curing unit according to the manufacturers' instructions to activate the polymerization, the specimen was irradiated for 20s at room temperature (23±1), and the shrinkage behavior of the resin was recorded with stereomicroscope used for taking the images of the specimen surface, and a computer to save the images.The specimen was mounted on a precision motion stage so that the uncured resin surface in the cavity could place horizontally to minimize the influence of gravity.

2-D Digital Image Correlation System

Image correlation method is used widely in the field of computer vision,(7-9) utilizes patterns unique to an object's surface. Patterns and brightness distributions on the object to be measured are photographed using a stereomicroscop device before and after deformation. Then, the amount of displacement on the surface of the object can be measured. More specifically, a small region (subset: N x N pixels) centered on an arbitrary position in an image before deformation acts as a standard subset. The position showing the greatest correlation with this standard subset in the image after deformation is then identified so that the amount and direction of displacement can be determined (Figure 2).To correlate the subsets, a rough search is conducted in which the displacement is measured to the accuracy of a pixel. In addition, a detailed search is conducted in which the displacement is obtained with measurement accuracy greater than a pixel. In the rough search, the correlation function C_R is determined using the minimum residual method (Eq. 1).Where $I_u(X, Y)$ and $I_d(X+u, Y+v)$, respectively, are the light intensities before and after deformation; X and Y are the center coordinates of a subset; u and v are displacements in the x- and y-directions, respectively; and $N = 2M+ 1$. When CR reaches a minimum, the subset containing this position is considered to be the pixel nearest the center of displacement following deformation.

Since the actual displacements do not equal integral multiples of the pixel values, it is necessary to obtain displacements with an accuracy greater than a pixel. Correlation coefficients for the pixel with the highest correlation coefficient and pixels on its periphery

are subjected to interpolation using an approximate curve. The peak-value position is then identified by the displacement of the standard subset after deformation (10). In this study, the former method was used for analysis. The correlation function CD was used for the detailed search (Eq. 2). Using this equation, deformation can be measured with a measurement resolution higher than a pixel:

$$C_R\left(X+u,Y+v\right)=\sum_{i=-M}^{M}\sum_{j=-M}^{M}\left|I_d\left(X+u+i,Y+v+j\right)-I_u\left(X+i,Y+j\right)\right| \quad (1)$$

$$C_D\left(X+u,Y+v\right)=\frac{\sum_{i=-M}^{M}\sum_{j=-M}^{M}\left(I_d\left(X+u+i,Y+v+j\right)\times I_u\left(X+i,Y+j\right)\right)}{\sqrt{\left(\sum_{i=-M}^{M}\sum_{j=-M}^{M}I_d\left(X+u+i,Y+v+j\right)\right)^2\times\left(\sum_{i=-M}^{M}\sum_{j=-M}^{M}I_u\left(X+i,Y+j\right)\right)^2}} \quad (2)$$

The method allows determination of displacements of selected points of the mesh (triangular or rectangular network of points) on the surface of the deformed specimen by comparing successive images acquired during a test and cross correlating the gray intensity patterns of the direct neighborhood of the points (or the reference areas)[11].

Such capability is provided by the MOIRE Software Package system showing in Figure 3 and has been successfully applied to a wide range of experimental problems. Detailed description of measurement principles, system specifications, calibration procedures, and sample applications may be found in [12].

Results

The values of polymerization shrinkage of different composite resin with standard deviations are summarized in Table 2 and 3 and Figure 4 there were different between three types of composite resin. The result table 2 showed that CHARISMA composite resin had more polymerization shrinkage than the Densply and Ecusphere when bond agent was not applied. Table3 revealed that the polymerization shrinkage of Ecuspher and Densply composite resin with bonding was lower than CHARISMA composite resin with bonding. The analysis result of the composite resin without bonding were depicted in Figures5,6 and 7, in the form top views. While Figures 8,9 and 10 showing the analysis result of the composite resin with bonding in the form top views there were different in the cavities prepared with and without the bonding.

Discussion

Shrinkage of resin composites during and after curing is concern to clinicians and manufacturers since it may result in restoration-tooth gap with further cusp fracture, tooth sensitivity, or recurrent caries. The smaller the filler particles and the higher the monomer viscosity, the lower polymerization shrinkage[13]. Polymerization shrinkage of dental composites was measured using digital image correlation based on a steromicroscope which allowed dimensional changes to be determined in x and y axes. To study the shrinkage deformation is given in pixels with the first image called (reference image "before deformation") and the second one called (deformed image "after deformation") showing the displacements in horizontal direction and vertical direction respectively, figures 5,6,7,8,9and 10 shows the analysis results there were several things to be noted: First, the marginal gap between the tooth and resin significantly increased at one side of the interface due to the massive movement of the resin during the polymerization process of the cavity prepared without the bonding agent. Second, no big displacement was observed on the tooth substrate surrounding the resin because the bonding agent plays an important role to maintain a good adhesive strength between the resin and tooth substrate during the polymerization process acting as shock absorber and can stretch or flow to allow stress relaxation, this result agree with Karthicket al. and Castenada-Espinosa *et al.*[14,15]. Finally, non-uniform distribution of local deformation fields in dental composites with greater deformations peripherally and smaller deformations centrally, this result agree with Taichi Furukawa *et al.*[6] due to the resultant forces preventing the material movement in middle (central axis) of the dental composite. Tables 2and3 and figure 4 showing CHARISMA composite resin without and with bonding resin high polymerization shrinkage than Ecuphere and Densply composite resin this due to polymerization shrinkage decreased by the increasing quantity of inorganic fillers affected the shrinkage of dental composites this result were found to be in agreement with Bilge *et al*[16].The result also revealed that the Ecuphere and Densply composite resin low shrinkage values than CHARISMA composite resin (table 2 and 3) reported for BisGMA and TEGDMA are substantially higher than those displayed by typical composites, which range between 2 and 3%[17], this difference is due to the presence of pre-polymerized composite particles, sometimes referred to as 'organic fillers', which render them in terms of the actual volume fraction of polymerizing resin this result agree with Roberto *et al*[18,19].

Conclusions

Polymerization of dental composites is characterized by heterogeneous deformation patterns with variable shrinkage values at different locations within the material. Digital image correlation using MOIRE Software Package system is a promising tool enabling qualitative and quantitative mapping of local deformation fields in dental composites. The shrinkage behavior was different in the cavities prepared with and without the bonding agent.

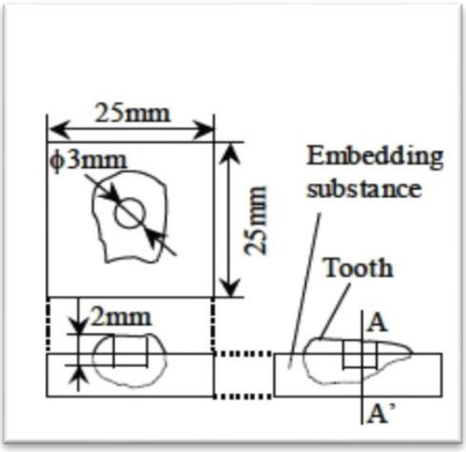


Fig. (1):- Specimen geometries.

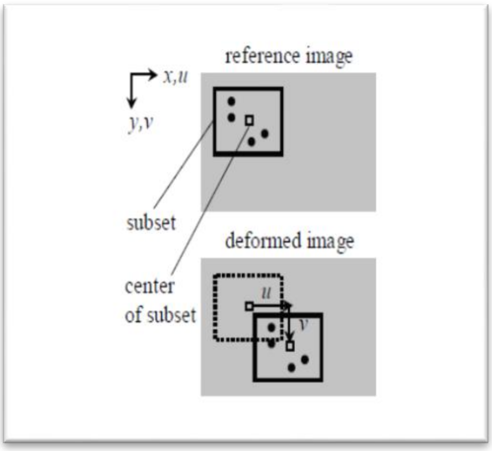
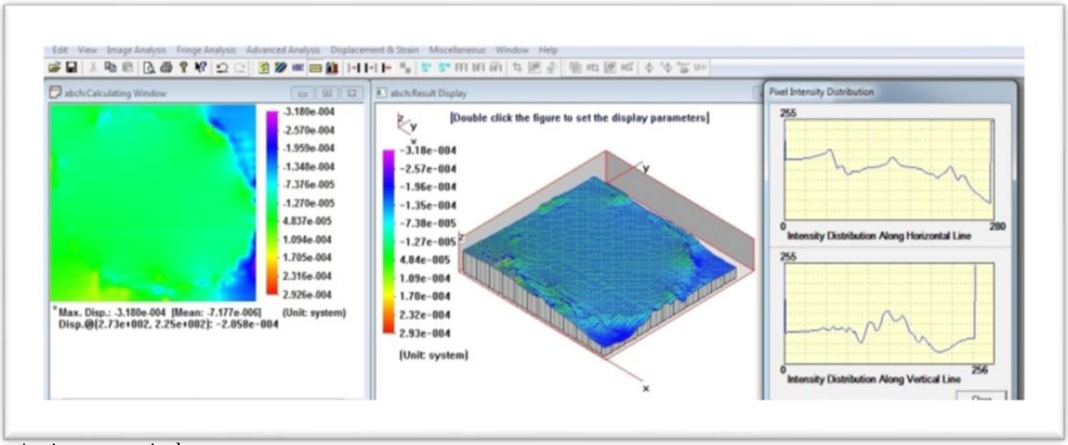


Fig.(2):- image correlation method.



*unit system=pixel

Fig.(3):- MOIRE Software Package system.

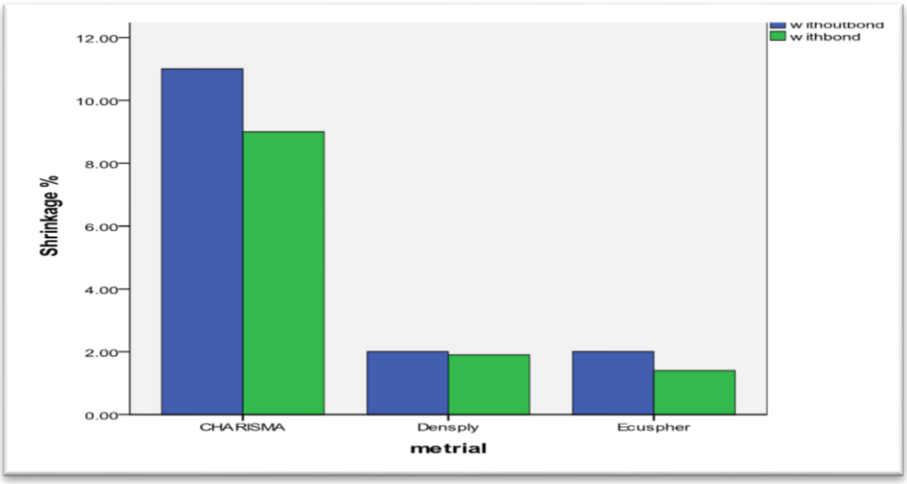


Fig.(4):- values of polymerization shrinkage with and without bonding.

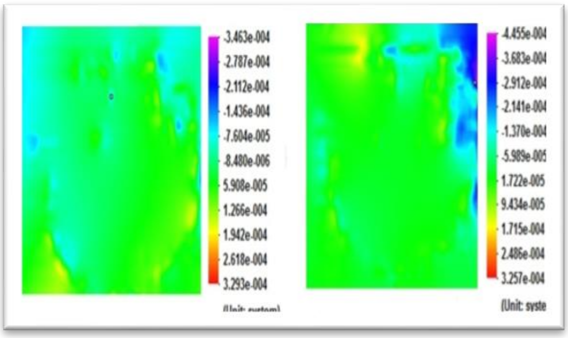


Fig. (5):- analysis results of Ecusphere before and after deformation.(without bonding)

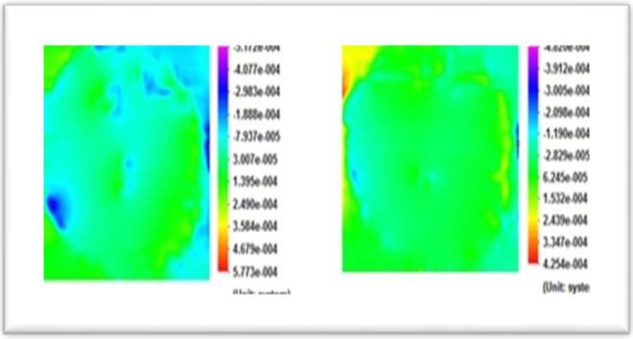


Fig. (8):- analysis results of Ecusphere before and after deformation.(with bonding)

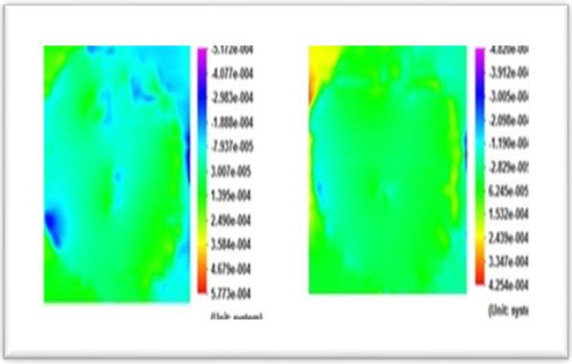


Fig. (6):- analysis results of Densply before and after deformation.(without bonding)

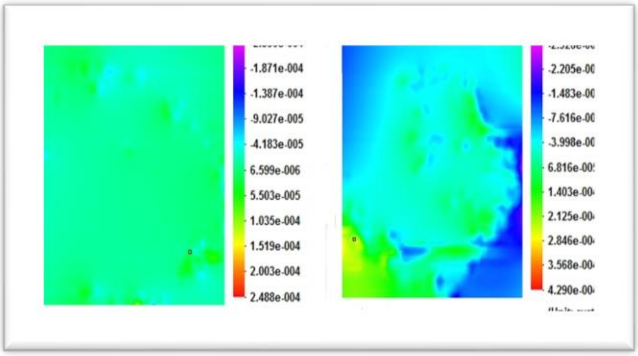


Fig. (9):- analysis results of Desply before and after deformation.(with bonding)

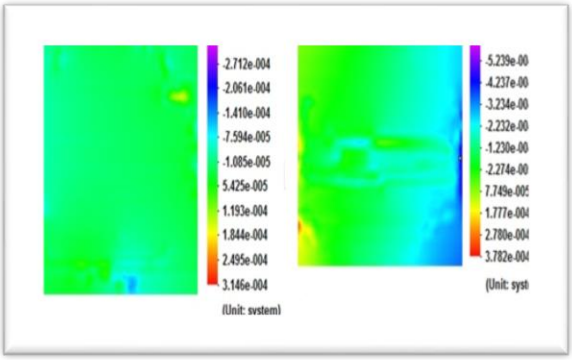


Fig. (7):- analysis results of CHARISMA before and after deformation.(without bonding)

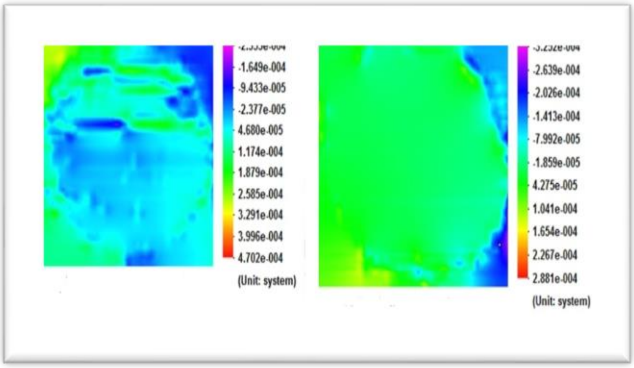


Fig. (10):- analysis results of CHARISMA before and after deformation.(with bonding)

Table (1):- Composite resins used in this experiment.

Types of composite resin	Matrix	Filler	Weight*
Ecusphere	**Bis-GMA-base**	**Barium glass**	**77%**
Densply	**Bis-GMA TEGMA UEDMA**	**$(BoFBaAl)Sio_4$ Sio_2**	**82%**
CHARISMA	**Bis-GMA**	**$(BoFBaAl)Sio_4$ Sio_2**	**58%**

*inorganic filler %weight as informed by the manufacturer

Table (2):- The values of polymerization shrinkage of composite resin with standard deviations(without bonding).

Types of composite resin	Values of polymerization shrinkage	standard deviations
Ecusphere	**2%**	**$9*10^{-4}$**
Densply	**2%**	**$4.3*10^{-4}$**
CHARISMA	**11%**	**$3.6*10^{-4}$**

Table (3):- The values of polymerization shrinkage of composite resin with standard deviations(with bonding).

Types of composite resin	Values of polymerization shrinkage	standard deviations
Ecusphere	**1.4%**	**$2.6*10^{-4}$**
Densply	**1.9%**	**$5.3*10^{-4}$**
CHARISMA	**9%**	**$3.6*10^{-4}$**

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