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Mechanical behavior of dental composite filling materials using digital holography

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ABSTRACT

Photo-activated composites started to be used from the 60´s, and are nowadays widely applied for dental restorative procedures. In that respect they have almost replaced amalgam fillings. Composites are directly bonded into teeth hard tissues restoring most of the original strength structure.
This study concerns to experimental hybrid composites development for the direct dental restoration. These materials substitute the traditional dental amalgams and have its aesthetic and effectiveness. Studies showed that recurrent marginal decay is the main reason for failure in both amalgam and composite restorations. Polymerization shrinkage that occurs during the composite curing process has been implicated as the primary reason for postoperative marginal leakage. Polymerization of composite filling is considered to be an important factor in achieving longevity of the restorative treatment. Contraction induces certain amount of stress, which is transferred to surrounding dental structures (dentine and enamel).
The objective of this work is the study of the dimensional changes in resin, produced by light-induced polymerization of dental nanocomposite filling using Digital Holography (DH) and ESPI. Both techniques present some characteristics that make them well adapted to this study; a reasonable resolution can be achieved in non contact displacement field measurements with small objects.

1. INTRODUCTION

Dental material for tooth repair in nowadays are essentially prepared with dental amalgam and composite material based on organic resins photopolymerizable [1,2]. In this study, resin artificial teeth (molar) are used with an specific clinical protocol. A class I cavity in the occlusion side was previously drilled and restored with composite material, according to the

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time-Honored principles of G.V. Black. The cavities were drilled with a f 2,5 mm depth using a calibrated drill with a stop.
All the preparations (artificial tooth recovered with nanocomposite material) were placed in a digital holography or ESPI set up to obtain the holographic recordings. A blue led lamp (420nm - 480nm) is used to induce composite polymerization, and the real time deformation during resin cure was recorded. Experimental data was post processed for the deformation assessment. Indirect measurements of the resin behavior were obtained from the teeth deformation. Direct measurements on the resin surface are very difficult due to the speckle correlation which occurs because the texture surface changes during polymerization.

2. MATERIALS AND METHODS

2.1. Material

The formulation of experimental Nano composite was prepared with 35% of organic mass (matrix, initiator, co-initiator, monomer acrylic) and 65% of filler (nano layered silicates).

2.2 Apparatus

The ESPI (*Electronic Speckle Pattern Interferometry*) is one interferometry technique that uses coherent light illumination to obtain with no direct contact the displacement distribution associated to the superficial deformation of an object. Digital holography is an interferometry technique, similar to the ESPI, however it uses the classical off axis set up with no optical system for image formation. One hologram is recorded and later reconstituted numerically. Both techniques can be used with image processing methods to extract the displacements of each point in the area of measurement.
All the preparations were placed in a digital holography or ESPI set up to obtain the holographic recordings. A blue led lamp (420nm - 480nm) is used to induce composite polymerization, and the real time deformation during resin cure was recorded. The experimental system of Digital holography is represented in fig.1 and the experimental system of ESPI (*Electronic Speckle Pattern Interferometry*) is in fig. 2. Experimental data was post processed for the deformation assessment. Indirect measurements of the resin behavior were obtained from the artificial teeth deformation.

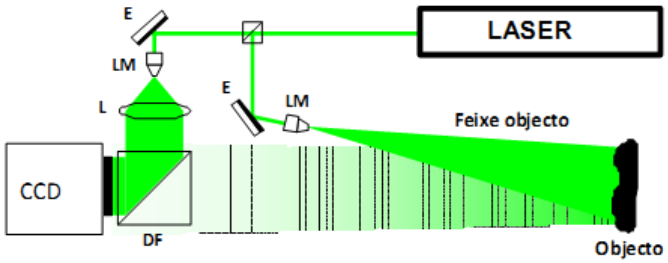

Figure 1. Experimental system of Digital holography

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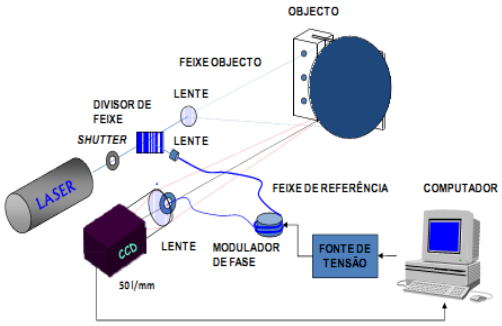


Figure 2. Experimental system of ESPI (*Electronic Speckle Pattern Interferometry*)

For each measurement the blue lamp (420nm – 480nm) was used to polymerize the nanocomposite previously applied on cavities prepared in the artificial teeth [3]. Several measurements were performed with different polymerization times and different thickness of resin layers.

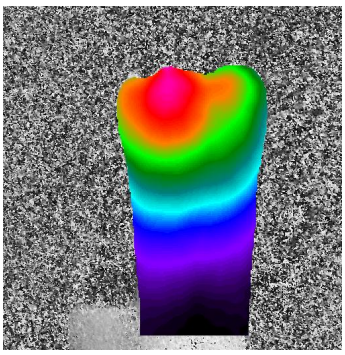
2.2 Measurements

The deformation induced by the polymerization was reported in real time during the cure reaction of the experimental nanocomposite formulation. The measurement was done indirectly on the tooth and not on the resin under shrinkage. The laser insertion was done on the artificial tooth wall owing to the effect of surface roughness of the resin if directly irradiated.

3. RESULTS AND DISCUSSION

3.1 Holography results

The nanocomposite applied on artificial tooth when exposed to blue light suffers shrinkage due to cure reactions. The entire tooth wall moves in form of frames as shown in fig.3. zones of high intensity of shrinkage are represented by red color while zones of lower intensity are blue. The total displacement of nanocomposite in relation of wall of artificial tooth was 4.3µm.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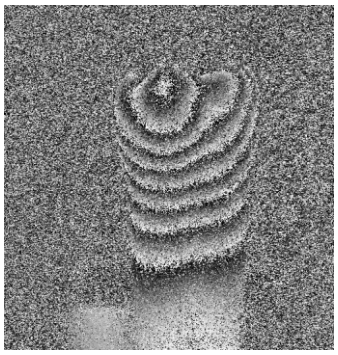
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Figure 3. A) Colored frames indicates regions of surface displacement with more intensity in the red.

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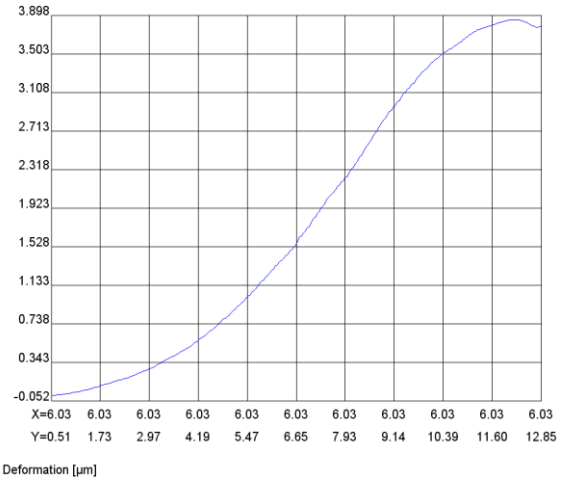

Figure 4. Plot of the deformation indirectly obtained.

This methodology developed with the Universidad of Porto is complementary to previous study that evaluated shrinkage effect on restorative resins through thermo mechanical test [3]

4. CONCLUSIONS

The results obtained proved the suitability of both techniques to resin shrinkage assessment through an indirect measurement. The technique showed that the entire tooth surface (wall) deforms in the shrinkage during the polymerization.

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