LABORATORY MEASUREMENTS OF HYGROSCOPIC EXPANSION FOR DENTISTRY RESINS

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Abstract*. In this study, the hygroscopic expansion of three composite resin types was evaluated, with the objective to determine if it would be sufficient to induce the relaxation of the stresses originated in the polymerization shrinkage. Twenty specimens were produced for three types of resin, using a steel matrix of 2 mm thickness and 10 mm diameter. Two different types of curing lights were used, a halogen and a LED. The resins tested were Spectrum TPH (Dentsply), Filtec Z250 (3M) and Fill Magic Flow (Vigodent). The specimes were prepared following the norms of the manufacturers. After curing, each specimen was left into a dark box. The linear expansion of resins was evaluated using an optic microscope connected to two digital micrometers (accuracy of 0.001 mm). Data was collected at day 0, day 1, day 3, day 7, day 14 and day 30. After the first day of measurement, the specimens were put inside containers with distilled water and maintained at 37ºC, during the remainder of the experiment. All the resins suffered an expansion after contact with water. No difference was observed in the hygroscopic expansion when varying the type of curing light. Resin Fill Magic Flow presented the smaller value of expansion, however, no significant difference was observed between the three tested resins. Resin Z250 presented a larger expansion than the polymerization contraction found in the literature. It can be concluded that the expansion can compensate at least in part the contraction of polymerization.*

Keywords *dentistry resins, hygroscopic expansion, residual stresses, dental restorations.*

1 INTRODUCTION

After the decade of 50, the composite resins became a material adequate for the restoration of anterior teeth. Besides reestablishing the function of the dental element, it presented adequate mechanical properties, good marginal adaptation and reproduces the natural color of the teeth (BARATIERI et al., 1995). Subsequent alterations in the chemical structure and in the components of the composite resins provided better mechanical properties. The resins then passed from a restricted indication to the anterior teeth to be utilized also in the restoration of the posterior teeth.

Among the physical properties of the composite resin, the shrinkage of the organic matrix during the polymerization is an undesirable property (VERLUIS & TANTBIROJN, 1999). The volumetric shrinkage during polymerization causes residual stresses in the interface tooth-restoration (HANSEN, 1982a; RIGSBY et al., 1990; DONLY, 1990). The stress can exceed the resistance of union in the walls, resulting in open margins that lead to marginal discoloration, germ penetration, sensibility and, later, caries lesions (LUTZ et al., 1986; COX, 1987).

HOFMANN et al. (2002), UHL et al. (2005) and JANDT et al. (2000) evaluated the effects of curing a composite with a conventional light (halogen) or curing the same composite utilizing a Light Emitted by Diode (LED) and did not find any difference in the shrinkage due to polymerization. Despite of all of the efforts to minimize the effects of the shrinkage, up to now it is not possible to eliminate entirely such factor. We have them a material with some excellent properties but with a serious limit of its durability.

Resin is formed for two distinct materials: an organic part and an inorganic part composite of inert material. As it presents an organic part, it is subjected to sorption of water when in contact with the saliva. That causes expansion of the material, eventually leading to the relaxation of the stresses arising from the polymerization shrinkage. For that reduction to occur or for reaching the closure of the marginal cracks, the borders should not be polished immediately after filling of the restoration (HANSEN, 1982a; HANSEN and ASMUSSEN, 1988; HANSEN and ASMUSSEN, 1989; BARREIROS et al. 1994; BARREIROS, 1998).

The required time for the compensation of the polymerization shrinkage by the hygroscopic expansion is still not well established in the literature. ASMUSSEM and JORGENSEN (1972) observed that the time for closing the cracks cause by contraction varied from 8 to 32 days for different resins. BOWEN et al. (1982) observed that only after a year, the expansion due to the sorption of water was sufficient for compensate entirely the shrinkage in the evaluated composite resins. HANSEN (1982a) observed a reduction of the marginal cracks after 7 to 28 days of immersion in water. For JEDYNAKIEWICZ & MARTIN (1998) & MARTIN et al. (2003), hygroscopic expansion did not compensate entirely the volumetric shrinkage occurred during the polymerization in their experiments.

The aim of this work is to reach a better understanding of the behavior of hygroscopic composite resin expansion and the possible relaxation of the stress originating from the volumetric shrinkage that occurs in the resin during its polymerization.

2 MATERIAL AND METHODS

Laboratory tests were carried out for obtaining the hygroscopic expansion values for three composite resins: TPH Spectrum® (Dentsply), Filtek Z250® (3M) and Fill Magic Flow® (Vigodent). Those composite resins present different clinical characteristics and are of wide use in the market.

For the cure of the resins, two devices were used with different curing light technology. The first was a curing light device based on conventional halogen light (L3000®, 3M) and the other using a LED, light emitted by diode (Bright Lec® MMoptics).

2.1. – Producing the Samples

For producing the composite resin samples, a cylindrical steel matrix was used, with 10 mm diameter and 2 mm thickness. (The geometries of the samples are in accordance with the established in the norm ISO 4049, which regulates the parameters for tests on sorption and solubility of composite resins).

The cylindrical steel matrix was completely filled with resin, and then polymerized using two curing light devices with different technologies.

For an appropriate polymerization of specimens to occur, the cylindrical steel matrix was set on a glass plate and filled with resin up to the top, receiving a soft pressure through a 0,1 mm thickness polyester strip. The tip of the curing light device was positioned on the matrix and kept in the central region for twenty seconds, followed by four more polymerization twenty second periods in each end of the test sample. No stratagem was carried out to lubricate the matrix and facilitate the removal of the samples.

Ten samples for each group of curing light device for each resin were produced. So there were three groups of resins TPH Spectrum® (Dentsply), Filtek Z250® (3M) and Fill Magic Flow® (Vigodent), and each group was divided into two subgroups according to the applied curing technology: conventional halogen light (L3000®, 3M) or light emitted by diode (Bright Lec® MMoptics). A total of 6 groups of specimens was produced.

2.2. – Measuring the hygroscopic expansion with a Microscopic optical

To evaluate the expansion that occurs in the resins in contact with water, the linear expansion was measured using two digital micrometers coupled in an optical microscope. To improve the visualization of the edges of specimens, marks in format of X were made in the surface to be measured, and the point of intersection of the X was our point for measurement.

A simple approach was used to analyze the variation of distance of the extremities of two straight lines in each test sample. Three measurements were carried out for each one of the straight lines and the average was calculated.

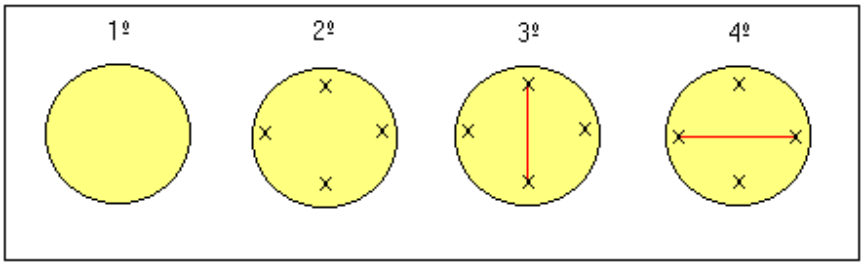

Figure 1 – First – producing the samples; Second – marks the samples; Third and Forty – measurements.

In order to verify the hygroscopic expansion of specimens and the percentage of volume increase, the measures were performed made in 5 different moments: before immersion in water, day zero; after one day in water; after three days; after seven days; after fourteen days; and with thirty days in water.

In the intervals between the measurements the specimens was kept in containers impermeable to the light into distilled water at 37± 1 ºC. For each new measurement, the specimens were removed from water, and dried with a paper towel. A new measurement was then performed and once again the samples were inserted into the container with water. A FANEM (FANEM LTD, SP) heater was used to maintain the temperature constant.

3 RESULT

The tables present the obtained results of the linear expansion of the resins. The results are expressed in percentage.

Table 1 – Resin Tph

	Day 1	Day 3	Day 7	Day 14	Day 30
Halogen	0,52 ± 0,22	0,7 ± 0,31	0,72 ± 0,3	0,7 ± 0,33	0,73 ± 0,24
LED	0,49 ± 0,22	0,59 ± 0,15	0,63 ± 0,11	0,65 ± 0,17	0,6 ± 0,14

Table 2 – Resin Fill Magic Flow

	Day 1	Day 3	Day 7	Day 14	Day 30
Halogen	0,1 ± 0,14	0,46 ± 0,2	0,46 ± 0,23	0,48 ± 0,21	0,5 ± 0,17
LED	0,05 ± 0,1	0,37 ± 0,21	0,35 ± 0,16	0,33 ± 0,16	0,41 ± 0,14

Table 3 – Resin Z250

	Day 1	Day 3	Day 7	Day 14	Day 30
Halogen	0,56 ± 0,2	0,66 ± 0,26	0,77 ± 0,23	0,77 ± 0,26	0,82 ± 0,17
LED	0,48 ± 0,17	0,57 ± 0,25	0,52 ± 0,2	0,58 ± 0,24	0,61 ± 0,18

Observing the values for each resin, we can verify that there is no difference between the kind of curing light used in the polymerization of the resins. So we can consider an average value obtained for each resin and elaborate the graphic of hygroscopic expansion given in Fig.2.

Table 4 – Medium of the values of the higroscopic expansion lineal

	Day 0	Day 1	Day 3	Day 7	Day 14	Day 30
TPH	0	0,5	0,64	0,68	0,67	0,66
Flow	0	0,07	0,42	0,41	0,41	0,45
Z250	0	0,52	0,62	0,65	0,67	0,71

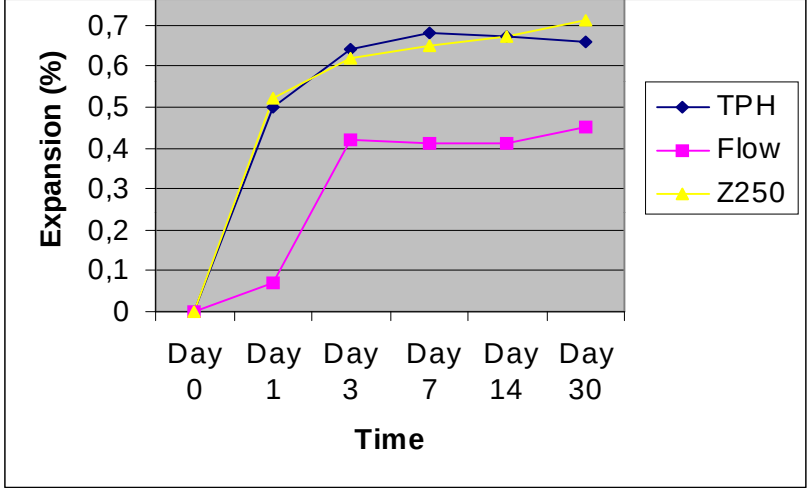

Figure 2 – Graphic of the linear expansion in function of time in water.

The volumetric expansion corresponds to 3 times the linear expansion. So we have the following values of expansion:

Table 5 – Volumetric Expansion

Tph	1,98 %
Fill Magic Flow	1,35 %
Z250	2,13 %

4 DISCUSSION

The dentistry resins present a well established behavior during polymerization shrinkage (LABELLA et al. (1999), ASMUSSEN & JORGENSEN (1972), WEINMANN et al. (2005) and LEE et al (2005)). As the resin presents micro-retention to the tooth, its shrinkage, during polymerization, causes stress in the tooth. That stress can provoke the fracture of the tooth, fracture of the resin or of the adhesive.

The generation of residual stresses in restored teeth can cause to the enamel three different effects: crack propagation, micro-infiltration and post-operative sensibility, among other consequences (VERSLUIS & TANTBIROJN, 1999).

However, the resin, including an organic matrix that suffers sorption of water, expands when entering in contact with the saliva. For FEILZER et al. (1990), exposing the restoration of composite resin subsequently to his polymerization to the presence of water can cause a relief in the developed residual stress, since the water diffuses for inside the material, causing a gradual expansion, eventually reaching a value of equilibrium.

In the analysis of the experiment, it can be noted that expansion occurred in the three resins tested. That expansion was more intense in the beginning and gradually reduced to a tendency of stabilization. BRADEN et al. (1976) concluded that the trial of sorption of water by the composites is based in diffusion, and the coefficient of diffusion diminished with the increase of the concentration of water in the resin.

The required time for the compensation of the polymerization shrinkage by hygroscopic expansion is still not well established in the literature. ASMUSSEM and JORGENSEN (1972) observed that the time for total closing of the cracks varied from 8 to 32 days for different evaluated resins. BOWEN et al. (1982) observed that only after a year, the expansion due to the sorption of water was sufficient to compensate entirely the shrinkage of the composite resins evaluated. HANSEN (1982a) observed a reduction of the marginal cracks after 7 to 28 days of immersion in water.

The stabilization of the sorption period in this experiment was initiated about the seventh day after the immersion of the test sample into water. That difference regarding the literature can be easily explained by the fact that, in our experiment the test sample (the resin) was entirely free of water, causing a fast initial diffusion. In the experiments of the literature, normally the resin are put inside a tooth, in this way there is a bigger smaller diffusion since there is practically only one surface in contact with the water

No esthetic resin showed, however, an expansion capable to compensate its polymerization contraction MARTIN et al. (2003), JEDYNAKIEWICZ & MARTIN (1998) and FERREIRA (2001). At present we have a material with high quality esthetics and with adequate mechanical properties, however of limited use. The polymerization contraction is a fast event, in forty seconds practically all the contraction already occurred, thus provoking the opening of fissures in all the tooth-resin interface, causing post-operative pain, marginal infiltration, sensibility and the discoloration of the resin in the interface with the tooth. Subsequent hygroscopic expansion is a slow phenomenon, taking days so that a total locking occur at the margins of the restoration, and, often times, not reaching the point of crack closing.

This experiment presents values for the hygroscopic expansion compared to values found in the literature; the agreement with the reported values is poor, with the exception of resin FLOW, that presented an experimental value quite close to the one found in the literature

TABLE 6 - Results of the literature and Experimental. MARTIN et al. (2003) and PALIN et al. (2005).

Resin	LITERATURE (%)	EXPERIMENTAL(%)
TPH	0,6	1,99
Z250	1,0	2,14
FLOW	1,5	1,36

A possible factor responsible for that difference is the absence of control of the room temperature during the analysis in the microscope. Another factor can be associated with the specificity of the test; we used an optical microscope with increase factor of 30, while the marks were not made so as to allow such precision in measurements.

The resins tested did not present significant difference among the values found for the linear expansion. The resin Z250 presented a value of expansion higher than for contraction; the volumetric shrinkage found in the literature is of 2,0%, while the value found for the volumetric expansion in this experiment was 2,14%. This could be an interesting fact, as it would permit a significant release of stresses in the tooth-resin interface. However, when compared with the literature, the value of volumetric expansion is of barely 1,0%. The resins TPH and FLOW presented in the test lower expansion values than the measurements described in the literature for contraction. Resin TPH I contracted 3,0%, and expanded 1,99% and the resin FLOW I 4%, and expanded 1,36%. Even though, the values of expansion differ from the ones found in previous works, the trends were the same, with the expansion presenting a lower value than contraction, resulting that, even after expansion, the tooth-resin interface still does not recover its initial free-stress state.

In an attempt of minimize the effects of the shrinkage of polymerization, various authors described stratagems as alteration of the preparation, form of polymerization and different technique of cavity filling. However they did not obtain a solution to the contraction nor to the harmful effects that it provokes.

Today two kinds of curing light devices exist, one based in light halogen and another based in LED. In this study it was evaluated the expansion of the resins when submitted to these two different technologies, and we did not find any significant difference between the way of polymerization of the resins.

Authors (HOFMANN et al. (2002), UHL et al. (2005), JANDT et al. (2000)) are unanimous in stating that there is not a significant difference between the curing light devices based on light halogen and in LED. However, there is a tendency to consider that curing resin with the light halogen will provoke a slightly higher contraction. This would be related to a bigger conversion of monomer in polymer. In this experiment was found a slightly lower tendency to expansion in based LED devices, in agreement with this theory. That can be explained by the fact that the expansion occurs in the polymer and not in the monomer, that is, the higher the conversion, the higher will be the expansion. A factor associated to this difference is that curing LED light does not heat the resin, as it is based in cold light, whereas in the device of light halogen there is an increase in temperature, and as we know, the temperature is a catalyst of chemical reaction and can further expand the material.

5 CONCLUSION

Different composite resins were subjected to test of water sorption of and expanded, with high gradient of diffusion of water to the interior of the resin in the beginning of the test period, reducing fast after the first period.

The hygroscopic expansion provokes release of residual stresses in the resin and in the dentine.

There is not significant difference between the light curing devices based in conventional technology (Halogen) or in LED technology (Light Emitted by Diode) in terms of hygroscopic expansion.

The observed expansion is insufficient to counteract the damage induce by contraction. Resins with smaller contraction would contribute to the longevity of resin based restoration.

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