METHODS FOR DETERMINING THE POLYMERIZATION EFFICIENCY OF LIGHT-CURED RESIN COMPOSITES

[1]GABRIELA BOTA, [2]LAURA STEF, [3]ANDREEA ŞTEŢIU

[1,2,3]"Victor Papilian" Faculty of Medicine, Sibiu

Abstract: *Nowadays, more than ever before, the dentist has at his/ her disposal a wide choice of materials for restoration. In most of the cases, the success of a dental treatment depends on the selection of the most appropriate materials for the case given, as well as on its correct use. The restoration replacement represents the main working task, especially for adult patients. The conclusion of this study is that restoration failure is an important problem in dentistry practice, mainly when it comes to the treatment of grown-ups.*

Keywords: *materials, DCR, amalgam, properties*

Rezumat: *Inţierea polimerizării prin radiaţii luminoase s-a făcut mai întâi cu radiaţii UV, iar ulterior cu radiaţii din spectrul vizibil, radiaţii luminoase incoerente (surse de halogen) sau radiaţii luminoase coerente (furnizate de laser). Profunzimea polimerizării poate fi corelată cu un index de eficienţă al fotopolimerizării specific fiecărui tip de compozit fotopolimerizabil. Profunzimea polimerizării depinde de tipul compozitelor şi de caracteristicile lămpii: intensitatea fluxului emis prin fibra optică şi timpul de iluminare.*

Cuvinte cheie: *radiatii luminoase, materiale fotopolimerizabile, proprietăţi*

INTRODUCTION

The organic phase of light-cured resin composites generally contains as an initial system in a polymerization reaction an alpha-diketona (camforquinona) and a reducing agent.

The opening system, specific to photopolymerization, camforquinona, is activated by light radiation in the spectral range between 400-500 nm (visible area).(1) Therefore, the lamps used in polymerization must release radiations within the spectral field, the depth of the polymerization depending also on the intensity of radiation emitted.(2,3)

The fine quality control of polymerization is practically impossible to be achieved in actual clinical cases. One of the subpolymerization effects is the appearance of a hard surface layer, under which we can find incomplete polymerized resin.(4)

For several years scientists were concerned in achieving a ISO Standard light-cured resin unit. There are many difficulties in preparing an acceptable standard because it is difficult to separate the lamp performance from the performance of the material. Therefore, producers were limited to the development of devices to monitor the quality of light-cured resin units. These devices consist of photosensitive diodes used as devices for measuring light intensity. When the reading drops below a critical value, it is recommended to check the device – it may require a bulb replacement.

Another way to check the quality of photopolymerization lamps is making a test which analyses the polymerization depth using the chosen combination: photopolymerization unit – composite material.

The use of such tests is usually considered to be the best way of monitoring material and polymerization unit performance. Most manufacturers provide the elements necessary to perform these tests in any dental office.(5,6)

MATERIAL AND METHOD

The aim of this study is to develop a methodology for experimental verification of the effectiveness of light-cured resin composite polymerization, in correlation with illumination time and material thickness.(7)

In this study we have evaluated the polymerization efficiency for 4 types of light-cured resin composites in the visible field. These composite materials have the following properties:

- Point 4 (KERR) – universal use, hybrid, linear constriction of average polymerization;
- ALERT (Jeneric / Pentron) - use in the lateral area, cvasifilling, linear constriction of reduced polymerization;
- SILUX PLUS (3M) - use in the frontal area, microfilling, linear constriction of medium polymerization;
- CHARISMA (Heraeus / Kultzer) – universal use, microfilling, linear constriction of reduced polymerization.

The lamp used for sample photopolymerization has the following technical characteristics:

- Electric power - 60 W;
- Power of halogen bulb - 30W;
- Radiation (total flux emitted per area unit of the optic fiber) in the spectral field between 400 - 500 nm is smaller than 540 mW / cm

- Diameter of the optic fiber - 9 mm.

The maximum emission found during the analysis of spectral distribution of a lamp used in this study is located at 500 nm. The analysis was performed using a spectrophotometer with diodes area.

The photopolymerization of composite materials was made in a test matrix designed by Vivadent especially for using it in this purpose. The matrix, made of ceramic material, is a 3 or 10 mm thick cylinder which has three holes as shown in picture no. 1.

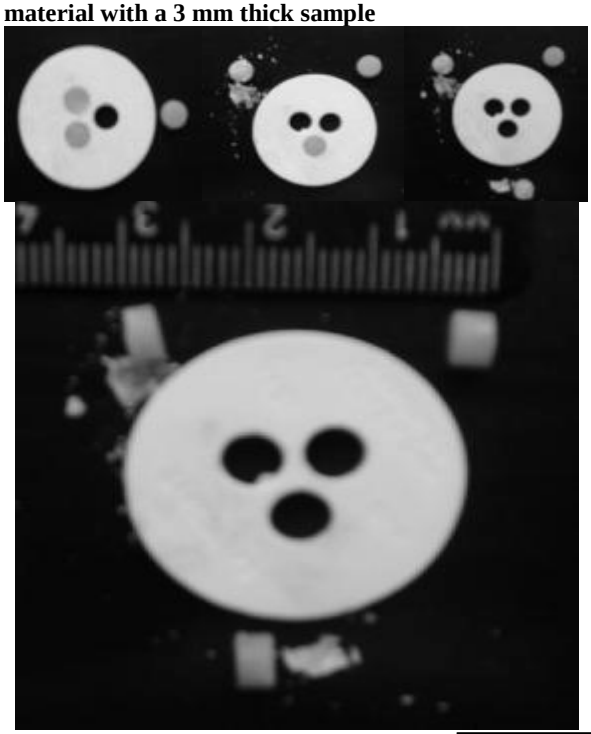
All three cavities of the matrix were filled (by pressing with a plastic plugger) with light-cured resin composite, medium colored, from each material taken into consideration in the study.

Picture no. 1.Test matrix

We have photopolymerized each sample at a time. After each photopolymerization one new hole was filled so that the last hole was polymerized for 20s, the second hole for 40 s and the first hole for 60s. The experience was repeated for each material and in this manner we have obtained 6 samples for each light-cured resin composite.

After photopolymerization, the 3 mm and 10 mm thick samples were removed from the matrix (Picture no. 2.).

Picture no. 2. Light-cured resin composite filling material with a 3 mm thick sample



After this phase each sample was weighed on an analytical balance. The mass values obtained in these initial measurements were marked with mь symbol.

Subsequently, each sample was submerged in 5 ml of methanol for 24 hours in order to dissolve the unpolimerized organic components.(8)

The samples were then dried for two days in the desiccator and weighed again on an analytical balance. The mass values obtained in this measurement were marked with md symbol.

The following hypothesis was taken into account in the calculation of photopolymerization efficiency. We considered that, for maximum efficiency (100%) of the polymerization, the mass of the sample after immersion in methanol and drying (md) should be equal to the mass of the sample before immersion in methanol (mь).

Therefore we calculated the efficiency of polymerization (Ep) as: **Ep = (md / mь) x 100**

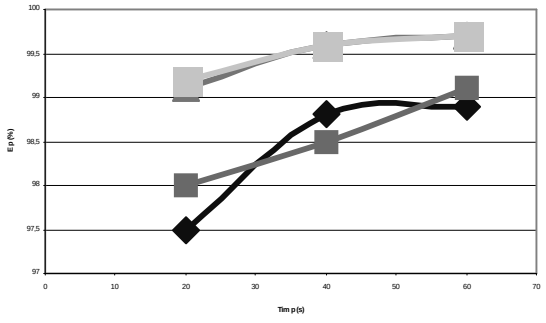
RESULTS AND DISCUSSION

The results obtained by weighing the 24 samples on an analytical balance were used to calculate the polymerization efficiency using the formula written above. In the data analysis we used two variables: illumination time and polymerization depth for a certain type of lamp in the visible spectrum.

The polymerization efficiency was determined at different illuminating times for each of the four light-cured resin composite materials. Figure 3 shows the influence of illuminating time on the efficiency of polymerization for 3 mm thick samples, and figure 4 for samples of 10 mm.

The calculation of polymerization efficiency provided us with the following polymerization efficiency values for the various types of samples analyzed.

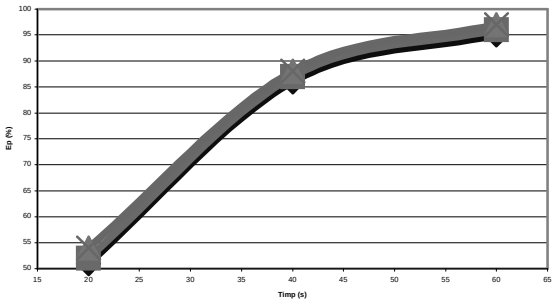
Picture no. 3. Influence of illumination time on polymerization efficiency in 3 mm thick samples



The following results were obtained from analyzing 3 mm thick samples of composites with microfilling (Charisma, Silux Plus):

- Polymerization efficiency at 20s of 99% illumination,
- Polymerization efficiency at 40s of 99.4% illumination ,
- Maximum polymerization efficiency at 60s of 99.7% illumination.

Picture no. 4. The influence of illuminating time on the polymerization efficiency in 10 mm thick samples.



For 3 mm samples of hybrid composites (Point 4) and with cvasifilling (Alert) the following data ware obtained:

- polymerization efficiency at 20s of 97.5% and 98% illumination,
- polymerization efficiency at 40s of 98.4% and 98.2% illumination,
- maximum polymerization efficiency at 60s of 98.8% and 99% illumination.

For 10 mm thick samples of microfilling composites the following results were obtained:

- polymerization efficiency at 20s of 54.5% illumination,
- polymerization efficiency at 40s of 87% illumination,
- maximum polymerization efficiency at 60s of 96% illumination.

For 10 mm thick samples of hybrid composites with cvasifilling:

- polymerization efficiency at 20s of 51.2% and 52.3% illumination,
- polymerization efficiency at 40s of 85.1% and 85.7% illumination,
- maximum polymerization efficiency at 60s of 94.2% and 95.1% illumination.

The data obtained in this study allow us to conclude that polymerization efficiency depends, first of all, on the thickness of composite material layer, and this statement is also supported by literature. Therefore, most companies producing light-cured resin composite materials confirmed a satisfactory polymerization for a material layer up to 2 mm thick.

In addition, we have observed that the photopolymerization is more efficient in the case of hybrid composites with microfilling and in fine hybrids, if the irradiation time is higher than 40s. This happens because the filling particles of these composite are more translucent than those of composites with conventional fillers [9].

Materials with darker color or those which are more opaque can't be polymerized at the same depth as those which have a lighter color or are more translucent. For example, the translucent paste (for enamel) of a material can be polymerized to a 2.5 mm depth in 30 seconds of light exposure. Dark colored, opaque pasta of the same material can be polymerized only to a depth of 1mm in the same exposure time.

The increase of exposure time has very insignificant effects on the depth of polymerization. If a material is polymerized to a 2.5 mm depth after a 30 seconds exposure, if we increasing the exposure time to 1 or 2 minutes, the polymerization will not occur at a significantly greater depth. But reducing the exposure time below the one indicated by the manufacturer may cause significant decrease in the depth of polymerization.

Compatibility between the light source and composite materials has been the subject of much study and debate. Most light-cured resin composites use the same kind of catalyst system, and most of the light activation units are designed to provide high-intensity radiation, with appropriate wavelength.

But, there are many significant differences between the performances of light-cured resin composite units, with an up to 10 times variation of light intensity on the same wavelength (470nm). Since the depth of polymerization indicated by the manufacturer is measured using a specific light source, it may not be possible to reach the same depth with another light source.(10,11)

The operator can also control other photopolymerization parameters. Therefore, the distance between the light source and the material is considered to be very important. The depth of polymerization significantly decreases when the distance is increased.
The operator should not attempt to perform a polymerization at a higher depth than the one recommended by the manufacturer, or to use a shorter exposure time. In the filling of large cavities, the composite material must be polymerized layer by layer to ensure adequate polymerization.

When working with a common material chemically activated, the temperature increase for a medium filling is between 1-5 ˚ C. For light-cured resin materials, the temperature increase is generally between 5-15 ˚C, depending on the used monomer system and on the filling contained.

Temperature increase during the photopolymerization process is higher than in other composites because the polymerization heat is released in a much shorter time. In addition, the heating effect of a photopolymerization unit determines an additional increase in temperature when the composite material is illuminated.

In order to minimize the last mentioned effect, manufacturers incorporate filters in the photo-activating units. These filters are designed to remove "the hot parts" of white light, which are located in the red end of visible spectrum. Therefore the radiations used in most photopolymerization units appear in blue color.

CONCLUSIONS

- Photopolymerization efficiency in composites materials is directly proportional to the increase of illumination time. This is not visible in samples with less than 2mm thickness, but in samples with greater

thicknesses, this becomes much more visible.

- The efficiency of lamp polymerization with incoherent light in the visible spectrum is higher in microfilling composite systems than in the hybrid or with cvasifilling composites.
- Incoherent visible light penetration is good in depths of up to 3 mm, the composite showing some convection in front of an intense light flux.
- Light-cured resin composite manufacturers can control the polymerization depth by designing products which allow easier light penetration.
- In addition, they can provide / recommend a suitable light source and they can suggest the exposure time required for a certain depth of polymerization.(12)
- The methodology presented gives every dentist the possibility to precisely determine, for each type of light-cured resin composite, the illumination time required for obtaining the most effective polymerization of different thicknesses composite layers.

For a correct and effective implementation of this system in any dental office we consider it is very useful to make an appropriate calibration of photopolymerization efficiency for each type of composite material used as follows:

- The use of a particular composite must be preceded by polymerization efficiency determination in 2 mm thick layers at 20 s, 40 s or 60 s illumination.
- The change of a photopolymerization lamp requires completing again the initial tests, taking into consideration that each photopolymerization lamp has its own characteristics as far as the intensity of light flux and the power of the light source are concerned.
- The use of the system which determines the photopolymerization effectiveness requires minimum additional equipment in any dental office: test matrix, methanol solution and analytical balance.
- The system can be simplified by determining the photopolymerization efficiency of one composite material sample in the test matrix using a scratch test applied on the deepest area of the light-cured resin composite sample.

REFERENCES

1. Cook W. Spectral distribution of dental photopolymerization sources. J Dent Res 2002;61:146.
2. Wats C, Amer O, Combe E. Characteristcs of visible light – cured composite system. Brit Dent J, 2004;156:209-215.
3. Watts C, Cash A. Analysis of optical transmission by 400-500nm visible light into aesthetic dental biomaterials. Journal of Dentistry, 2004;22:112-117.
4. Românu M, Bratu D, Lakatos S, Florinta Z. Polimerizarea în stomatologie. Ed. Brumar, 2000;137:159-174.
5. Baker J, Dermaut L, Bruynooghe W. The depth of polymerisation of visible light-cured composite resins. Quint Int, 1995;10:693-701.
6. Barghi N, Berry T, Hatton C. Evaluating intensity output of curing lights in private dental offices. J Am. Dent Assoc, 1994;125(7):992-996.
7. Nicola C, Văleanu S, Borzea D. Determinarea eficienţei de polimerizare la compozitele fotopolimerizabile. Medicina Stomatologică, 1998;2(1):17-19.
8. Hirose T, Wasaka K, Yamaki M. Visible – light curing units – effect on the depth of cure in a dental composite resin. J Master Sci, 1990;25:1209-1213.
9. Pollack B, Lewis A. Visible-light curing generators: An update. Gen Dent, 2004;32(3):193-197.
10. Feilzer A, Dooren L, Davidson C. Influence of light intensity on polymerisation shrinkage and integrity of restoration-cavity interface. Eur J Oral Sci, 1995;103:322-326.
11. Fowler C, Swartz M, Moore B. Efficacy testing in UV-curing. Elsevier Applied Dental Science, New York, 2003;49.
12. Feilzer A, Davidson C. Setting stresses in composites for two different curing modes. Dent Mater, 2003;19:2-5.