Original paper

Contributions on the Study of the Compressive Strength of the Light-Cured Composite Resins

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ABSTRACT The mechanical properties of the light-cured composite resins are related to the material composition, but also vary according to the light-source characteristics used for polymerization. In this study we followed the compressive strength variation for a light-cured composite resin according to the time of exposure to the curing light. With that end in view,18 test pieces were made from a light-cured hybrid composite material (Filtek Z250). The test pieces where then submitted to a compressive force by a mechanical properties universal testing machine. Our results didn't show an increase of the compressive strength according to the light-curing time increasing, than only in the light-curing time limit indicated by the manufacturer. A longer light-curing time may induce a shrinkage polymerization growth with the formation of internal tensions inside the material. The composite materials light-curing in short layers as long as there is indicated by the manufacturer seems to be a safer method to make the best from a resin qualities, then an exaggerated increase of the light-curing time. The light-curing is indicated to be done in the direction of the compressive forces. To confirm this supposition other mechanical tests are also necessary.

KEY WORDS *Composite resins, compressive strength, light-curing time*

Introduction

The light-cured composite resins represents an important category of restorative materials used in modern dentistry. These resins may be used to restorate the teeth shapes and the functions from the anterior area, but also from the posterior area.

The mechanical properties of these materials are a crucial factor for their clinical performance. These properties are tightly related to the material composition (organic matrix, inorganic filler) and may vary according to the light-source characteristics used for polymerization.

The composite materials monomers have the capacity to form by addition polymerization a cross-linked structure, under the influence of a curing-light of appropriate wavelength and intensity. The addition of the inorganic fillers is done in order to significantly increase the mechanical properties of the material.

By the particles size of the inorganic fill, the composite resins can be classified like this:

- with large particles :
  - Traditionals
  - Moderns medium particles
  - fine particles
- with microfine particles
- hybrids. *(1)*

Today, the hybrid composites are the most frequently used. The percentage of inorganic filler and the particles sizes influence directly the mechanical properties. The mechanical properties are also depending on the efficiency of the coupling agents between the two phases.(2)

However, these factors which depend on the resin composition are determined by the manufacturer and can not be modified by the clinician. The light radiation is an instrument available for the clinician, instrument that can contribute to the determination of the final mechanical properties of the material.

Several studies have demonstrated that the conversion degree of double bonds is a co-determinant of the mechanical properties of the resulting polymer (3,4). The conversion degree depends on the curing-light characteristics which will be applied to the restorative material in order to activate the initiator and start the polymerization.

The curing-light characteristics depend on:

- The light-curing unit used: halogen (600 – 800 Mw/cm2), PAC (1000 Mw/cm2) , LED (350 Mw/cm2) (5)
- The method used: continuous light-curing method, exponential light-curing method,

stepped light-curing method, intermittent light-curing method (6)

– The light-curing time

The light pencil doesn't present the same intensity both in the centre and in the periphery; that' why it is important to scan the large surfaces of the obturations so that entire area will derive advantage from an adequate exposure

In this study we followed the compressive strength variation for a light-cured composite resin according to the time of exposure to the curing light.

Material and method

In order to carry out this study 18 specimens were made from a light-curing hybrid composite (Filtek Z250) with a percentage of 60% inorganic filler with diameters varying between 0,19 and 3,3 μm. The composite material was introduced in cylindrical type moulds with diameter of 5 mm and height of 10 mm. (fig. 1 and 2). The material introduced in this way was cured from 2 directions with a light-curing halogen unit XL 2500 from 3M ESPE , time of 10 seconds, 15 s, 20 s, 25s, 30s, 40s.(fig.3).

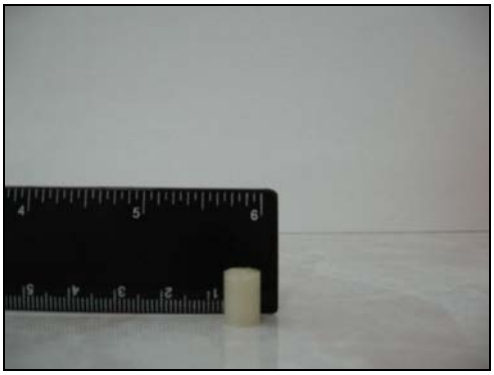

Fig.1 and 2 The specimens of light-curing composite material with 5 mm diameter and 10 mm height

Fig.3 The light-curing halogen unit XL 2500 from 3M ESPE

The obtained specimens were then maintained in distillate water at 25^0C, ph 6,5, time of 20 h.

The specimens were then subjected to a compressive force in an Universal Testing Machine for mechanical properties with a gamma from 0 to 1000kgF and a gradation of 2 kg. (fig.4).The necessary force to destroy the specimen was read on the quadrant of the machine and the compressive strength was calculated after the formula:

$$R.C. = F/\pi r^2 = \frac{X \odot 9,81}{19,63 \odot 10^{-6}} \cdot \frac{N}{m^2}$$

Fig.4 The Universal Testing Machine for mechanical properties with a gamma from 0 to 1000kgF and a gradation of 2 kg

The obtained results are presented in the next table.

Nr. crt.	Timp	Forţa medie (Kgf)	Presiunea medie (MPa)
1	10	320	160
2	15	400	200
3	20	440	220
4	25	420	210
5	30	380	190
6	40	360	180

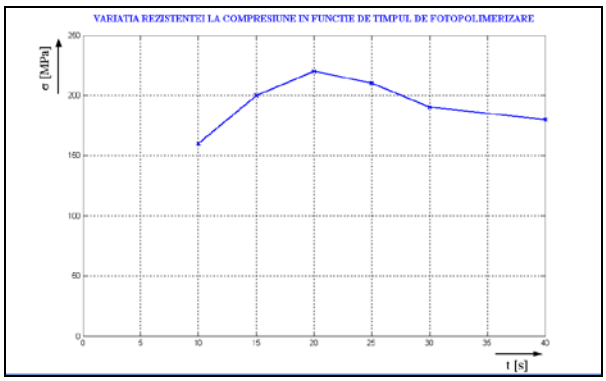

Fig.5 The graphical expression of the compression strength variation of the composite materials specimens according to the light-curing time

Discussions

The stress at compression is very important in the process of mastication because most of the developed forces are compressive.

The conversion degree of double bonds induce the mechanical properties of the resulting polymeric matrix. The degree of conversion depends on the energy density, which is direct function of the light-curing time.(7)

Our results didn't show a higher compressive strength related to the increase of the light-curing time, than in the limit of the light-curing time indicated by the manufacturer (20 seconds). Even more, by increasing the light-curing time over this limit we have even pointed out a slow diminution of the obtained values.

When a structure is subjected to compression, the failure of the body may occur as a result of a complex stress formation. *(8)* See fig.6.

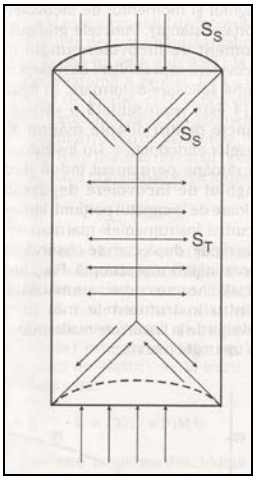

Fig.6 Drawing of complex stress pattern developed in cylinder subjected to compressive stress.. (after. Craig R.. and colab, 2001)

The most plausible explanation for the obtained results seems to come from the used method and more exactly, because the compressive force was applied to a perpendicular direction on the light-curing direction. While the light penetrates the material, it is dispersed and reflected, and its intensity is reduced. The polymerization degree at a certain depth from the material surface, after the light-initiation is influenced by several factors (9):

The photo-activator concentrations ;

The content of inorganic filler and the particles dimensions *(10)* ;

The resin shade; darker tones are reducing the light transmission.*(11)*

A too big amount of energy may induce too high engendering levels of free radicals. At high engendering levels of free radicals may appear the mutual annihilation or shorter lengths of the reaction-chains which lead to the forming of weaker networks with lower mechanical properties.

A prolonged light-curing time may induce an increasing of the polymerization shrinkage with the emergence of internal tensions inside the material.*(12)*

The compressive force seems to have actioned to an nonhomogeneous polymerised material, along the delimitation lines of zones with distinct structure, which had facilitated their deterioration.*(13)*

The exaggerated increase of the light-curing time may induce the accumulation of internal tensions and the accentuation of the material nonhomogenous appearance with changes of its mechanical properties.*(14)*

Conclusions

The light-curing of the composite materials in thin layers on the period indicated by the manufacturer seems to be a safer method to exploit at maximum the qualities of a resin, then the exaggerated increase of the light-curing time.

The light-curing is indicated to be done on the direction in which the compressive forces will action. In order to sustain this supposition other mechanical tests are also necessary.

The results of this study, from the point of view of the mechanical properties, do not allow the elaboration of conclusions with irrevocably character. Laboratory tests in conditions nearer by those from the oral cavity, but also microscopical tests in order to evaluate the polymeric network structure according to the light-curing time, tests that corroborated with other clinical tests, are necessary to give a more realistic picture about the behaviour of the composite resins according to the light-curing time.

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