THE INFLUENCE OF THE POLYMERIZATION TECHNIQUE ON PULP TISSUES

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Abstract: *The light curing materials used in dental medicine raise a series of new problems concerning the light curing technique, the equipment used and the adhesive systems applied. This paper aims at presenting the effects of the light curing technique on the pulp tissues.*
Keywords: *light curing material, polymerization techniques*
Rezumat: *Materialele fotoplimerizabile, ubiquitare în medicina dentară ridică o serie de probleme noi legate de tehnica de fotopolimerizare, de echipamentele folosite, de sistemele adezive implicate. Lucrarea îşi propune o trecere în revistă a implicaţiilor pe care le are tehnica de fotopolimerizare asupra ţesuturilor pulpare.*
Cuvinte cheie: *materiale fotopolimerizabile, tehnici de polimerizare*

The application of the polymerization materials undergoes the following steps:

- Preparation of the sub-layer;
- Application of the adhesive system;
- Polymerization;
- Application of the polymerization materials;
- Polymerization.

Within each step, aggressive factors for the dental pulp may occur.

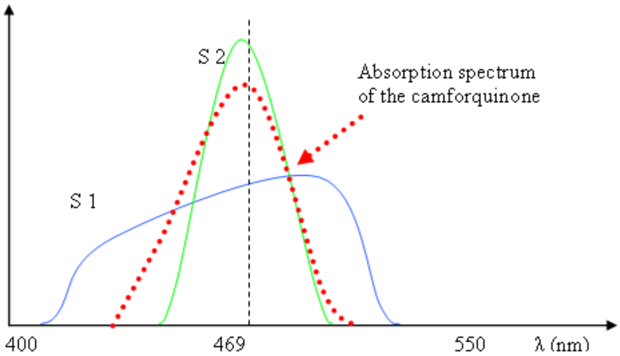
Polymerization represents the step which transforms the adhesive solutions from the ground state into the gel state by polymerizing the monomers. It raises a series of problems:

- Temperature variations of the tooth as a result of light exposure;
- Appearance of a large number of oxidative groups involved in the polymerization process;
- Final degree of conversion.

Taking into account the great variety of light sources for polymerization available on the market, the idea of establishing the value of the total energy issued by the source and necessary for polymerization occurred instead of a standard polymerisation time.

One must also consider the emission spectrum of the lamp because not all the radiant energy of the lamp can be used by the photoinitiator. The excess of energy is to be found at the level of the tooth under the form of heat.

Picture no. 1 The emission spectrums of 4 different polymerization lamps: S high power halogen light bulb, S 2 high power led.



The emission spectrum of the halogen lamp is large, while that of the led lamps is very narrow. (see picture no. 1)

Wiggins K.M. and his collaborators made a study on two halogen lamps and two LED lamps and concluded, that the minimum increase of temperature in the case of camphorquinone was obtained when using the LED lamp at a power of 400mW/cm2, in the conditions in which, comparable values of the material polymerization resulted. The emission spectrum of these lamps is integrated completely in the degree of absorption of camphorquinone, thus eliminating all losses. The time for exposure is higher than for the sources with higher power in order to observe the total energy regulation. The polymerization reaction is an exogen one, in which the released energy depends on the degree of conversion of the monomers. A faster polymerisation by means of a higher lamp power will condense the release of this energy into a shorter time, thus enhancing the final temperature at the material level.

The use of a LED lamp with a power of 1000mW/cm^2 reduces the curing time, because the total energy necessary for curing will be supplied more rapidly, however there is the risk of not totally corresponding to the absorption curve of camphorquinone and, as a result an increase of temperature may occur.

Moreover, the increase of temperature due to a faster curing and the increase due to the excess of energy, caused by a too powerful LED lamp, exceeds the increase of a LED temperature with reduced power but it remains below the temperature generated by the halogen lamps, no matter if they have reduced power or high power.(14)

Conasi S. and his collaborators tried not to reproduce the conditions of the oral cavity but to measure in a laboratory experiment and in optimum conditions, the temperature oscillations brought about by two LED lamps and two halogen lamps, concluding that the temperature oscillations between the materials are caused by the different optical properties of the filling and by the different quantity of organic matrix. The higher the quantity of organic matrix, the higher will be the temperature due to the exogen reaction of polymerization.(3)

Studies indicate an increase of temperature when applying a 2 mm surface material, at a light curing time of 40 seconds with low power lamps and at a curing time of 20 seconds with high power lamps, revealing that the temperature increases can be tolerated by the dental pulp, which means an increase of less than 5,5 degrees Celsius.

Based on extrapolation, one can assume, that the dental exposure to low power lamps for 10 seconds and for 5 seconds to high power lamps will not determine significant increases of temperature at the level of the dental pulp.(2,3,4,12)

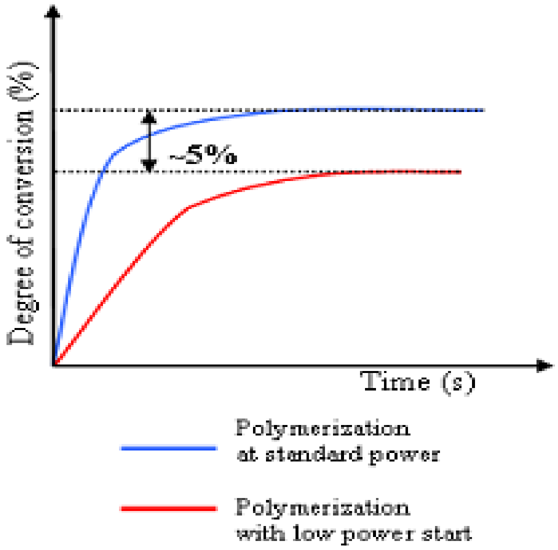
The testing of dental adhesives is very problematic, because the dental substrate can modify the behaviour of adhesives during polymerization, by changing the pH, for example; thus, it is very difficult to compare the degree of conversion of some adhesives with different properties and application techniques.(1)

The polymerization method can influence the degree of polymerization, the increase of temperature at the level of the pulp chamber, as well as the value of the setting contraction. There is a direct connection among all these parameters depending on the polymerization degree of the material.

A study published in 2005 by H. Lu and his collaborators showed that the soft-start polymerization method followed by a maximum power polymerization triggers a lower setting contraction, but also a lower increase of temperature at the level of the sample. At the same time, the degree of conversion of the double connections was significantly lower, than in the case of the polymerization through the standard method, i.e. the lamp will be used at maximum power throughout the entire polymerization process.(picture no. 2)

The phenomenon can be explained through the occurrence of vitrification at a degree of conversion of maximum 10%, which significantly influences the dynamics of the polymerization reaction. After the installation of vitrification, a Trommsdorff effect may occur, caused by an extra space generated by the difference between the microscopic contraction at the level of the polymer chains and the belated macroscopic contraction. The Trommsdorff effect is also enhanced by the increase of the temperature of the polymerized material. It was observed that 70% of the setting contraction occurs at the conversion of the last 15% from the total degree of conversion of the double bonds.(6)

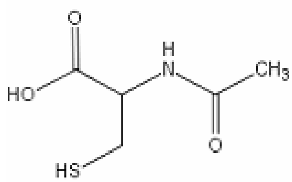
Picture no. 2 Comparative graphic regarding the analysis of the degree of conversion at standard polymerization (lamp with maximum power start) and polymerization with lamp at low power start.



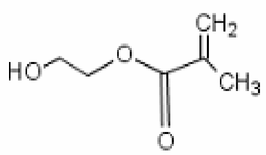
The low polymerization triggers the stabilization of the spatial structure of the polymer with consecutive inhibition of the mobility of the reactive species and the occurrence of a phenomenon of stopping the polymerization reaction.(9)

Under the influence of light, the photoinitiators get activated and form free radicals which will initiate the polymerization reaction. These free radicals are able to induce oxidative stress at the cells level of the dental pulp and may lead to damages of the cell DNA. However, this oxidative stress can be fought by the administration of antioxidants, such as: vitamin C and N-acetyl-L-cysteine. N-acetyl-L-cysteine in combination with glycine and L-glutamic acid is transformed into glutathione, one of the most active antioxidants. Vitamin C has also the role of keeping the glutathione in an active form. A similar effect as fotoinitiators is held by HEMA and TEG-DMA, which activate the cellular death by stimulating the production of free radicals.(picture no. 3)

Picture no. 3. The most efficient antioxidant compound, N-Acetyl-Cysteine and the most frequent cytotoxic compound of the adhesives, HEMA.



N-acetyl-L-cystein



HEMA

Studies showed that this effect can be fought, as well, by stimulating the production of glutathione by means of vitamin C and of N-acetyl-L-cysteine.(8,10,13,15)

The nanotechnologies allow the building of some nanorecipients to release the active substances capable of modifying the cell metabolism.

Integrating such nanorecipients into adhesives and composites could be a key element for their biocompatibility.(5,7,11)

CONCLUSIONS

1. The emission spectrum of the photocuring lamps must comply with the photoinitiator used.
2. The increase of temperature due to the photopolymerization is below 5,5 degrees Celsius and is tolerated by the dental pulp.
3. A slower polymerization will trigger a reduction of the light curing degree but also a smaller contraction of the light curing material.
4. The oxidative stress produced by free radicals, which initializes the polymerization reaction, can be fought by the administration of antioxidants. Their efficiency in vivo still has to be proved.
5. The use of nanorecipients with antioxidant substances integrated in light curing materials can be a way of raising their biocompatibility.

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