MEASUREMENT OF WATER SORPTION AND SOLUBILITY OF DENTAL RESIN CURED BY ARGON LASER

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Abstract: Water sorption can affect the physical and mechanical properties of dental resins. Properties such as tensile strength, flexural strength, modulus of elasticity and wear resistance have been shown that may negatively be affected by water sorption. Solubility of unreacted monomers may also promote allergic reactions in some patient. In the present work the effect of different wavelengths and power density of argon laser on the water sorption and solubility of a Bis-GMA-based dental resin was studied. The resin was prepared by mixing Bis-GMA and TEGDMA with a mass ratio of 75/25. Camphorquinone (CQ) and DMAEMA were added as photo initiator system. The resin was inserted into the disk-shaped stainless steel moulds between glass slides and was cured by applying the laser beam at wavelengths of 488 and 514 nm and power densities of 1075 mW/cm^2 and 700 mW/cm^2 for 40 sec. Water sorption and solubility were then measured according to ISO 4049. The results indicated that the specimens cured with 514 nm showed higher water sorption (58.5μg/mm^3)and higher solubility of unreacted monomers (16.4μg/mm^3). No significant difference between water sorption and solubility of specimens was observed when cured with 488nm wavelength at different power densities.

Introduction

Composite materials based on a polydimethacrylate matrix resin along with silane-coated inorganic fillers are extensively used in dentistry in a variety of applications. They possess excellent mechanical properties, aesthetic quality and the ability to bond to enamel surface [1]. |One of the issues raised in the application of dental composite is that in aqueous environment they can absorb water and elute unreacted monomers. The release of unreacted monomers from resin composite may stimulate the growth of bacteria and promote allergic reactions [2]. The water intrusion in the dental material can lead in a deterioration of the physical/mechanical properties, decreasing the life of resin composites mainly by silane hydrolysis and microcrack formation[3]. Excessive water uptake can promote breakdown causing a filler–matrix debonding [4].

The water ingress may have, however, some beneficial effects on the expansion of the composite. Thus compensating the polymerization shrinkage with improved marginal sealing and relaxation of the stresses set up within the matrix during shrinkage [5].

Studies have shown that water is absorbed predominantly within the matrix resin and is most affected by the structure and the amount of this phase [6]; so the study of the water sorption and solubility of polydimethacrylate resins made from neat monomers is important to understand their behaviour in the composites.

Polydimethacrylate resins are glassy polymers. The sorption of water in glassy polymers is generally described by a dual-mode theory, which assumes that the amount of the sorbed molecules consists of two populations [7]. One is held by ordinary molecular dissolution in the polymer matrix according to the Henry's law and the second is trapped in polymer micro -voids following the Langmuir isotherm. A clear physical picture of this behaviour is described by the free volume theory, which suggests that glassy polymers generally have a non-equilibrium liquid structure, containing an equilibrium hole-free volume responsible for Henry's sorption and an extra non-equilibrium hole-free volume, frozen into the polymer (micro-voids) responsible for Langmuir's sorption. The total hole-free volume effective for water diffusion depends on the macromolecular packing density. Flexible polymer chains with polar groups, especially those forming hydrogen bonds, which increase the intermolecular attractions, favor high packing density [7]. The sorbed water which is molecularly dispersed into the polymer matrix acts as plasticizer, causing the swelling of polymer. The quantity of thus sorbed water depends on the available equilibrium hole-free volume, the physicochemical affinity of polymer groups to water, and the resistance of polymer chains to a swelling deformation stress.

On the contrary, the water molecules which are accommodated in micro-voids are hydrogenbonded, form clusters and do not cause swelling of polymer but act rather as filler particles [8].

Polydimethacrylates are cross-linked glassy polymers. The presence of cross-links between polymer chains generally results in a significant

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decrease in the solvent permeability of polymer because they decrease the hole-free volume and the ability of polymer chains for swelling [9].

The most widely used resin in dental composites is that based on the copolymer prepared from a combination of bisphenol A glycol dimethacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA).TEGDMA is usually added to Bis-GMA in order to achieve workable viscosity limits since the latter monomer possesses very high viscosity due to the intermolecular hydrogen bonding [10].

In this study the argon laser was used as irradiation source for photocuring of the dental resin monomers and the effect of the laser wavelengths and power densities on the water sorption and solubility of the resin monomers were investigated.

Materials and Methods

A mixture of 75% (wt%) Bis-GMA and 25%(wt%) triethylene glycol dimethacrylate (TEGDMA) (Rohm, Degussa Group, Germany) was used as a resin. This composition is similar to that used in most of commercial dental resin formulations. Camphorquinone (CQ, 0.5%wt, Fluka) and N , N'-dimethyl aminoethyl methacrylate (DMAEMA, 0.5%wt, Fluka) were used as photoinitiator system.

The resin was inserted into stainless steel mold with 6 mm diameter and 1mm thick between two glass slides. The resin then irradiated for 40 s on each side with argon laser (Mellos Griot) at different wavelengths and power densities to form disk shape specimens. Five specimens were prepared for each wavelength and power density. The specimens were placed in a desiccator containing freshly dried silica gel. After 24 hours they were removed, stored in another desiccator at 23°C for 1 hour and weighed with a precision of 0.01 mg. This cycle was repeated until a constant mass (m_1) was reached. The discs were immersed in distilled water at room temperature and after fixed intervals they were removed, blot dried to remove excess water, weighted (m_2)and returned to the water. The water uptake was recorded until there was no significant change in weight. The specimens were reconditioned to a constant mass (m3) in the desiccators using the above described cycle. The diameter and the thickness of the specimens were measured at five points and the volume (V) was calculated in cubic millimeters. The values of water sorption (WS) and solubility (SL) were calculated for each disc using the following formulae:

$$WS = (m_2 - m_3)/V \,, \quad SL = (m_1 - m_3)/V \qquad (1)$$

Results

The water sorption as a function of time in different power densities at the wavelength of 488nm is shown in Fig.1.

It shows the water sorption at both power densities follows the same pattern. It shows a rapid increase in water sorption during the first three days and then the curve reaches a plateau. There is no significance difference ($p>0.05$) between water sorption of specimens cured with 488nm at 1750mW/cm^2 (23.7μg/mm^3) and specimens cured with 488nm at 700mW/cm^2 (25.8μg/mm^3). Fig.2 shows the effect of wavelengths on the water sorption of the resin at the power density of 700mW/cm^2. As it can be seen ,the water sorption of the cured resin is much higher for the specimens cured at the wavelength of 514nm.

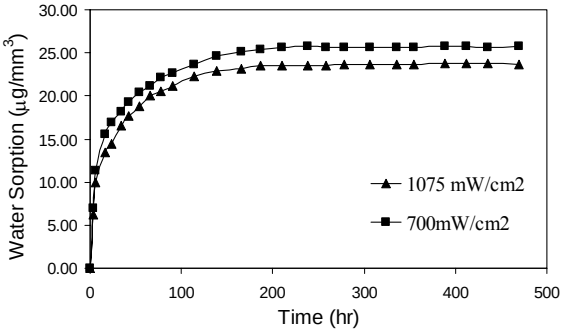

Figure 1: Effect of power density on water sorption of dental resin cured at the wavelength of 488nm.

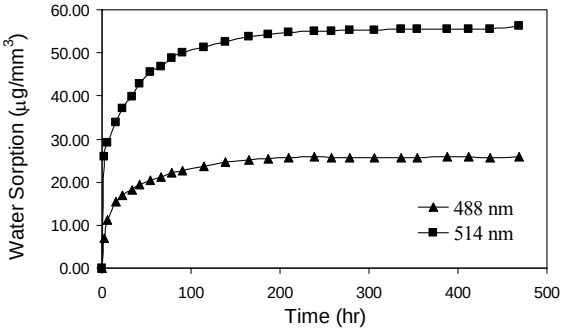

Figure 2: Effect of wavelength on water sorption of dental resin cured at power density of 700mW/cm^2

The effect of argon laser wavelength and power density on the water sorption and solubility of dental resin are summarized in Table 1.

Table 1: Solubility of resin cured by different wavelengths and power densities.

λ (nm)	PD (mW/cm^2)	WS (μg/ mm^3)	SL (μg/ mm^3)
488	1075	23.7	2.20
488	700	25.8	3.40
514	700	56.3	16.40

Discussion

The water sorption in dental resins is dependent on the monomers, composition and degree of polymerization. Other factors influencing water sorption are immersion time , temperature and surface condition .

The dissolution of the resin components is also influenced by the polymerization, immersion time ,

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temperature, water sorption and environmental stress [11]. However, in this study, only the relationship among polymerization conditions, immersion time and water sorption of resin is focused on.

According to ISO9000s standard for dental restorative resins, a resin in order to be suitable for use as dental material must show water sorption lower than 50μg/mm^3 and solubility lower than 7.5μg/mm^3. The values of water sorption and solubility for specimens cured at 488nm are within the range of the ISO's standard, but the value of water sorption for specimens cured with 514 nm is out of the range of this standard (Table 1).

The solubility of polymers is concerned to the amount of leachable unreactd monomers which are trapped during the polymerization inside the microgels between the polymer chains. The monomers are adsorbed to the surrounding network, or are trapped in the micropores (monomer pools).The monomers in micropores are more susceptible to leaching out than the monomer inside the microgels[7].

According to the water sorption and solubility data in Table 1 the water sorption and solubility of specimens cured with argon laser at wavelength of 514nm is significantly higher than the water sorption and solubility of the samples cured at 488nm.The results can be explained considering the degree of conversion (DC%) of these specimens. In a previous work ,the effect of argon laser wavelengths and power density on the degree of conversion of dental resin were studied. As that study showed DC% of specimens cured with argon laser at wavelength of 514 nm was about 27% and for the specimens cured at 488nm was higher than 40%.

For the argon laser curing the highest degree of conversion was obtained using 488nm emission line which is in the range of blue light. The 488nm line is close to the camphorquinone absorption peak .The absorption peak of camphorquinone is about 470nm. The wavelength of the 514 nm line appears at the tail-end of the camphorquinone absorption peak and therefore results in lower degree of conversion in camphorquinone-based dental resin and higher water sorption and solubility. The value of solubility depends mainly on the degree of conversion. The higher the degree of conversion and thus higher the amount of the unreacted monomer, the lower the solubility value.

As the Fig.1 shows the effect of power density on the water sorption is not significant for the power densities of 700 and 1075 mW/cm^2. The light intensities more than 300-350 mW/cm^2 is recommended for photo polymerization of dental resin monomers. The power density of 700 mW/cm^2 (or 1075 mW/cm^2) are much higher than the minimum requirement for photo polymerization of the resins. So no significant difference was observed between the water sorption of the resin cured in these two power densities.

As the light emission of argon laser is monochromatic and coherent, it can cover the absorption peak of photoinitiator more effective than halogen light curing units resulting in higher degree of conversion and less water sorption.

Conclusions

The study of water sorption and solubility of polymethacrylate resin cured by different wavelength and power density of argon laser showed that curing of dental resin with 448 nm at 1075mW/cm^2 decrease the water sorption and solubility of specimens and may reduce the problems due to release of unreacted monomer.

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