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Research Report

The effect of UDMA and Bis-GMA irradiation period on residual monomers in resin packable composite

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ABSTRACT

Background: *Residual monomers are non-polymerized monomers which can cause clinical harm, for example inflammation, to oral cavity tissue while the remaining monomers can potentially be carcinogenic. The more residual monomers that remain due to an imperfect polymerization processes, the lower the compressive strength level and the higher the number of micro slits that can cause secondary caries and tooth sensitivity. Urethane dimethacrylate (UDMA) and bisphenol A glycol dimethacrylate (Bis-GMA) constitute two of the resins most frequently used in packable composites. During the short irradiaton period forming part of the polymerization process, UDMA and Bis-GMA have the potential to produce residual monomers.* ***Purpose:*** *This study aimed to compare the number of residual monomers in packable composite resin following irradiation lasting 1x20 seconds and 2x20 seconds.* ***Methods:*** *28 samples of cylindrical packable composite with a thickness of 2 mm and a diameter of 5 mm were divided into four groups. Groups 1 and 2 were irradiated for 1x20 seconds, and groups 3 and 4 for 2x20 seconds with the composite subsequently being immersed in ethanol solution for 24 hours. The number of residual monomers using high-performance liquid chromatography (HPLC) devices was calculated and the results statistically analyzed using a Mann-Whitney Test.* ***Results:*** *Repeated irradiation had no effect on the amount of residual monomers in packable composite resins. However, there were differences in the number of residual monomers in the material contained in packable composite resins Bis-GMA and UDMA, while the remaining monomers in UDMA outnumbered those in Bis-GMA.* ***Conclusion:*** *The number of residual monomers in Bis-GMA is lower than in the remaining UDMA after 1x20 seconds irradiation, while the number of residual monomers in Bis-GMA and UDMA following 2x20 seconds irradiation was no different to that after irradiation of 1x20 seconds duration.*

Keywords: *irradiation; packable composite; residual monomer*

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INTRODUCTION

Composite resin constitutes a material indispensable to anterior and posterior tooth restoration.[1] Certain of the existing literature states that the definition of a composite is a mixture of two or more materials which enhances the properties of the material.[2] Materials are classified as either packable composite resins or flowable composite resins according to the volume of composite resin filler they contain. Due to their utility, packable composites were introduced in the late 1990s. Packable composite resin is a di-methacrylate resin which contains several fillers of 66-67% with a particle size of 0.7-2 nm.[3] The advantages of this composite include a reduction in shrinkage during polymerization.[4] For process efficiency and maximum restoration results, more beam-activated composite resins are employed.[5]

Currently, quartz tungsten-halogens (QTH) and light-emitting diodes (LED) constitute the light sources most frequently used for hardening composite resin as the photon suppliers which activate photon-initiators. Composite polymerization is initiated by exposure to light produced by a light curing unit (LCU).[6] The polymerization process consists of four stages: induction, propagation, chain

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transfer and termination.[7] Several factors potentially affecting polymerization include filler type, size, material content, thickness, color of the restoration material, effectiveness of light transmission, exposure time, the distance between rays and restoration materials and light intensity.[6] After photoactivation, monomer conversion to a simplified polymer will occur in relation to the degree of conversion (DC). The higher the value of DC monomer crosslinking, the more extensive the polymer network formed.[8] The DC constitutes an important parameter in determining the final properties of active composite resin irradiation including: physical, mechanical and biological properties the light wavelength and depth employed, ray tip size, photo activation method, distribution, number of inorganic fillers, composite resin color, and the exposure period which is directly affected by an increase in the irradiation period.[5] A low degree of conversion causes decreasing resin properties and the number of non-reactive (trapped or free) residual monomers. One strategy to maximize DC and minimize monomer elution as a means of providing sufficient energy to the material is that of prolonging the hardening time.[9]

The main problem often encountered in composite resin stacks is that of incomplete polymerization. The more residual monomers remain due to imperfect polymerization, thereby reducing the compressive strength and gap microstructure that can lead to secondary caries and tooth sensitivity. Based on previous research, post-curing in a ultraviolet (UV) lightbox proved capable of enhancing the polymerization process due to more evenly distributed light reflection which, in turn, increased the solidity of composite resin. Post-curing is an additional polymerization technique implemented after initial irradiation with the aim of increasing the degree of conversion as a means of perfecting the polymerization process.[10] The purpose of this study is to explain the effect of the urethane dimethacrylate (UDMA) and bisphenol A glycol dimethacrylate (Bis–GMA) irradiation period on residual monomers in packable resin composite.

MATERIALS AND METHODS

The investigative method applied constituted laboratory-based experimental research incorporating a posttest-only control group design. There were four treatment groups. Group 1: packable composite with Bis-GMA base materials 1X irradiation, Group 2: packable composite with UDMA base material with 1x irradiation, Group 3: packable composite with Bis-GMA base materials 2X irradiation, and Group 4: packable composite UDMA base material with 2X irradiation. The total sample size consisted of 28 packable composites.

Composite resin Filtex Z350 XT Packable (3M ESPE) samples were produced in 2 mm-thick, plastic, cylindrical composite molds, 5 mm in diameter. Packable composite materials were applied using plastic filling instruments. LED light curing was subsequently performed (Woodpecker DTE Curing Light LED) on the members of the four groups at a light intensity of $\geq$ 500mW/cm^2. The samples produced were immersed in ethanol solution for 24 hours in an incubator at 37^{o}C. Following immersion, the number of residual monomers was calculated using an HPLC (Agilent 1100 series, Korea).[11]

The data produced was analyzed using a Kolmogorov-Smirnov test in order to establish whether data was normally distributed, while a Levene`s test was conducted to determine the homogeneity of the samples. Both a Mann-Whitney test and an Independent T test were completed on the homogeneous and non-homogeneous groups as a means of identifying any differences between them. All data produced was analized statistically at a degree of confidence of p=0.05.

Table 1. Average amount of monomer residue calculated with HPLC.

Group	N	Monomer residue (%)
1	7	19.991
2	7	58.430
3	7	10.304
4	7	39.155

RESULTS

The results of this research into monomer residues after Bis-GMA and UDMA irradiation were calculated with HPLC as shown in Table 1. The contents of Table 2, the results of a statistical calculation conducted, indicated that UDMA and Bis-GMA subjected to one-time and two-time irradiation both demonstrated significant differences with respective p-values 0.003 and 0.001. The UDMA group exposed to one-time irradiation, with a p-value of 0.180, showed no significant differences compared to the UDMA subjected to illumination on two occasions.

There were no significant differences in the Bis-GMA group with a p-value 0.848 that had been subjected to one-time irradiation, compared to the Bis-GMA group that had been irradiated twice. Table 2 contains the results of the different test treatment groups.

Table 2. Test treatment groups

Treatment groups	p-value	Test
One-time UDMA and one-time Bis-GMA	0.003*	Mann-Whitney test
Two-times UDMA and two-times Bis-GMA	0.001*	Independent T test
One-time UDMA and two-times UDMA	0.180	Mann-Whitney test
One-time Bis-GMA and two-times Bis-GMA	0.848	Mann-Whitney test

*The differences were significant (p-value< 0.05)

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DISCUSSIONS

From the various test results, it could be seen that repeated irradiation produced no effect on the number of residual monomers in packable composite resins. This is possibly due to the activator material present in the composite resin in the form of champhoroquinon having already reacted during the first polymerization process. Consequently, when a second polymerization occurred, no monomer was polymerized. Champhoroquinon absorbs visible light in the region of 467 nm.[12] However, there are differences in the number of residual monomers, namely Bis-GMA and UDMA, in the material contained in packable composite resins. The residual monomers in UDMA are more numerous than the remaining monomers in Bis-GMA due to the difference in molecular weight between UDMA and Bis-GMA. The molecular weight of UDMA is lower than that of Bis-GMA with the result that UDMA is easily lifted and its morphology is small, enabling its easy detection on HPLC. UDMA also demonstrates high affinity, namely the ability to react with other chemicals, together with strong solubility properties. In Bis-GMA, the cross density is high compared to that of UDMA, and its high molecular weight is more stable and not easily biodegradable.[13]

Previous studies have argued that polymerization is influenced by several factors, including molecular weight and affinity.[14] The more numerous the molecules polarized, the fewer the residual monomers which, in turn, reduces the likely occurrence of allergies in oral tissue, toxicity to residual monomers and contamination of pulp space due to residual monomers. It is anticipated that two 20-second exposures can reduce the number of residual monomers that are unpolymerized for several reasons. The molecular shape of the Bis-GMA, which is large and solid, could render the monomers crowded and less able to absorb irradiation, while it is also influenced by molecules that are slow to form polymer bonds. Statistically, the two groups have no significant differences ($p \leq 0.05$).

From this study, it can be concluded that the number of residual monomers on Bis-GMA is lower than that on the remaining UDMA at 1x20 seconds irradiation, while there is no difference in the number of residual monomers on Bis-GMA and UDMA at 2x20 seconds compared to 1 x 20 seconds irradiation.

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