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Review Article

Role of Photoinitiators on Commercial Resins: A Review

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***ABSTRACT*:**
Since the early 1970s, dental resin composites have been the material of choice for direct esthetic anterior and posterior restorations. Dental resin composites serve as a more esthetic material to use over dental amalgam. Dental resin composites, no matter traditional or bulk-fill, require the use of initiators to help initiate the polymerization process. In light-cured resin composites, photoinitiators in the soft raw material are activated by the curing light and they start the cascade reaction of polymerization, which make the resin composites harden and stronger.
Keywords: Photoinitiators, Commercial Resins, Camphorquinone, light-cured dental resin

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INTRODUCTION:

Camphorquinone (CQ) is the most commonly used photoinitiator in light-cured dental resin composites. However, this yellow agent is associated with a yellowing effect of the dental resin composites. Since color stability is a very important concern in esthetic restorative dentistry, the yellowing effect of CQ has led manufacturers to add alternative initiators into resin composites to reduce the amount of CQ used. Experimentally, other initiators, such as trimethyl benzoyl diphenylphosphine oxide (TPO) (1) and phenyl propanedione (PPD) (2), have been introduced as alternatives. The addition of the alternative photoinitiators as a coinitiator lowers the content of CQ and has been suggested to overcome the esthetic issue arising due to the color of CQ (3).

Background of dental resin composites

Since early 1970s, dental resin composites have been the material of choice for direct esthetic anterior restorations. Based on the dental insurance claim data in 2005, about 166 million dental restorations, which include amalgams, resin composites and crowns, are placed per year in the United States (4). Of these, 77 million are resin composites (4). In general terms, resin composites are a mixture of inorganic filler particles surrounded by a coupling agent, dispersed in an organic matrix of resin (5). The organic monomers, which are soft in the un-cured dental resin composites, are converted into rigid polymers through a polymerization process. Some commonly used resins in dental resin composites are bisphenol A-glycidyl methacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA) and ethoxylated bis-phenol A methacrylate (BisEMA) (5). Fillers, such as silica, are reinforcing particles or fibers that are dispersed in the resin matrix. Fillers also enhance radiopacity, alter the thermal expansion behavior, and reduce the polymerization shrinkage by reducing the resin fraction (6). Resin composites with low filler contents typically exhibit low mechanical properties and show high flowability and adaptability prior to curing (7). Filler contents of 60 to 87 wt% are necessary to achieve low shrinkage and high mechanical properties (8). A coupling agent such as silane is used to enhance the bond between resins and fillers. Initiators are added to help begin the polymerization process when external energy, such like light or heat, is applied. During the activation of the initiators, free radicals are produced and they break the double bond of the monomer and bond with them to start the reaction. As a result, a polymer forms during the polymerization process (9).

Dental resin composites can be cured through light cure or chemically without light cure or by both ways (dual cure). Reaction of the chemical cured resin composites is produced by mixing two pastes. However, the chemically cured resin composites have some disadvantages: no control over the setting time, poor color stability, and high viscosity (10). On the other hand, light-cured dental resin composites have only one paste, and do not require mixing which provide dentists full control of time. The first commercially available light-cured resin composites was NuvaFil (Dentsply) (10).

Background of photoinitiators

Initiators used in light-cured resin composites are photoinitiators. In brief, photoinitiators have the ability to absorb light, and as a result, either directly or indirectly, generate a reactive species that can then initiate the polymerization (11). Photoinitiators have certain wavelengths for excitation/absorption. The spectral emission from the light curing unit should overlap the absorption spectrum of the photoinitiator in the resin composites (12). Four basic types of dental curing lights are quartz tungsten halogen, light-emitting diode (LED), plasma arc curing (PAC) and argon laser (13). The light provided to cure the resin composites is in the range of the visible blue light spectrum. Camphorquinone (CQ) is the most common photoinitiator used in light cured dental resin composites (10). This yellow agent is activated by absorbing external blue light. CQ can absorb light in the spectral range of approximately 380-500 nm, and has an absorption peak near 470 nm (3,11). CQ is relatively inefficient as a photoinitiator, thus amines, such as dimethylaminoethyl methacrylate (DMAEMA), are added as co-initiators to accelerate the initiation process during polymerization (3). Although CQ in conjunction with a tertiary amine has traditionally been used in dental resin composites, the intensive yellow color of CQ has limited its use particularly in extra white shades of resin composites (14). Other initiators, such as trimethylbenzoyldiphenylphosphine oxide (TPO) (1) and phenyl propanedione (PPD) (2), have been introduced as alternatives. TPO is a well studied photoinitiator. The absorption spectrum of TPO is situated more toward the UV spectrum (380-425 nm) (15). Lucirin® TPO (Lucirin is the trade name of BASF (16)) is completely colorless after light curing (17). PPD was suggested to be an alternative photoinitiator for resin composites in 1999 (18). Subsequent studies have evaluated the use of PPD in dental resin composites as a photoinitiator (19,20). The absorption peak of PPD is around 392 nm (2). The commercial use of this photoinitiator is not as common as TPO. This photoinitiator was studied mainly experimentally. Beside less yellowing, PPD was suggested to reduce polymerization stress by producing a slower polymerization rate without affecting final degree of conversion, compared to CQ (2,18). However this was not conclusively proved and it is a matter of controversy that a low rate of polymerization will reduce polymerization stress development (2). Use of PPD alone or in combination with CQ was reported by Schneider et al. to not improve the final properties when compared to CQ alone (21). The same group also found that it was not possible to polymerize formulations containing PPD without amine using 40s of halogen light exposure (21). These disadvantages associated with PPD might be the reason for its limited use commercially. Even though alternative photoinitiators has been suggested to overcome the esthetic issue arising due to the color of CQ (3), currently there are no non-CQ dental resin composites available commercially in the market. This may be due to the fact that most of the light curing units on the market and in dental offices are optimized for curing CQ and are not as suitable for use with alternative photoinitiators that absorb light at different wavelengths than CQ. Combining CQ with an alternative photoinitiator is a safer and more effective solution in the current situation, since the use of additional photoinitiators can reduce the amount of CQ used and the remaining CQ can ensure the initiation of polymerization by the majority of light curing units available.

Bulk-fill resin composites and color change

Incremental filling techniques have been recommended due to a limited depth of cure in traditional resin composites as well as a way to minimize stress from polymerization shrinkage during curing (22). Unlike traditional resin composites, which typically are placed in maximum increments of 2 mm, bulk-fill resin composites are designed to be placed in 4 mm, or sometimes greater, increments (23). The manufacturers explain that the higher depth of cure of the bulk-fill resin composites is due to the more potent initiator system and/or higher translucency (24). However, few studies have examined the color changes after polymerization and aging on the bulk-fill dental resin composites with different initiators. Most bulk-fill resin composites require an additional 2 mm occlusal layer being placed using a traditional resin composites (25). Using such a veneering layer not only improves the aesthetic quality of the translucent bulk-fill resin composites, but also overcomes the low wear resistance of bulk-fill resin composites due to their low filler content for the sake of translucency of the material (26). In the bulk-fill resin composites, such as SonicFill 2 where the occlusal layer is not required, color change is an important issue.

Color measurement

Being able to maintain its optical properties is important for resin composites, especially for those applied in the anterior teeth, since the color is always selected carefully to match the adjacent tooth for esthetic concerns in clinic. However, optical properties change as a result of polymerization (27). Resin composites become lighter and more translucent on irradiation with light (27, 28).

Color stability

Resin composites tend to discolor during long-term service in the oral cavity (29,30).

Significant color changes of resin composites have been reported after aging, even though in most of the cases, such change in color of resin composites after aging, such as storing in water, was found to be in the acceptable range (29). Discoloration after aging may be due to a color change in the resin component, but also the other minor ingredients, such as photoinitiators, may contribute to the color stability. Exposure to high temperature and a rough composite surface are expected to affect color stability as well (29).

CONCLUSION:

Data on color stability of commercially available resin composites with additional photoinitiators beside CQ are insufficient to show whether or not such an approach is beneficial.

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