Visible light-cured composites and activating units

Council on Dental Materials, Instruments, and Equipment

Photoactivated composite restorative resins are polymerized by ultraviolet or visible light. A recent council report stated: "The main clinical advantage of identification for using a photopolymerizing system is the regulation that the effect of direct light exposure is limited and intense cavity preparations or with patient behavioral problems. This control can prove most valuable. The incremental addition of resin to build restoration contours and to minimize the amount of excess material removed during finishing is also noteworthy advantages for a photopolymerizing system. The number of visible light-activated systems has increased substantially in the past 2 years. Several ultraviolet light-activated systems are also available. There are also composites that can be activated by either visible or ultraviolet light. The visible light systems are gaining popularity and replacing the ultraviolet systems for many reasons, which include the possible hazards of ultraviolet radiation and the more extensive visible light penetration of tooth structure for deeper depths of cure. This council report summarizes the current informations on photoactivating composites and photoactivating light units.

Composites

The compositions of photoactivated composite resins differ from the chemically activated resins only in the activators and initiators. The ultraviolet light-activated composites contain benzoin alkyl ethers as initiators. The visible light-activated composites usually contain diketone initiators such as camphorquinone and a reducing agent such as a tertiary amine to produce radical initiators controlled irradiation by visible light to initiate polymerization of the resins. The camphoroquinone initiator is activated by wavelengths in the range of 400-500 nm (blue region of the visible spectrum). As a comparison, chemically activated composites depend on the mixing of the initiator for example, benzoyl peroxide, and the activator for example, dihydroxyethyl-p-toluidine for polymerization. For all currently available composites, the basic resin matrices are based on Bis-GMA, modified Bis-GMA, or urethane dimethacrylate type systems with diluents such as ethylene glycol dimethacrylates or methyl methacrylate. The inorganic fillers may be quartz, lithium aluminum silicate, barium glass, strontium glass, colloidal silica, or mixtures of these fillers. The filler particle sizes may range from as small as 0.04 µm in microfilled composites to 1-20 µm in conventional composites as well as the "polishable" composites (up to 5 µm) or mixtures of these particle sizes.

The physical and mechanical properties of photoactivated composites, when adequately polymerized, are similar to those of chemically activated composites. Both types are evaluated under specification no. 27 for direct filling resins. A recent listing of certified products includes both visible light-activated, ultraviolet light-activated, and chemically activated resins. Photocured composites appear to be comparable to chemically activated composites at this time, and may have some advantages. Only a limited amount of clinical data; however, is available for photoactivated composites versus chemically activated composites. In a 2-year study involving Class IV resto-
rations, an ultraviolet light-activated system (Nuva-Fil) was reported to be significantly better than two chemically activated systems (Exact, Restodont) in color match, cavosurface margin discoloration, and marginal anatomic form. In a study of composites in posterior restorations, three ultraviolet light-activated resins (Nuva-Fil PA, Urioc-Fil, Estilux) showed little loss of anatomic form after 3 years, and color matching was reported to be excellent. These results were considered better when compared with two chemically activated composites (Adaptic, Concise) used in another study of posterior restorations. An extension of the study of ultraviolet light-activated resins reported that surface comparisons of the photocured resin systems are significantly superior to the auto-cured systems when subjected to occlusal loading. A 3-year study of a “polishable” visible light-cured composite (Prisma-Fil in Class III, IV, and V restorations reported significantly better performance when compared with a conventional, chemically activated composite resin (Concise). It has been postulated that the reported differences that favor photoactivated composites may be related to the method of activation. Photoactivated composites do not require spatulation and, therefore, have less porosity as the spatalation of the two components of chemically activated composites would incorporate air bubbles. Furthermore, the action of mixing and manipulating chemically activated composites after the initiation of the polymerization, but before setting, could compromise the microstructures and the resin matrices of the systems, resulting in less desirable properties. Adequate polymerization (curing) of composites is of paramount importance to ensure clinical performance. Underpolymerization is usually associated with inferior physical and mechanical properties, higher solubility, and less than optimal performance for the composites. The internal degree of polymerization of a photoactivated composite decreases with increasing distance from the surface. In fact, the presence of a hard top surface of a photoactivated composite restoration is not an indication of adequate polymerization throughout the restoration. The depth of cure of photoactivated composites is of great importance and is the subject of numerous investigations. Methods of depth of cure evaluations include scraping,19-21 dye22 and optical distinction,23-24 and surface hardness measurements, which are predominantly used in the majority of the studies because hardness is an indicator of the degree of polymerization. A comparison of these methods for determining depths of cure indicated that the former two methods showed deeper (3 mm) values where the hardness values were less than 30% of the top surface values. A spectroscopic study reported high percentages of unreacted methacrylate groups at 2 to 3 mm below the surface. Most depth of cure evaluations were done in vitro. Some studies also incorporated simulated in vivo conditions with consideration of the presence of enamel32-34 or dentin35 (or both). Results of all these studies indicate that several factors influence in vitro depth of cure evaluations. These factors include mold material,33-35 mold size,36 exposure time,37-39 photostimulating light source intensity,34-44 and other variables. Two inherent factors in the composite, composition34-41 and transmission coefficients28-31,49-50 also influence depth of cure. Most of these factors affect the intensity of photostimulating light reaching the bottom surface of samples tested. In general, reported depth of cure values are higher for translucent molds such as Teflon as compared with opaque metal molds.34-35 Mold size larger than the photostimulating beam sizes also give higher values as the surrounding composite acts as a translucent mold. Exposure times longer than recommended by manufacturers usually result in somewhat higher hardness values for both the bottom and top surfaces. Although there are reports suggesting that sequential exposure (more than one light application to achieve total exposure time) and slow scanning over large samples may result in lower hardness values,25-26 no difference in hardness values was observed by Stanford and others32 when several composites were adequately polymerized by sequential exposure or continuous light. Pooling of photostimulating light on the initial light application and hardness increases up to 1 day.41 Also, lower activating light intensity is associated with lower hardness values and corresponding shallower depth of cure.42-43 The transmission coefficient or attenuation factor of a composite is an indication of the reduction of photostimulating light intensity passing through the composites. Microfilled composites, because of larger light scattering by the smaller filler particles, have lower transmission coefficients and normally shallower depth of cure. This, however, may be compensated by the composition used in forming the composites. The ultraviolet light-activated composites also have shallower depth of cure because of the increased amount of scattering at lower wavelengths.43-45 Currently, there is no consensus on the measurement of depth of cure evaluations. There is also no information on either an absolute hardness value or relative ratio of hardness of the bottom and the top surfaces for a depth of cure criterion. At the present time, the subcommittee on ANSI/ADA specification no. 27 for direct filling resins is revising the specification to include depth of cure considerations. The profession should be cautious in the interpretation of claims of extensive depth of cure and should follow manufacturers’ instructions explicitly. Care should be taken to recognize that a hard, adequately polymerized top surface does not necessarily indicate that the deeper areas are adequately polymerized. Inadequate evidence to show that prolonged exposure will eventually cause adequate polymerization in deep restorations. It is suggested that for visible light-activated composites, thickness beyond 2 to 3 mm should be placed in increments and polymerized after each increment. For some darker shades, even thicknesses less than 2 mm may require increment placements. It is also suggested that if there is doubt on the amount of exposure time required, a longer exposure time should be used. Visible light-activated composites may also be significantly affected by exposure to ambient light. The intensities of dental operator lights cause some degree of polymerization if the composites are exposed or manipulated in these light beams.52 Even strong ambient lighting may be sufficient to cause some polymerization. These conditions may result in premature polymerization of the composites to the extent that desirable restorations with the photostimulated composites may be hindered and the materials would have limited working time and adversely affect the properties. It is suggested that visible light-activated composites be subjected to minimize exposure to dental operator lights and other room lighting systems until photoactivation by the use of a light-curing unit is desired.

Light activating units

A photoactivating light unit or dental curing light unit generally consists of a light source, a filter to select the range of wavelength transmitted, and a light tube for delivering the light beam to the area of application. There are at least two types of designs. A gun type unit has the light source and filter in a casing to be held by the operator, and the light tube is rigid and either type of design has the light source and filter baselined on a flat surface in the operatory or in a part of a dental unit, with a long, flexible light tube, which may be a fiber-optic bundle or other light transmission design. Most units have timers for automatic switching off at the end of the selected exposure time.

Visible light-photoactivating units usually emit wavelength spectra from around 400 nm to about 550 nm.53-56 Some units may also have small to moderate amounts of light below and above this range. There are differences in the spectral distribution, luminous intensity, and radiation intensity among the visible light-curing units. The intensity among models have been reported to be 4 times,5 16 times,59-61 and 59 times59 between the lowest intensity unit and the highest intensity unit tested. The results are influenced by the differences in measuring methods and instrumentation used. The instrument used and rankings of visible light-curing units based on measured intensity varied among the reports (Table). In addition, there is inadequate information on the intensity of the different units in the range of 400-500 nm, which is more effective in the photoactivating process. The brightness or illumination ability is not a measure of effective photoactivation.

At the present time, there is insufficient information on the quantum efficiencies at various wavelengths and the spectral distribution correlation to use the total light intensity as the only criterion in the selection of a light unit. In our institution, the information available on the luminous intensity and spectral distribution of the light units as affected by variations in line voltage, age of the light bulb, age of the filter, condition of the light tube, and several other factors. A standard for visible light activator devices is being developed. At the present time, these devices may be evaluated under an ANSI/ADA Acceptance Program for Visible Light-Activating Devices of the Council.

The use of different combinations of composites and activating light units has been studied by several investigators.24-34-54-57 The results indicated that curing time, amount and depth of cure varied among the combinations. The results were also influenced by the experiment conditions used, methods of measure-
A number of companies are marketing protective glasses for dental personnel or patients (or both), to be worn when light-curing devices are used. Product claims include filtering out high percentages of light below 450-525 nm. As emitted blue light with wavelengths 400-500 nm is of concern, protective lenses that filter out light in this region would be effective in reducing the intensity of blue light reaching the eye. Preliminary measurements on the filtering efficiencies of these and some other commercially available lenses were obtained by the council laboratory (unpublished report) and the Center for Devices and Radiological Health (O. Ellington, R. Landry, and R. Bostrom, unpublished report). The wavelengths below which transmissions are reduced to 1\% or less for some of these protective lenses are: Liteshield, 500 nm; Guardian Perception Orange Lenses, 500 nm; Noviol, 470 nm; Work 470 nm; and Guardian Perception Yellow Lenses, 440 nm. Coming CPF 550 transmits less than 1% below 550 nm but it transmits up to 10% between the wavelength range of 350 to 450 nm. Protective glasses intended to filter out ultraviolet light, such as no. G-40, which allows less than 1% transmission below 400 nm, do not filter out visible light in the blue region. The long-term effectiveness of protective glasses for visible light has not been clinically evaluated. The council will publish a report on this topic when additional information becomes available. Meanwhile, until the absence of a hazard has been demonstrated, the prudent approach would be to take proper precautions to minimize the potential hazard by the use of special filter glasses to diminish the light intensity reaching the eyes. It is important to recognize that the use of these special filter glasses should not imply that it is safe to stare at the lights.

Heat generation by the visible light-curing units or by the exothermic reaction of the photoactivated composites (or both) has been reported.

The results of these in vitro studies indicated differences among units and compositions. Conclusions were postulated that, in some systems, the amount of heat generated may have the potential to affect the pulp; however, no in vivo study on this heat effect has been reported.

Summary

In summary, visible light-activated composites offer better regulation of working time. Their composition differs from chemically activated composites only in the initiators and activators. The physical and mechanical properties of adequately polymerized photo-activated composites are similar to chemically activated composites. Depth of cure evaluations of the photoactivated composites are dependent on many factors, both experimental and inherent. There is currently no consensus on depth of cure values and evaluation methods. It is suggested that, if necessary, visible light-activated composites should be placed and polymerized in about 2-mm increments. It is prudent to use a longer exposure time. Exposure of visible light composites to dental operatory lights or strong ambient lighting (or both) during restorative procedures should be minimized to avoid premature polymerization. There are differences in design, spectral distribution, and radiation intensity of photoactivating light units. No definitive information is currently available on the effectiveness and optimal conditions for different light composite combinations. Little information is currently available on the bioeffect of visible light radiation on human optical systems and oral tissue. At the present time there are reports of afterimages but no long-lasting bioeffects. It is strongly recommended that precautions should be taken in the use, and operation of photoactivating light units. Protective filter glasses should be used.

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though Hyatt’s ideas were not fully accepted by the dental profession even before modern methods of prevention, they probably led to the “preventive filling” approach to caries control. A time when the development of caries was more generalized and severe than it is today and preventive options were few, this approach was probably rational enough.