Estimated Light Exposure Time for Composite Resin Restorative Materials

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QUESTION

How much light exposure time is required to polymerize an increment of composite resin restorative material?

ANSWER

The exposure time necessary to adequately polymerize an increment of composite resin restorative material is very difficult to determine. However, with the wide variety of curing lights and composite resin restorative materials available today, it is important that practitioners have a basic understanding of the factors related to photopolymerization in order to estimate appropriate light exposure times. Photopolymerization of composite is affected by factors related to both the light and the composite.

Light-related factors include intensity, exposure time, spectral distribution, and light dispersion. As the intensity of the light source increases, more photons are available for absorption by the photoinitiators. With more photons available, more photoinitiator molecules are raised to the excited state to form free radicals for polymerization. At the top surface, polymerization is more efficient because of the ample number of photons. However, deeper in the composite, attenuation of light leads to a potential gradation of cure within the depth of the material and is responsible for what has become known as the depth of cure.

Clinicians are unable to judge the depth of cure clinically. Hardness at the top surface provides little indication of the degree of cure at the bottom surface. Reduced polymerization might reduce the mechanical properties of a material and result in premature restoration failure because of marginal defects, secondary caries, or restoration fracture. To compensate for this gradation of cure, the duration of exposure can be increased, within practical limits, providing enhanced opportunity for creation of free radicals.

A reciprocal relationship has been demonstrated between irradiance and exposure time on the degree of polymerization of composite resins. Irradiance is typically determined by the power in milliwatts (mW) divided by the surface area (cm^2) of the light guide. The total radiant exposure from a curing light is the product of the irradiance (mW/cm^2) and time (seconds) and is expressed as millijoules per area (mJ/cm^2). Dental manufacturers have been increasing the irradiance of their curing lights and marketing the advantage of reduced curing times. However, the reciprocity is not completely linear and studies have shown that mechanical properties of composite resin materials might be reduced when high-powered curing lights are used at shorter exposure times.

A modification of light-curing protocols, or "soft-start polymerization," has been suggested to reduce the effects of polymerization shrinkage stress by initially

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exposing the composite resin to light at lower intensity. The results of laboratory studies investigating the marginal gap or interfacial stress of composite resin polymerized with ramped or stepped light intensity has been equivocal, with some studies finding an advantage and others showing no difference. However, the preponderance of evidence from limited published studies suggests that effect of modulated light-curing protocols on composite resin restorations may not be clinically significant.

The spectral distribution of the emitted light can play a role in the polymerization of composite resins. Compared with quartz-tungsten-halogen (QTH) or plasma-arc (PAC) curing lights, light-emitting diode (LED) curing lights have a higher percentage of their emitted light in wavelengths that more closely match the absorption spectrum of the most common photoinitiator, camphorquinone, thus increasing curing efficiency. However, curing lights may have different effective spectral emission ranges that influence how much light is available to optimally interact with the photoinitiator. Additionally, a few composite resin materials contain other photoinitiators that may not be initiated by the light of narrow-spectrum LED curing lights. To compensate for this potential incompatibility, some manufacturers have introduced a new generation of LED curing lights with a combination of chips with different emission wavelengths to produce a broader spectrum of light. These multi-spectrum LED curing lights have the potential to cure all dental materials containing any photoinitiator, similar to the broad spectrum QTH and PAC curing lights.

Curing-light guides can have a dramatic influence on the collimation, or dispersion of the emitted light. Emission from curing lights that is minimally divergent and evenly distributed horizontally across the face of the light guide will maximize curing effectiveness. Divergence of the light can arise from a wide variety of factors and affects the rate at which irradiance decreases as the light guide is moved away from the tooth surface. The less the divergence, the less the irradiance loss with increasing distance. Using laboratory-grade instrumentation, studies have shown large differences in light divergence among dental curing lights. Clinicians can obtain a rough estimate of the divergence angle of the light from their curing lights by placing a white card against the side of the light guide and visually tracing the light projection from the tip.

Operator technique can have a considerable impact on the irradiance delivered to the surface of a composite resin restorative material. Researchers at Dalhousie University (Canada) recently developed a teaching tool that accurately measures the useful energy actually delivered to a simulated composite resin restoration from a curing light. The clinician places the tip of the light guide over an energy sensor in a resin tooth that is mounted in a dental mannequin head. With the use of a simple user interface on a laptop computer, the clinician can determine the total radiant exposure received by dental restorations in a clinical setting. Studies using the device showed a dramatic increase in energy when the light guide of the curing light was held steady and carefully placed perpendicular to the surface of the simulated restoration.

In addition to light-related factors, multiple composite-related factors influence the light exposure time of composite resins. Composite-related factors include shade, translucency, type and concentration of photoinitiator, and filler particle size, load and distribution. Some composite manufacturers provide general guidelines for recommended curing time often based on composite increment thickness and shade. However, the basis for such recommendations is rarely identified by manufacturers and no consensus exists in the literature.

Common laboratory techniques for determining depth of cure include scraping the unset material and measuring the remaining specimen thickness (i.e., ISO Standard 4049) or measuring bottom-to-top hardness or conversion ratios. However, the radiant exposure (irradiance × time) levels necessary to adequately polymerize an increment of a specific brand or shade of composite resin are not typically provided by the manufacturer.

Also, there is no consensus on the amount of radiant exposure necessary to achieve adequate polymerization,

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which is not surprising given the large variation in the composition of composite resins. A few studies have shown that a relatively wide range of radiant exposure is necessary, from as low as 12,000 to as high as 36,000 mJ/cm^2 with values of 21,000 to 24,000 mJ/cm^2 commonly reported.

Lighter or translucent shades of hybrid composite resins are generally easier to polymerize whereas darker shades of microfill composites may be more difficult. With microfill composites, the natural agglomeration of the small filler particles may cause light to scatter, decreasing the effectiveness of the light. Manufacturers may provide suggested curing depths for their composite resins depending on the type, shade, or opacity. However, for most composites, a 2-mm increment is routinely recommended due to the attenuation of light.

Curing lights are available today with a wide range of irradiance levels. The curing light manufacturers typically provide these values in their instruction manual. Radiometers are a useful adjunct to be used chairside to monitor the performance of your light over time. However, significant discrepancies in the measurement of irradiance have been found using radiometers; therefore, they are not considered reliable in estimating curing time. Manufacturers should be encouraged to develop and market accurate and economical chairside hand-held radiometer units.

Studies have shown that many of the latest generation of LED curing lights with irradiance levels above 1,000 mW/cm^2 may cure a 2-mm increment of lighter shades of composite in close proximity in 20 seconds. Likewise, PAC curing lights with irradiance levels typically above 2,000 mW/cm^2 may cure a 2-mm increment in three, 3-second cycles. Using the light- and composite-related factors described previously, the curing time should be increased with darker, less translucent shades of composite or microfill composites polymerized at greater distances with poor light-guide angulation or poor collimation of the light.

The current trend by manufacturers is to market LED curing lights with high irradiance values and short curing times (e.g., 5 seconds). Caution should be exercised until research is published investigating the adequacy of polymerization with multiple composite types at various distances using reduced curing cycles with these new high-powered lights. Conversely, there has been a recent suggestion to universally light-cure composite increments for 40 seconds to predictably assure adequate polymerization. However, this general recommendation ignores the potential of high heat exposure, especially with new high-powered lights in close proximity to the teeth and gingival tissues.

The exposure time necessary to adequately polymerize an increment of composite resin depends on a complex combination of factors related to the particular curing light and the composite resin itself. Clinicians should be aware of the basic variables related to photopolymerization and apply them accordingly. The ultimate goal is to decrease the potential of reduced mechanical properties due to insufficient light exposure or over-heating due to overexposure. Manufacturers should be encouraged to provide recommended radiant exposures for each individual shade of composite. Ideally, they should provide a range of time and irradiance values at a given incremental thickness necessary to cause sufficient polymerization.

SUGGESTED READINGS

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EDITOR'S NOTE

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