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Curing Lights In Dentistry And Its Implications – A Review

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Abstract: The purpose of this article is to focus on the ideal requirements, advantages and disadvantages and recent advances of diffetrent curing lights. Light is used to activate the photo-initiator system in the light curing units. Clinicians must understand the principles of light-curing because unbound monomers are cytotoxic. As well, under-curing can cause flex with pumping of the restoration, resulting in postoperative sensitivity.

Keywords: Polymerization; Light; Curing Lights, Dental; Photo-initiators, Dental; Dental Restoration, Permanent.

I. INTRODUCTION

The ability to light cure dental resins "on demand" in the mouth has revolutionized modern dentistry. Consequently the dental light curing unit (LCU) has become an indispensable piece of equipment in almost every dental office. As a general recommendation, when light curing a dental resin, adhesive, sealant, or cement the clinician should aim to deliver sufficient radiant exposure at the correct wavelengths of light required by the photo-initiators in the resin. It is not as just simple as using any curing light for 10 seconds, despite its routine use, the curing light and how it is should be used is not well understood by most operators. For example, every published study that has evaluated LCUs in dental offices has shown that most curing lights are poorly maintained and deliver an inadequate light output. In the majority of offices, the dentists did not know the irradiance from the curing light6 and were unaware that their light was unable to adequately cure their resin restoration. This deficiency is a concern because the use of resins is expected to rise with the worldwide phasedown in the use of dental amalgam as a part of the Minamata Convention.

The use of bonded restorations in restorative dentistry continues to increase, including the number of resin-based composite restorations placed instead of amalgam. Factors that may affect polymerization of resin-based composite restorations include light intensity, exposure time, and wavelength as related to the type of photo-initiator incorporated in the resin-based composite material.

Clinicians must understand the principles of light-curing because unbound monomers are cytotoxic. As well, under-curing can cause flex with pumping of the restoration, resulting in postoperative sensitivity. The effectiveness of a light-curing procedure depends on the light's output power as well as its light spectrum and tip design. The curing exposure time, resin chemistry, photoinitiator type, location and orientation of the restoration, materials that partially block the light, and the clinician's ability to aim and maintain the light on or at the target at 90 degrees are also important factors.

II. POLYMERIZATION

In dentistry almost the entire gamut of resin-based restorative products use the same basic monomer family and polymerization mechanism: methacrylates and vinyl, free radical addition polymerization.

INITIATION OF THE POLYMERIZATION PROCESS

Once created, the freshly formed free radical diffuses through the resin medium in search of a highly electron-rich area, which happens to be the carbon-to-carbon double bond of a methacrylate based monomer. When these two species collide, the resulting effect is the initiation of polymerization, and is displayed in the following diagram. In this process, the free radical takes one electron from the 4 contributing to the carbon double bond, and forms a covalent bond between itself, and one carbon atom. In addition, the now extra electron between the carbons atoms moves to a different shell, leaving behind a single covalent bond between the two carbon atoms, where a double bond occupied this space before. Now, the extra electron in the outermost carbon atom becomes the free radical species, and actively diffuses through the low viscosity resin medium in search of another electron-rich, carbon double bond with which to react, in a similar manner.

III. TERMINATION

The polymerization reaction can stop for a number of different reasons. The concentration of available monomer decreases as the reaction progresses, and the growing radical chains have an ever-increasing difficulty in diffusing through the initially gel like and then glass-like resin matrix. However, the most easily understood mechanism is the scenario when two growing radical ends collide. This results in formation of a covalent bond between them, thus quenching each radical element, bringing further growth of either polymer chain to a halt.

GENERATIONS OF CURING LIGHT

1st Generation- Ultra-Violet Light
2nd Generation- Visible Light Curing Units
3rd Generation- Plasma Arc Units
4th Generation- Light Emitting Diodes
5th Generation- Lasers

ULTRA-VIOLET LIGHT CURING UNITS

As with most advances in dentistry, the original use of ultraviolet (UV) light to cause polymer curing did not originate in the profession, but instead already existed in the printing industry. In the late 1970's, the LD Caulk company introduced the first dental, UV-cured restorative system. The resin formulation was a urethane-methacrylate based, and the compound absorbing radiant energy (the photo-initiator) was activated by exposure to electromagnetic radiation at wavelengths around 365 nm. Formulations for sealants as well as filled, direct, esthetic restorative materials were available (NUVA, Dentsply/ Caulk, Milford, DE).

Despite restorations made using this system lasting many years, problems with lack in incremental thickness placement greater than 1 mm, coupled with the need to expose each increment for 20 to 60 seconds per increment, led to slow adaptation into clinical practice. However, the goal of providing the dentist with a "set-on-command," direct, esthetic restorative material was finally a reality. Light curing units of that time used a UV-emitting source that, unfortunately had to be continually powered, even when not in use, causing decrease in bulb output over time. Additionally, because of the potential for causing cataract formation in the operator, as well as the chance of significantly altering the oral microflora wherever the radiation was directed, radiation limits for dental photopolymerization were restricted to be within that considered as only visible light (380 nm and 700 nm).

VISIBLE LIGHT CURING

It is the physical interaction (absorption) of photons at a given wavelength that gives rise to the conversion of visible light into stored energy, later used for creation of free radicals. Within the visible spectrum, absorption of photons involves consumption of their energy and converting that energy into raising an outer shell electron from its regular orbital layer (the ground state) to a higher orbital layer, where it is not usually present (an excited state). Depending on the photoinitiator used, the compound must either react with an intermediary molecule (an amine), which then goes on to form free radicals (a Type 2 initiator), and cause polymerization, or can directly break down into one or more free radicals, which need no such secondary compounds to assist in initiating polymerization (Type 1 compounds). If the excited state does not result in radical formation, the outer shell electron returns to its lower energy state, releases heat, and a lower wavelength photon. In light-cured system, however, formation of free radicals is totally dependent on the presence of photons within the local restorative environment (within a depth) to cause polymerization. This process is unlike chemical curing, where free radicals are formed throughout the bulk of the curing material, regardless of depth.

PLASMA ARC LIGHTS

In an attempt to reduce light exposure times, PAC lights were introduced. These lights were promoted to deliver a high irradiance and the initial units recommended that exposure times between 3 and 5 seconds could be used to photocure a 2-mm-thick increment of resin composite. Instead of a filament, the PAC light source uses 2 tungsten electrodes that are surrounded by xenon gas. When a high voltage potential is applied, a spark is formed that ionizes the xenon gas.

This spark then acts as both a light emitter as well as an electrically conductive gaseous medium (a plasma) to maintain the spark. The gap between the electrodes is parallel to the long axis of a parabolic-shaped reflector that directs the emitted light forward through a sapphire window. Extreme optical filtering is used in PAC lights to prevent the emission of unwanted ionizing radiation, as well as to prevent an unacceptable temperature increase in the tooth or soft tissues. Most PAC lights deliver a broad emission spectrum, a high radiant power, and a high irradiance. However, at least 1 brand of PAC light had multiple tips to provide different light outputs and outcomes: a bleaching tip (full spectral output), a 470-nm tip for photocuring CQ-containing materials. Although PAC lights are excellent curing lights, they are also expensive, noisy, large, not portable, and cannot be battery operated. As a result, PAC lights have become less popular in recent years.

LIGHT-EMITTING DIODE TECHNOLOGY

The next innovation in dental photo-curing came in the early 1990s when it was reported that the emission spectrum from blue LEDs closely matched the absorption profile of the CQ photo-initiator used in most dental resins. LED curing lights have many advantages because they are solid state, lightweight, battery driven, very efficient, and non-filtered. Their emitting sources can provide a long working life when compared with filament or spark-based light sources. The semiconductor material in blue LEDs is made of a mix of gallium nitride and indium nitride that has been doped with impurities to create a p–n junction between the 2 semiconductor materials. The “p” (positive) side contains an excess of ‘holes,’ and the “n” (negative) side contains an excess of electrons. The color of the emitted light corresponds with the energy of the emitted photon that is in turn determined by the composition of these 2 semiconductors and their resulting “band gap” potential. The blue light emitted from the LED has a relatively narrow bandwidth with a full width half maximum range of about 20 to 25 nm.

LASERS

The term LASER is an acronym for ‘Light Amplification by the Stimulated Emission of Radiation’. As its first application in dentistry by Miaman, in 1960, the laser has seen various hard and soft tissue applications. Dental lasers were introduced and recognized as a tool for better patient care in the early 1990s.The wavelength of the argon laser(between 450 and 500 nm) has been used effectively to polymerize composite resins because it enhances the physical properties of the restorative material compared with conventional visible light curing. Lasers produce little heat, because of limited infrared output. The argon laser is useful in Class II composite restorations, not only because of the decreased curing time needed, but also the small fiber size allows for easy access of the curing light to the interproximal box area and provides a highly satisfactory result for the completed restoration. A major limitation of arc and laser lamps is that they have a narrow light guide (or spot size). This requires the clinician to overlap curing cycles if the restoration is larger than the curing tip.

IV. MECHANISM

Laser light is a monochromatic light and consists of a single wavelength of light. It consists of three principal parts: An energy source, an active lasing medium, and two or more mirrors that form an optical cavity or resonator. For amplification to occur, energy is supplied to the laser system by a pumping mechanism, such as, a flash-lamp strobe device, an electrical current, or an electrical coil. This energy is pumped into an active medium contained within an optical resonator, producing a spontaneous emission of photons. Subsequently, amplification by stimulated emission takes place as the photons are reflected back and forth through the medium by the highly reflective surfaces of the optical resonator, prior to their exit from the cavity via the output coupler. In dental lasers, the laser light is delivered from the laser to the target tissue via a fiberoptic cable, hollow waveguide, or articulated arm. Focusing lenses, a cooling system, and other controls complete the system. The wavelength and other properties of the laser are determined primarily by the composition of an active medium, which can be a gas, a crystal, or a solid-state semiconductor.

V. CONCLUSION

Clinicians currently have few choices in the broadband light category for curing dental composite restorations. Careful evaluation of the requirements for the wide variation in light curing applications and material variations should make the choice easy.

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