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Review Article

The influence of curing light intensity on composite restoration durability

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ABSTRACT

Curing light is currently a crucial part of multiple procedures in dentistry. The main function of curing light is polymerization of composite restorations. Curing light intensity and time are two important factors that can significantly affect the polymerization process. Inadequate curing may lead to restoration fracture, microleakage, secondary caries, and postoperative sensitivity. Recently, different curing light devices with various light intensities have been developed, aiming to minimize polymerization shrinkage. This review aims to examine the impact of different curing light intensities on the durability of various types of composite restoration. Curing light intensity can influence the depth of cure and degree of conversion of the composite restoration. Types of curing light include light-emitting diode (LED), argon lasers, quartz-tungsten halogen (QTH), and plasma arc curing (PAC). Both ultra-fast curing and conventional curing led to an adequate degree of conversion and polymerization degree in bulk-fill resin-based composites. Overall, while ultra-fast curing shows promise, careful consideration of material compatibility and technique sensitivity remains essential to ensure restoration longevity and clinical success.

Keywords: Curing light, Curing, Composite restoration, Restoration, Durability, Curing light intensity

INTRODUCTION

Curing light units have become essential tools in the daily routines of clinicians. This device is used to polymerize restoration, improving its function and durability. Light-curing devices have undergone multiple technological developments, leading to the evolution of various light-curing protocols. These developments include increasing the radiant exitance and narrowing the emission spectrum to a useful wavelength range.[1]

Light produced by these units can affect the polymerization process in different ways, as it has different spectral profiles and light intensities. The irradiated light enters the specimen and is absorbed by the photoinitiator molecules.[2] Notably, light penetration depth into a composite depends on the amount and type of filler, particle size, and particle size distribution.[3]

Camphorquinone is the most used photoinitiator in curing procedures. However, it is important to keep its concentration in a composite resin to a minimum level due to its yellow color that may impair color matching and esthetics. Thus, it is difficult to achieve full polymerization. 1-phenyl-1,2-propanedione (PPD) is another photoinitiator developed to overcome this limitation. It has an absorption peak near 410 nm and has been proposed as an alternative for camphorquinone.[4]

Activation of camphorquinone leads to free radical formation and conversion of C=C double bonds to C–C single bonds, resulting in polymer chain formation and replacing larger van der Waals intermolecular spaces with smaller covalent bonds.[5] This process leads to volumetric shrinkage and subsequent contraction stress. Previous studies have shown that composite resins undergo volumetric shrinkage of 1.7-7.1%, mostly shrinking at 2-3%.[6,7] This polymerization shrinkage leads to fractures of restorations, increased incidence of marginal leakage, postoperative sensitivity, and recurrent caries.[8]

Curing light intensity and time can significantly affect the number of photons delivered to a specimen in the process of polymerization. Typically, a light intensity of 400 mW/cm^2 for 40 seconds is sufficient to polymerize specimens of 2 mm thickness.[9] Recently, light intensity modulation techniques have been introduced in irradiation modes with the aim of minimizing polymerization shrinkage. The conversion of monomers into polymers during the polymerization process requires the delivery of adequate irradiance energy in order to improve the clinical function and physical properties of composite restorations.[10] This has led to the introduction of high-intensity light-curing units, including light-emitting diode (LED), plasma arc, and quartz–tungsten–halogen systems.[11] The LED system has shown better results than other light-curing systems.[12]

It has been reported that the newly introduced high-intensity LED light-curing units result in an adequate depth of polymerization and better physical properties of the resin-based composite restoration along the whole depth of the 2 mm increment of composite restoration owing to their higher irradiance.[13] Given that findings from previous studies assessing the impact of curing light intensity on the function and durability of composite restoration are inconsistent, it is critical to further investigate this impact. The aim of this review is to explore current literature about the influence of different curing light intensities on the durability of various types of composite restoration.

METHODS

A comprehensive literature search was conducted in Medline (via PubMed), Scopus, Google Scholar and Web of Science databases up to 21 July 2025. Medical Subject Headings (MeSH) and relevant free-text keywords were used to identify synonyms. Boolean operators (AND', OR') were applied to combine search terms in alignment with guidance from the Cochrane Handbook for Systematic Reviews of Interventions. Key search terms included: "curing light" OR "curing light intensity" AND "composite" OR "restoration". Summaries and duplicates of the found studies were exported and removed by EndNoteX8. Any study that discusses the influence of curing light intensity on composite restoration durability and published in peer-reviewed journals was included. All languages are included. Full-text articles, case series, and abstracts with the related topics are included. Case reports, comments, animal studies, and letters were excluded.

DISCUSSION

Curing light in dentistry

Curing light plays a key role in the restoration field in dentistry. Its main function is polymerization of light-cured resin-based composites. Curing light devices can convert composites from a soft paste into a functional, long-term restoration through producing specific wavelengths of light, which leads to polymerization of photoinitiators in the composite material. This procedure has been developing since its introduction in the 1970s, becoming more efficient, portable, and light-output controllable.[14] Light-emitting diodes are the current gold standard dental curing lights due to their reduced heat production, compact design, and energy-saving properties.[14] This type can also generate specific wavelengths that align with the absorption spectrum of camphorquinone, the most widely used photoinitiator, which absorbs light optimally at approximately 470 nm.[15] Currently, new generations of LED curing units, such as second and third generation, can generate intensities exceeding 2000 mW/cm^2. They also involve multiple wavelength LEDs to cure a broader range of photoinitiators.[14] Other types of dental curing lights include argon lasers, quartz-tungsten halogen (QTH), and plasma arc curing (PAC).[14]

Curing light intensity and time are important parameters that significantly affect the durability and function of restoration. Curing light intensity can influence the depth of cure and degree of conversion of the resin. Curing time mainly depends on light intensity, composite type, and thickness of the restoration and typically ranges from 10 to 40 seconds.[14] Shorter exposure times can be achieved by applying higher curing intensity, resulting in the introduction of high-intensity curing protocols, such as 3- to 5-second "ultrafast" curing. However, this protocol may lead to significant polymerization shrinkage stress, particularly in conventional composites, potentially worsening marginal integrity.[16]

Besides curing light intensity and time, composite formulation significantly affects the effectiveness of polymerization, particularly the type of monomers and filler content. Notably, adequate curing should be applied to both the top and bottom surfaces of the restoration. A bottom-to-top microhardness ratio of ≥80% indicates satisfactory depth of cure.[17] Improper curing may result in worse mechanical properties, increased microleakage, wear, marginal degradation, postoperative sensitivity, and secondary caries. Furthermore, it is critical to appropriately handle and maintain curing light. It is critical to clean the light tip of resin debris or scratches and to regularly use radiometers to check the output intensity before the procedure, as these factors can significantly reduce curing efficiency.[18] Advancements in bulk-fill resin composites, which are designed to be cured in thicker increments (up to 4–5 mm), have driven the demand for more powerful curing units.[17] These materials have enhanced translucency and modified filler and matrix compositions to facilitate deeper light penetration. Manufacturers often recommend specific light intensities and exposure times for optimal results with these materials.

Curing light intensity impact on composite

Multiple studies assessed the effects of high-intensity and conventional-intensity curing light on different types of composites by evaluating marginal discoloration, marginal adaptation, secondary caries, and postoperative sensitivity.

Marginal adaptation

Marginal adaptation plays a key role in the prognosis and durability of composites. Shrinkage stress can be minimized through proper placement of resin composites, composite formulation, and curing.[19] Furthermore, secondary caries may result due to marginal defects in restoration 20 or high-caries-risk patients.[21]

Azazy et al reported adequate marginal adaptation with both curing light intensities, as no significant difference was observed between them.[22] Fahim et al reported similar results; however, they reported a significant increase in the percentage of discontinuities in high-intensity cured restorations during in vitro assessments.[23] It is critical to achieve a perfect seal between teeth and restoration to prevent microleakage, marginal discoloration, recurrent caries, and pain.[24] A previous study by Par et al found that high-intensity curing (3 s at 3440 mW/cm²) achieved marginal integrity similar to conventional curing (10 s at 1340 mW/cm²).[25] These findings highlight that selection of composite types is more important than curing protocols.

The improved marginal adaptation reported by Azazy et al can be attributed to the ethanol-based nature of Futurabond M+, which can result in a higher adaptation of the adhesive to the dentin, reducing marginal microleakage.[26] Furthermore, finishing and polishing can improve marginal integrity by maintaining the seal of the restoration, preventing the microcracks, and resisting leakage.[27] Despite the clinical adequacy of marginal adaptation achieved, restorations cured with high-intensity light had two times more risk for low marginal adaptation score (score B), mainly due to polymerization stress at the tooth-restoration interface.[22,28] This stress may result in hydrolytic degradation over time.[29]

Marginal discoloration

Marginal discoloration is an early sign of resin restoration failure that occurs due to defects between the restoration and the tooth surface. Azazy et al found no significant difference in marginal discoloration between curing protocols at different follow-up periods.[22] However, only a few restorations showed discoloration at later follow-ups. Fahim et al and Yazici et al reported results that support these findings.[23,24] On the other hand, Karaarslan et al. reported that three x-tra fil restorations cured for 10 s at 1200 mW/cm^2 light intensity were exposed to marginal discoloration (scoring B) after 12 months.[30] Azazy et al also reported positive outcomes of x-tra fil that may be attributed to its high depth of polymerization and resin matrix (Bis-GMA and UDMA), which can decrease stress and improve depth of cure.[31,32] Additionally, finishing and polishing can improve appearance and prevent marginal discoloration, plaque retention, and secondary caries.

Secondary caries and postoperative sensitivity

Azazy et al reported no cases of secondary caries except for only one case in the high-intensity light-curing group that showed secondary caries (score B).[22] This rarity of secondary caries can be attributed to adequate sealing, adequate marginal adaptation, and adequate oral hygiene in the patient. Fahim et al reported comparable findings, while Karaarslan et al reported different findings.[23,30] Postoperative sensitivity is a common complication of resin composite restoration that usually occurs due to shrinkage stress.[33] Azazy et al reported no postoperative analysis, which may be attributed to selective etching with universal adhesives, satisfactory marginal adaptation, and rubber dam isolation.[34,35] Fahim et al also reported no significant sensitivity at follow-ups.[23] In contrast, Karaarslan et al found sensitivity in cases lacking calcium hydroxide liners.[30]

Microhardness

Microhardness and surface roughness are essential properties for the durability, function, and esthetics of restorations. High microhardness of restoration improves the resistance to surface wear and scratching, while low microhardness leads to plaque accumulation, periodontal disease, and secondary caries.[36,37] Low microhardness is mainly a result of inadequate polishing. A recent study by Jakupovic et al examined the effects of different curing light intensities and different composite types on the microhardness of resin restorations.[38] Notably, resin composite hardness is determined by the monomer-to-polymer conversion ratio, influenced by curing protocols, materials' compositions, and process parameters.[38]

Jakupovic et al found that both composite materials and curing protocols significantly affect microhardness, with composite materials having a stronger effect.[38] Notably, curing protocols have a significant effect on the bottom surfaces of specimens.[39] The effects of different curing light intensities on the microhardness have been inconsistent in previous studies, mainly due to differences in materials and testing procedures.[40-42] Regarding composite types, sculptable composites demonstrated better microhardness than flowable composites, with Tetric Evo Flow exhibiting the lowest values.[38]

Par et al also reported that different curing protocols led to various microhardness values in flowable composites.[1] Furthermore, high-intensity curing light has shown more negative effects on flowable composites. Such results may be attributed to their lower filler content and structural strength.[43,44] Therefore, sculptable composites are more suitable for high-stress areas.

High intensity versus conventional intensity curing

A recent scoping review evaluated the effects of ultra-fast high-intensity curing light on different properties, including degree of conversion, microhardness, and polymerization kinetics, of bulk-fill resin composite. The ultra-fast curing in the 3 s PowerCure system has shown an adequate degree of conversion, with bulk-high viscosity composites showing a similar or higher degree of conversion than conventional composites.[45,47] However, ultra-fast curing light was associated with a lower degree of conversion in two previous studies.[1,48] The ultra-fast curing resulted in lower microhardness in PowerFlow and PowerFill composites, while other studies reported no significant differences in microhardness between curing light protocols.[38,49-52] Previous studies have shown differences in the polymerization kinetics of bulk composites using the 3 s PowerCure system.[53]

Notably, no significant differences in cell viability were observed between ultra-fast and standard curing.[54] Various studies have evaluated the effects of ultra-fast curing on viscoelastic and mechanical behavior, including quasi-static behavior, resistance, flexural modulus, linear shrinkage, and artificial aging, of different types of composites. No significant difference was observed in quasi-static behavior, resistance, and flexural modulus between different curing protocols.[55,56] Furthermore, the effect of ultra-fast curing on linear shrinkage and polymerization stress of bulk composites was similar to that of conventional composites.[1,53] Artificial aging reduced mechanical properties for both composites.[45]

The positive outcomes of the usage of the ultra-fast curing 3 s PowerCure system in PowerFill composite included no cellular toxicity, moderate viscosity, high light transmission, improved marginal integrity, structural integrity improvements, comparable microtensile bond strength, and less polymerization shrinkage and similar shrinkage stress, while negative outcomes included increased water solubility, increased porosity, clinically unacceptable color stability, and greater volumetric wear.[28,46,47,51,57-60] The positive outcomes of its usage in PowerFlow composite included intact internal structure, lower water sorption and solubility, and comparable depth of cure to conventional curing, while negative outcomes included higher shrinkage stress, significantly lower marginal integrity, reduced bond strength to dentin, greater marginal discoloration, and negative impact on flexural modulus.[25,28,45,46,59]

In summary, the review found that the 3 s PowerCure system showed comparable results to conventional resin composites, even with ultra-fast light-curing delivering half the energy of the conventional curing, which demonstrates its suitability for clinical application.[55] It also found that polywave light-curing units with high irradiance benefit resin composites with alternative photoinitiators like Ivocerin and that ultra-fast curing of conventional bulk-fill resin-based composite is associated with inferior performance due to lack of optimization for low-energy curing.[51] Both ultra-fast curing and conventional curing led to an adequate degree of conversion and polymerization degree in bulk-fill resin-based composites with Ivocerin.[49,55,60] Additionally, the review reported that selecting the materials for the composite is more necessary than the curing protocol.[16,50,52]

CONCLUSION

Dental curing lights play a pivotal role in modern restorative dentistry, directly influencing the mechanical and clinical performance of resin-based composites. Advances in light-curing technology, especially the introduction of high-intensity and ultra-fast curing protocols, have significantly improved clinical efficiency. However, the effectiveness of these protocols varies depending on composite formulation, filler content, and restoration thickness. Overall, while ultra-fast curing shows promise, careful consideration of material compatibility and technique sensitivity remains essential to ensure restoration longevity and clinical success.

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