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Review Article

Dental Curing Light : Sustainability, Environmental and Cancer Responsibility

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Abstract

Cancer remains a significant global health concern, and while strides have been made in various medical domains, its potential correlation with dental curing lights warrants thorough investigation. This comprehensive review explores the evolution and utilization of photo-curable resin composite (RC) restorations, a cornerstone of modern dental practice, and the pivotal role of light-curing units (LCUs) in their application. The enhanced mechanical properties and superior esthetic outcomes of RC restorations have led to their widespread adoption, reflecting evolving patient preferences towards minimally invasive and cosmetic appealing dental treatments. However, the efficacy of RC restorations is intrinsically linked to the proper usage of LCUs, highlighting the critical importance of understanding their characteristics and correct application. Despite advancements in curing light technology, discrepancies in output descriptions and usage persist, potentially compromising the quality and longevity of dental restorations. The meeting of key opinion leaders and manufacturers in 2014 yielded invaluable recommendations for selecting and utilizing curing lights, emphasizing factors such as regulatory compliance and the adoption of standardized output metrics. The historical progression of curing light technology, from UV radiation-based devices to modern LED-based units, underscores a continual pursuit of safer, more efficient solutions for dental procedures. Nevertheless, concerns regarding potential health risks, including cancer, persist, particularly concerning prolonged exposure to blue light and the generation of free radicals during the curing process. While current evidence suggests that curing lights are generally safe for clinical use, ongoing research is necessary to elucidate any long-term implications and mitigate potential risks.

Keywords: Cancer; Dental Curing Lights; Free Radicals; Light Curing Units

Introduction

The utilization of photo-curable resin composite (RC) restorations has experienced a notable surge, thanks to several factors. Foremost among these is the marked enhancement in mechanical properties, rendering RC materials increasingly robust and dependable for various dental procedures [1]. This heightened durability ensures that RC restorations can withstand the demands of daily use, fostering their growing preference among both dental practitioners and patients alike. Moreover, RC restorations are prized for their ability to deliver superior esthetic outcomes [2]. Through precise color matching and meticulous application techniques, these materials seamlessly blend with surrounding teeth, yielding a natural and aesthetically pleasing restoration. This aesthetic appeal significantly contributes to patients' inclination towards RC restorations as they seek treatments that not only restore dental health but also enhance the overall appearance of their smile [3]. Furthermore, the escalating demand for RC restorations is reflective of evolving patient preferences. With a growing emphasis on cosmetic dentistry and a preference for minimally invasive procedures, RC materials align seamlessly with these evolving trends. Their capacity to preserve natural tooth structures while still achieving exceptional esthetic and functional results makes them an appealing choice for individuals seeking dental restoration. In summary, the convergence of improved mechanical properties, superior aesthetic outcomes, and alignment with patient preferences has propelled the widespread adoption of photo-curable resin composite restorations in contemporary dental practice [4]. The FDI World Dental Federation represents over one million dentists globally, who heavily rely on dental light-curing units (LCUs) in their practice [5]. The efficacy of these LCUs and their proper usage significantly impact the physical properties, biocompatibility, and clinical success of various light-cured dental polymer systems, such as resin-based composites, adhesives, orthodontic resins, luting agents, and sealants. A striking contrast exists between the reported longevity of resin composite restorations in controlled clinical trials and their real-world performance in dental offices. This disconnect can be attributed, at least in part, to a widespread lack of understanding regarding LCUs – their characteristics, output descriptions, and correct usage [7]. This knowledge gap often leads to dentists inadvertently using LCUs incorrectly or opting for cheaper, subpar devices under the mistaken assumption that all LCUs emit similar blue light with equivalent efficacy [8]. Consequently, patients may receive inadequate energy or incorrect wavelengths during the light-curing process, compromising the quality and durability of their dental restorations [9]. The goal of this article is to empower readers with the necessary insights to make informed decisions when purchasing and utilizing curing lights. By understanding the nuances of different LCUs and the potential pitfalls of relying solely on reported irradiance values, dentists can enhance the quality of their clinical practice and improve patient outcomes. The goal of this article is to empower readers with the necessary insights to make informed decisions when purchasing and utilizing curing lights [10]. By understanding the nuances of different LCUs and the potential pitfalls of relying solely on reported irradiance values, dentists can enhance the quality of their clinical practice and improve patient outcomes. In the dental industry, the prevailing trend revolves around the prevalence of compact, battery-operated LED curing lights, lauded for their energy efficiency and portability. However, when it comes to purchasing decisions, clinicians often prioritize factors such as cost and a single irradiance value surpassing 1,000 mW/cm², inadvertently overlooking the substantial variability in light output among the available array of curing units [11]. Recognizing this notable gap in understanding, a pivotal meeting held in 2014 brought together esteemed key opinion leaders and manufacturers. Their collective effort yielded a consensus on pivotal considerations essential for selecting and effectively utilizing curing lights. These invaluable recommendations have since been made readily accessible to clinicians seeking to optimize their practice [12]. It's imperative to underscore the regulatory classification of dental curing lights as medical devices in numerous countries. This classification underscores the critical importance of ensuring that any curing light used possesses the requisite certification or approval for patient application. Indicators of suitability encompass the presence of certification labels, comprehensive usage instructions, reliable avenues for support contact, and inclusion within regulatory authority databases [13]. Nevertheless, persistent discrepancies persist in the way manufacturers and researchers articulate descriptions of LCU light output, potentially leading to misconceptions and misinformation within the field. To foster clarity and precision, advocating for the universal adoption of the International System of Units (S.I.) for elucidating LCU light output emerges as a paramount recommendation [14].

History

According to Strassler, in the early 1960s, the first light-curing resin composites were introduced; this led to the development of the first curing light [15]. The first dental-curing light was developed in the 1970s. In the 1970s, a groundbreaking advancement in dental technology emerged with the introduction of the first dental-curing light. Developed by Dentsply/Caulk and known as the Nuva Light, this pioneering device utilized ultraviolet (UV) light for material polymerization. However, despite its innovative design, the Nuva Light encountered significant challenges associated with UV light usage. Chief among these challenges was the inherent limitation of UV light's shorter wavelengths, which restricted the depth of cure achievable during the polymerization process [16]. This limited depth of cure compromised the effectiveness of the Nuva Light in curing dental materials, impacting the quality and durability of dental restorations [17]. Furthermore, concerns regarding the safety of UV radiation added to the device's drawbacks. The potential risks associated with UV exposure raised apprehensions among dental professionals, casting doubt on the device's suitability for widespread clinical use. Ultimately, due to these limitations and safety concerns, the Nuva Light was discontinued [18]. Despite its discontinuation, Nuva Light's early efforts paved the way for subsequent advancements in light-curing technology. Through continued innovation and refinement, modern dental-curing lights have evolved to offer safer, more efficient, and effective solutions for dental procedures, ensuring optimal patient care and treatment outcomes. During the early 1980s, notable advancements occurred in the realm of visible light curing, marking a significant departure from the reliance on UV radiation for dental restorative procedures. A pivotal moment occurred on February 24, 1976, when Dr. Mohammed Bassoiuny, from the Turner School of Dentistry in Manchester, achieved a milestone by placing the first visible light-cured composite restoration on Dr. John Yearn, the department's head at the time. This breakthrough laid the groundwork for the development of a new generation of curing devices, harnessing the power of blue light. Subsequently, the introduction of the quartz-halogen bulb emerged [4,19] as a pivotal development, offering longer wavelengths within the visible light spectrum. This innovation facilitated greater penetration of curing light and energy, effectively supplanting UV-curing lights. The transition to quartz-halogen bulbs represented a significant leap forward in dental curing technology, enhancing the efficiency and efficacy of restorative procedures. The 1990s heralded remarkable advancements in light-curing devices, with a dual focus on refining existing technologies and pioneering new innovations. A primary objective during this period was to augment the intensity of curing lights to enable faster and deeper cures, thereby enhancing treatment outcomes and efficiency [20]. In 1998, the landscape of light-curing technology underwent a paradigm shift with the introduction of the plasma arc curing light. This groundbreaking device utilized a high-intensity light source, comprising a fluorescent bulb containing plasma, to polymerize resin-based composites. Promising swift curing times, as short as 3 seconds, the plasma arc curing light offered unprecedented speed and efficiency [21]. However, practical application revealed that actual curing times averaged between 3 and 5 seconds, highlighting the complexities inherent in translating theoretical advancements into clinical practice [4].

Diverse curing units dimensions of light

Within the realm of dentistry, the light-curing unit stands as a pivotal tool, proficient in emitting high-intensity blue light spanning the wavelength spectrum of 400 to 500 nm [22]. Crafted specifically to catalyze the polymerization of dental materials sensitive to visible light, an ideal light-curing unit should embody a spectrum of essential characteristics:

- **Broad Emission Spectrum**: A wide spectrum of emitted light ensures comprehensive polymerization, catering to varied dental materials.
- **Adequate Light Intensity**: Ensuring sufficient light intensity guarantees effective curing, pivotal for successful dental procedures.
- **Consistent Energy Delivery**: Minimal drop-off of energy over distances ensures uniform polymerization across dental surfaces.
- **Versatile Curing Modes**: Offering multiple curing modes grants flexibility, addressing diverse clinical requirements with precision.
- **Extended Operation Time**: Sufficient duration for multiple curing cycles allows for uninterrupted workflow, enhancing procedural efficiency.
- **Robust Durability**: Sturdy construction ensures longevity and reliability, vital for enduring performance in clinical settings.
- **Ample Curing Coverage**: A broad curing footprint enables simultaneous treatment of larger surface areas, optimizing time and resources.
- **Ease of Maintenance**: Simple repairability and maintenance facilitate seamless upkeep, minimizing downtime and maximizing utility.

Categorized into distinct generations, light-curing units have evolved through technological advancements:

- 1st Generation - Ultraviolet Light: Originating with UV light, this generation laid the foundation for subsequent developments.
- 2nd Generation - Visible Light-Curing Units: Transitioning to visible light, this generation enhanced safety and efficacy in dental procedures.
- 3rd Generation - Plasma Arc Units: Introducing high-intensity light sources, this generation accelerated polymerization, streamlining dental workflows.

- 4th Generation - Light-Emitting Diodes (LEDs): Marked by the advent of LEDs, this generation offered enhanced efficiency, durability, and versatility.
- 5th Generation - Cutting-edge Lasers: The latest frontier, leveraging laser technology for precise and expedited dental interventions.

Embedded within these technological advancements lie the key components of light-curing units: handpieces, light guides, power modules, and more, each contributing to the unit's functionality and efficacy [23,24].

Selection of composite materials and light-curing protocols

A comprehensive investigation encompassed seven distinct resin composites, carefully chosen to represent varied material classes: conventional, bulk-fill, sculptable, and flowable composites (refer to Table 1 for details). Noteworthy among the selection are Tetric Power Fill and Tetric PowerFlow, tailored specifically for high-intensity light-curing applications, adding depth and diversity to the composite materials studied [25].

Evaluation of Light-Curing Protocols

- 3-second Protocol ("3-s"): This protocol involved light-curing for 3 seconds, employing a radiant exitance of 3,440 mW/cm^2 (resulting in a radiant exposure of 10.3 J/cm^2).
- Conventional Protocol: In contrast, the conventional protocol entailed a longer light-curing duration of 10 seconds, utilizing a radiant exitance of 1,340 mW/cm^2 (resulting in a radiant exposure of 13.4 J/cm^2).

The meticulous execution of light-curing procedures was facilitated using a cutting-edge violet-blue LED curing unit (Bluephase PowerCure, Ivoclar Vivadent, Schaan, Liechtenstein), characterized by an emission wavelength range spanning 390 to 500 nm. Rigorous attention to detail was ensured through the periodic measurement and validation of radiant exitance values using a meticulously calibrated and NIST-referenced UV–Vis spectrophotometer system (MARC; BlueLight Analytics, Halifax, Canada). This meticulous approach guaranteed precision and reliability in the light-curing process throughout the experimental duration [13-15].

Health and safety issues

Potential cancer risks and safety measures related to dental curing Lights

- **Curing lights:** Widely utilized in dentistry to solidify dental materials, commonly employ LED technology to emit a specific light wavelength that triggers the curing process of dental resins. These lights are generally deemed safe for dental procedures when utilized appropriately and following safety guidelines. However, concerns regarding potential health risks, including cancer, have emerged primarily due to exposure to specific light wavelengths and the generation of free radicals [26].
- **UV Radiation**: Some older models of curing lights emitted ultraviolet (UV) radiation, a known carcinogen. Extended exposure to UV radiation can harm DNA in cells and heighten the risk of skin cancer. Nevertheless, modern curing lights predominantly utilize LED technology, which emits minimal UV radiation, thus substantially reducing this risk [27].
- **Blue Light:** LED curing lights emit blue light, which possesses a shorter wavelength and higher energy compared to other visible light wavelengths. Ongoing research investigates the potential effects of blue light exposure on health, including its influence on disrupting circadian rhythms and potentially contributing to eye damage. While no conclusive evidence directly links blue light exposure from curing lights to cancer, some studies suggest that prolonged exposure to blue light may elevate oxidative stress and induce cellular damage, theoretically increasing cancer risk [28].
- **Free Radical Production**: The curing process entails the activation of photo-initiators in dental resins, which generate free radicals to initiate polymerization. While vital for curing dental materials, excessive exposure to free radicals can induce oxidative stress and cellular damage, potentially increasing the risk of cancer development over time [29].

The interaction between diverse curing lights and the materials used in dental restorations during the curing cycle can potentially impact oral tissues in various ways, possibly leading to changes that contribute to cancer development. These lights emit different spectra of light, including visible light and sometimes ultraviolet (UV) radiation, which is known to induce DNA damage in cells, potentially causing genetic mutations conducive to cancer. Furthermore, some curing lights generate considerable heat during the process, which, upon prolonged exposure, can induce cellular stress and inflammation in oral tissues, fostering an environment favorable for cancer initiation or progression. Additionally, the materials used in restorations, such as composite resins and bonding agents, may contain substances that leach out or release toxic byproducts during curing. These substances, like monomers or additives, could have carcinogenic properties or disrupt cellular function, potentially promoting cancer development. Moreover, the polymerization process initiated by curing lights can generate free radicals, causing oxidative damage to cellular components and further contributing to tissue changes associated with cancer. The duration and intensity of exposure to these factors during dental procedures also play a role, with prolonged or repeated exposure increasing the cumulative risk of tissue damage and cellular changes linked to cancer development. While the specific mechanisms and clinical significance require further investigation, understanding these interactions is crucial for ensuring the safety of dental procedures and minimizing potential risks to patients' oral health [30,31].

Electromagnetic risk from curing lights

There have been concerns regarding electromagnetic (EM) emissions from external electrical devices, such as Light-Curing Units (LCUs), potentially interfering with intracardiac signals and disrupting the function of implanted cardiac pacemakers. However, a 2015 study found that dental curing lights did not appear to interfere with pacemakers or defibrillator pacing/sensing function, suggesting minimal risk to patients. It's worth noting that companies are mandated to test for this potential hazard before marketing electrical devices, ensuring patient safety when purchasing from reputable manufacturers.

Term	Units	Symbol	Notes
Radiant Power	Watt	W	Radiant energy per unit time (joules per second).
Radiant Exitance	Watt per square centimeter	W/cm^2	Radiant power emitted from a surface, such as the tip of a curing light, averaged over the tip area.
Irradiance	Watt per square centimeter	W/cm^2	Radiant power incidents on the surface of known area, averaged over the surface area.
Radiant Energy	Joule	J	Energy from the source (Watts per second).
Radiant Exposure	Joule per square centimeter	J/cm^2	Energy received per unit area, sometimes incorrectly described as "energy density".
Radiant Energy Density	Joule per cubic centimeter	J/cm^3	Volumetric energy density.
Spectral Radiant Power	Milli-Watt per nanometer	mW/nm	Radiant power at each wavelength of the electromagnetic spectrum.
Spectral Irradiance	Milli-Watt per square centimeter per nanometer	$mW/cm^2/nm$	Irradiance received at each wavelength of the electromagnetic spectrum

Table 1

These radiometric terminologies aid in describing the output from light sources and are crucial for understanding the energy distribution and potential risks associated with their use [20-23].

Discussion

Curing lights play a pivotal role in modern dentistry, facilitating the polymerization process of resin-based materials used in various dental procedures, including restorations, bonding, and orthodontic treatments. The utilization of curing lights has revolutionized dental practices, offering numerous benefits while also posing certain challenges and considerations.

Research on the effects of dental curing lights on cells and their potential for causing malignant transformations is limited, but there are some studies that have explored the topic. One study published in the "Journal of American Dental Association" investigated the genotoxic effects of LED and QTH dental curing lights on human gingival fibroblast cells. The researchers found that both types of curing lights caused DNA damage and oxidative stress in the cells, although the LED light exhibited a greater genotoxic effect compared to the QTH light. The genotoxic effects observed in the study on human gingival fibroblast cells exposed to LED and QTH dental curing lights are likely due to a combination of factors including emission of ultraviolet radiation, generation of heat, production of free radicals, and prolonged exposure duration, with differences in light characteristics potentially influencing cellular responses. These factors collectively contribute to cellular stress and DNA damage, increasing the risk of genetic mutations and potentially malignant transformations over time [24].

Enhanced clinical efficiency and precision

The advent of curing lights has significantly enhanced clinical efficiency by allowing for rapid and controlled polymerization of dental materials. Dentists can achieve precise and predictable outcomes due to the ability to control light intensity, duration, and spectral characteristics. This precision is particularly crucial in achieving adequate polymerization depths and ensuring the longevity and integrity of restorations [19-22].

Expanded Treatment Options

Curing lights have broadened the scope of treatment options available to dental practitioners. With the development of specialized light-curable materials, such as bulk-fill composites and adhesive systems, clinicians can now perform a wider range of procedures with improved ease and efficacy. This includes the ability to complete multi-surface restorations in a single visit, reducing chair time and enhancing patient convenience [11-14].

Challenges and considerations

Despite their numerous advantages, curing lights pose certain challenges and considerations that warrant attention:

- **Uniform Light Distribution:** Ensuring uniform light distribution across the treatment area is essential for achieving consistent polymerization and minimizing the risk of inadequate curing. Variations in light intensity and distribution may lead to incomplete polymerization, compromising restoration integrity and longevity [10].
- **Optimal Curing Parameters**: Determining the optimal curing parameters, including light intensity, exposure time, and wavelength, is critical for achieving optimal outcomes. Insufficient or excessive light exposure can result in undercured or overcured restorations, leading to compromised mechanical properties and increased risk of secondary caries [8].
- **Patient Safety**: Concerns regarding patient safety, particularly regarding potential adverse effects of curing light exposure on oral tissues and systemic health, require careful consideration. While current evidence suggests that curing lights are generally safe for clinical use, ongoing research is necessary to assess any long-term implications and mitigate potential risks [27].
- **Technological Advances:** Rapid advancements in curing light technology necessitate continuous education and training for dental professionals to stay abreast of the latest developments and best practices. Incorporating new technologies, such as LED and plasma arc curing lights, may offer advantages in terms of efficiency, versatility, and patient comfort, but require thorough understanding and implementation [15-17].

Conclusion

The utilization of dental curing lights in modern dentistry has significantly impacted patient care and treatment outcomes. While these devices offer numerous advantages in terms of clinical efficiency and precision, there are growing concerns regarding their potential implications for cancer risk. Research exploring the effects of dental curing lights on cells and their potential for causing malignant transformations is limited but noteworthy. Studies have indicated that prolonged exposure to certain wavelengths of light emitted by curing lights, particularly blue light, may elevate oxidative stress and induce cellular damage, theoretically increasing cancer risk. Additionally, the generation of free radicals during the curing process poses another potential mechanism for cellular damage that could contribute to cancer development over time. Despite advancements in curing light technology and safety measures, these concerns underscore the importance of continued research to elucidate any long-term implications for cancer risk associated with dental curing lights. Clinicians must remain vigilant in minimizing patient exposure to potentially harmful wavelengths and optimizing curing protocols to ensure patient safety. Additionally, regulatory authorities should consider implementing standardized guidelines for the safe use of curing lights in dental practice, with a particular focus on mitigating potential cancer risks. By addressing these concerns and advancing our understanding of the relationship between dental curing lights and cancer, we can better safeguard the health and well-being of dental patients worldwide.

Conflict of Interest

None.

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