Role Of Organic Led And Quantum Dots In Light Cure- An Update

Jai Rexlin P.E[1], JayalakshmiSomasundaram[2] ,Anitha Roy[3].

Running title: Organic LED and Quantum dots in Light cure.
Type of article: Review.

[1]Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India.
[2]Chief Scientist,White Lab- Material Research Centre,Saveetha Dental College and Hospitals,Saveetha Institute of Medical and Technical Sciences, SaveethaUniversity,Chennai, India.
[3]Associate Professor, Department of Pharmacology,Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India.

Mail ID:[1]151801033.sdc@saveetha.com, [2]jayalakshmisomasundaram@saveetha.com, [3]anitharoy@saveetha.com

Abstract:Dental curing light is a device that facilitates polymerisation in light cure resin based composites. Dental curing light polymerizes different materials that are curable by light. Due to the increase in need of Resin based composites with improved physical properties having less stress and marginal interface, recent advancements in light cure led to the introduction of Fourth generation LED, Organic LED and Quantum dots. Scanwave-MiniLed is the first fourth generation LED that can minimize heat effects thereby preventing the hotspots. Organic LED works on electric current wherein there is a formation of organic layer between the two electrodes. Organic LEDs can evenly irradiate all surfaces of photopolymerizable impression trays. Organic LEDs can cause photoinitiation in photocurable impression material, whose applications are Vital bleaching and veneer cementation. Quantum dots,on the other hand, are incorporated into photopolymerizable resin composite from where it allows curing from within. Transition of electrons from valence band to conduction band can cause photoinitiation and since the fluorescent properties of quantum dots closely match that of the natural human teeth, quantum dots are considered to have a good biocompatibility.Manufacture of Organic LEDs with flexibility, transparency and low energy light curing procedures and also quantum dot nanoshells in LED Light cure are the future scopes of this study.Hence, this study reviews the role of organic LED and quantum dots in light cure.
Keywords: Light Cure; Organic LED; Photopolymerization; Quantum dots; Resin based composite.

1. INTRODUCTION:

Photopolymerization has become a widely essential tool in 3D printing which is usually done with help of a cone beam computed tomography [1] , construction of polymer electronics , optical materials , membranes, and coatings, and in surface modifications. The common photopolymerization monomers are cyclic epoxides (cationic) and acrylate-based monomers (radical) [2].Post-operative sensitivity in teeth after doing a composite restoration is caused by residual stress buildup due to polymerization shrinkage resulting in de-bonding of the restoration ensuing in an enamel crack,microleakageat the margins of the restoration and secondary caries resulting in postoperative sensitivity [3]. Acrylate-based photopolymers are important materials for cardiovascular applications , in vivo drug delivery , and for minimally invasive procedures. Dimethacrylate-based resins [4] have many applications in restorative dentistry, being used as adhesives and pit-and-fissure sealants, and can be combined with silane-coated glass fillers to render the most widely used esthetic direct restorative material, and can be used as cementation agents and veneering materials.Additionally, Restoration using direct composite resin is an excellent treatment option to conserve more tooth structure in root canal treated teeth . Direct restoration with composite resin provides more resistance against tooth fracture [5]than amalgam, as well as providing intracoronal reinforcement and previous studies suggest the foci of calcification and collagen fibre bundles formation are seen within 7 days of its restoration [6]**.**In a direct composite restoration, the shape is more important than the shade,hence the operator should concentrate more on the line angles which is the determining factor for shape [7]**.**The treatment of tooth wear caused by enamel erosion, abrasion and attrition is complex and demanding in terms of both the operator's time and cost to the patient. The main complication is that teeth with severe wear have short clinical crown height, treatment extremely challenging.Studies support the use of composites to restore worn anterior teeth. After stable occlusion has been achieved, the composite can be maintained by polishing and repairing, or it can be replaced with crowns. And recent studies have found that grape seed and cranberry extract can be used to prevent enamel corrosion [8].Light-cured calcium hydroxide liners 56 A visible light-cured (VLC) calcium hydroxide liner consists of calcium hydroxide and barium sulfate dispersed in a urethane dimethacrylate resin containing initiators and accelerators activated by visible light.Calcium hydroxide is well known to be an intracanal medicament when it comes to root canal treatment [9].Photopolymerization starts with exposure to a light source, the operation wavelength of which depends on the photoinitiator added. For the photopolymerization process to be effective, the spectral radiant power of the light-curing unit must fall within the spectral range required to activate the photoinitiator present in the resin .Dental curing light is a device that facilitates polymerisation in light cure resin based composites. Dental curing light polymerizes different materials that are curable by light. The light falls under the visible blue spectrum with a range of wavelengths for each type. The sources of Dental curing light are 4 basic types which are Tungsten halogen, Light Emitting Diode, Plasma arc and Lasers [2]. Due to the increase in need of Resin based composites with improved physical properties having less stress and marginal interface, the light curing has evolved with advancements. Recent advancements in light cure includes Fourth generation LED, Organic LED and Quantum dots. *Scanwave*-MiniLed is the first fourth generation LED that can minimize heat effects thereby preventing the hotspots. On the other hand, Organic LED uses electric currents and it is extremely flexible. Quantum dots are semiconductor nanostructures that can release more energy.Organic Light Emitting Diode emits light in response to electric current. This electric current enhances the formation of organic layer between the two electrodes and it is used as a light curing device for photocurable impression material [10]. Quantum dots encapsulation in polymers can improve the photoluminescence and stability of the device performance(in case of optoelectronic light emitting diode) leading to the release of more energy [11]. Quantum dots are incorporated into light curable resin composite. Zinc oxide quantum dots arenon agglomeratednanoscale fillers for adhesive resins and are found to be biocompatible and these are incorporated into the dental resins. However, there is no clear data or information on the mechanism of how organic LED and quantum dots work. This study aims to determine the role organic LEDs and quantum dots in light cure. More than 100 articles were collected from bibliographic databases and 35 articles that were more appropriate with the title of this review article were selected to compile this review article.

2. RECENT ADVANCEMENTS IN LIGHT CURE:

*Scanwave*by MiniLed is the first fourth generation LED light that has come to the market. It features patented wavelength scanning technology incorporated into its mode selection, allowing the operator to choose the most appropriate spectral output mode and radiation time for any possible material and clinical situation. It has four different diode wavelengths , the most of any dental LED to date, offering broad spectrum curing in 'Full scan' mode for all resin-based materials, irrespective of their photoinitiationchemistry. *Scanwave*helps in curing experimental curing with three common dental photoinitiators found in modern resin-based restorations [12].

Organic LED works on electric current. The name Organic is because of the organic layer formation between the cathode and the anode [13]. Organic LEDs can evenly irradiate all surfaces of the impression trays. It can polymerize photocurable impression material. Vital bleaching and cementation of veneers are two of its main applications.Thereare two main families of OLED: those based on small molecules and those employing polymers. Adding mobile ions to an OLED creates a light-emitting electrochemical cell (LEC) which has a slightly different mode of operation [14].

Quantum dots are incorporated into the photopolymerizable resin composite and they allow curing from within. Its fluorescence properties closely match that of the natural human teeth. Dental resin composites are tailored using CdSe/ZnS core shell quantum dots.Inphotocatalysis, electron hole pairs formed in the dot under band gap excitation drive redox reactions in the surrounding liquid. Generally, the photocatalytic activity of the dots is related to the particle size and its degree of quantum confinement. This is because the band gap determines the chemical energy that is stored in the dot in the excited state. An obstacle for the use of quantum dots in photocatalysis is the presence of surfactants on the surface of the dots. These surfactants (or ligands) interfere with the chemical reactivity of the dots by slowing down mass transfer and electron transfer processes. Also, quantum dots made of metal chalcogenides are chemically unstable under oxidizing conditions and undergo photo corrosion reactions [15].

3. ROLE OF ORGANIC LED:

Mechanism of Action:

An Organic Light Emitting Diode has an emissive electroluminescent layer and is composed of a film of organic compounds Like any other LED counterparts, Organic LEDs produce light by the recombination of electrons and holes. When a voltage is applied across the device, electrons are injected at the cathode which provides electrons to the emissive layer. The conductive layer provides electrons to the anode, leaving holes within the layer [16]. These holes migrate to the emissive layer where they recombine with the excess of electrons, and as the electrons drop into the holes, they release energy in the form of light. The colour of the light emitted depends on the composition of the organic emissive layer [17].Experimental research has proven that the properties of the anode, specifically the anode/hole transport layer (HTL) interface topography plays a major role in the efficiency, performance, and lifetime of organic light-emitting diodes. Imperfections in the surface of the anode decrease anode-organic film interface adhesion, increase electrical resistance, and affect its lifespan. Mechanisms to decrease anode roughness include the use of thin films and self-assembled monolayers. Also, alternative substrates and anode materials are being considered to increase OLED performance and lifetime [18].

Applications**:**

It is flexible and extremely thin and also their output level remains below LED chips. It is utilized in an impression tray with walls and floor lined up with these emitting films which is designed to evenly radiate all surfaces of photocurable impression material [19]. It is used in vital bleaching wherein the LED Light emits light that acts as a trigger for the gel that can enter the enamel and lift the stains. Organic LED is recently used for the cementation of veneers as the veneer crowns [20]are thin enough to transmit light.Organic LED fabricated on flexible plastic substrates, leading to the possible fabrication of flexible organic light-emitting diodes for other new applications.

Limitations:

Water can easily damage an organic LED curing device. They are highly moisture sensitive, their cost of production is high, life span is very low, organic LEDs are highly sensitive to ultraviolet rays, to avoid this, a protective layer or filter is used to block UV rays [21].Degradation occurs because of the accumulation of nonradiative recombination centers and luminescence quenchers in the emissive zone. It is said that the chemical breakdown in the semiconductors occurs in four steps:recombination of charge carriers through the absorption of UV light,homolyticdissociation,subsequent radical addition reactions that form π radicals and disproportionation between two radicals resulting in hydrogen-atom transfer reactions [22].Additionally, use of 2% chlorhexidine cavity disinfectant increases the microleakage in cavities restored with light cured composites using a single bottle self-etching adhesives [23,24].CRI (Colour Rendering Index) is the measurement of the lights ability of revealing the actual color of the objects compared to the ideal light source i.e. natural [25] light. High CRI is a desirable characteristic. LEDs usually have poor CRI ratings whenever it comes to CRI.

4. ROLE OF QUANTUM DOTS IN LIGHT CURE:

Mechanism:

Quantum dots are high energy releasing semiconductor nanostructure. Encapsulation of quantum dots in polymers can improve the photoluminescence, stability of the device performance in case of optoelectronic light emitting diodes. Quantum dots are incorporated into the photopolymerizable resin composite [26]. Quantum dots can allow curing from within. It is highly biocompatible since its fluorescence properties closely match to the natural human teeth.Quantum dots can be an alternative to incorporation of fillers in adhesive resins. Zinc oxide quantum dots are incorporated into Trimethylene glycol dimethacrylate (TEG DMA) and glycerol dimethacrylate(G DMA).Quantum dots are fluorescent semiconductor nanocrystals which are composed of 200-10,000 atoms [27]. The structure of quantum dots can be split into two main parts: core and a shell that protects the core. These small crystals display a large band gap. Thus, as the difference in energy between the highest valence band and lowest conducting band increases. More energy is needed to excite the dot, and also, more energy is released when the crystal is back in its resting state. Such technology allows fluorescence to occur at shorter wavelengths than those of excitation. This condition would allow red exposure light resulting in emission of blue light, which might be used for photoinitiation. Quantum dots with gradually stepping emission from violet to deep are being produced in a kg scale [22].

Applications**:**

As Quantum dots are incorporated into the photopolymerizable resin composite, it might be possible to enable the entire mass to release light within itself, resulting in 'curing from within' [28]. Fluorescence intensity of dental resin composites are dependent on Quantum dots (QDs) concentration and can be tailored by using a CdSe/ZnS core-shell quantum dots of appropriate core sizes. This allows the fabrication of restorative materials with fluorescence properties that closely match those of natural human teeth and facilitates light curing [29].Several methods are proposed for using quantum dots to improve existing light-emitting diode (LED) design, including "Quantum Dot Light Emitting Diode" (QD-LED or QLED) and "Quantum Dot White Light Emitting Diode" (QD-WLED). Because Quantum dots naturally produce monochromatic light, they can be more efficient than light sources which must be color filtered. QD-LEDs can be fabricated on a silicon substrate, which allows them to be integrated onto standard silicon-based integrated circuits [30].

Limitations**:**
CdSe based quantum dots are highly toxic and require a stable polymer shell. The shells can alter the optical properties and it is also hard to control the size of the particles. Quantum dots degradation inside the living organism can also occur [31].The marginal leakage in composite restoration paves way for the bacterial penetration leading to inflammatory response [32]thereby causing the seepage of uncured monomer into the pulp [33] and leading to its necrosis. The overall conversion efficiency is lower and operation at lower temperature is needed.QDsare expected to be used in a new LED (light-emitting diode) variation, the QD-LEDs. However, the manufacturing of blue emitting QDs is a difficult process. It requires smaller sizes than the rest of the color emitting dots and an amplified emission compared to the other colors [34].

FUTURE SCOPE:
Manufacture of Organic LEDs with flexibility, transparency and low energy light curing procedures and also quantum dot nanoshells in LED Light cure, use of bioactive glass loaded with antibiotics as a composite [35].

5. CONCLUSION:
The increase in need of resin based composites with improved physical properties having less stress and marginal interface, recent advancements in light cure led to the introduction of fourth generation LED, Organic LED and Quantum dots. *Scanwave*-MiniLed is the first fourth generation LED that can minimize heat effects thereby preventing the hotspots.Organic LED and quantum dots. Quantum dots are the emerging technology whose alteration can exhibit excellent biocompatibility as their fluorescent properties are much similar to that of the natural teeth. Organic LEDs on the other hand, has a good application in vital bleaching and cementation of veneers. Organic LEDs usage in photopolymerization of impression material is its recent advancement.

6. ACKNOWLEDGEMENT:

The authors are thankful to Saveetha Dental college for providing a platform to express our knowledge.

AUTHORS CONTRIBUTIONS:
Data Collection: Jai Rexlin.P.E.[1]
Data Analysis and Interpretation: Jai Rexlin.P.E.
Drafting the article: Jai Rexlin.P.E.
Critical Revision of the article: JayalakshmiSomasundaram.
Final approval of the version to be published: JayalakshmiSomasundaram, Anitha Roy[3].

CONFLICT OF INTEREST:

No potential conflict of interest relevant to this article was reported.

6. REFERENCES:

[1] Ramanathan S, Solete P. Cone-beam Computed Tomography Evaluation of Root Canal Preparation using Various Rotary Instruments: An in vitro Study. J Contemp Dent Pract 2015;16:869–72. https://doi.org/10.5005/jp-journals-10024-1773.

[2] Bukovinszky K, Szalóki M, Csarnovics I, Szabó I, Kéki S, Nagy M, et al. Green LED as an Effective Light Source for Curing Acrylate-Based Dental Resins in Combination with Irgacure 784. Advances in Condensed Matter Physics 2018;2018. https://doi.org/10.1155/2018/8265305.

[3] Ramamoorthi S, Nivedhitha MS, Divyanand MJ. Comparative evaluation of postoperative pain after using endodontic needle and EndoActivator during root canal irrigation: A randomised controlled trial. Aust Endod J 2015;41:78–87. https://doi.org/10.1111/aej.12076.

[4] Hussainy SN, Nasim I, Thomas T, Ranjan M. Clinical performance of resin-modified glass ionomer cement, flowable composite, and polyacid-modified resin composite in noncarious cervical lesions: One-year follow-up. J Conserv Dent 2018;21:510–5. https://doi.org/10.4103/JCD.JCD_51_18.

[5] Jose J, P. A, Subbaiyan H. Different Treatment Modalities followed by Dental Practitioners for Ellis Class 2 Fracture – A Questionnaire-based Survey. The Open Dentistry Journal 2020;14:59–65. https://doi.org/10.2174/1874210602014010059.

[6] Kumar D, Antony S. Calcified Canal and Negotiation-A Review. Research Journal of Pharmacy and Technology 2018;11:3727–30. 5

[7] Teja KV, Ramesh S. Shape optimal and clean more. Saudi Endodontic Journal 2019;9:235. https://doi.org/10.4103/sej.sej_72_19.

[8] Nandakumar M, Nasim I. Comparative evaluation of grape seed and cranberry extracts in preventing enamel erosion: An optical emission spectrometric analysis. J Conserv Dent 2018;21:516–20. https://doi.org/10.4103/JCD.JCD_110_18.

[9] Manohar MP, Sharma S. A survey of the knowledge, attitude, and awareness about the principal choice of intracanal medicaments among the general dental practitioners and nonendodontic specialists. Indian J Dent Res 2018;29:716–20. https://doi.org/10.4103/ijdr.IJDR_716_16.

[10] Organic EL - R&D | Semiconductor Energy Laboratory Co., Ltd n.d. https://www.sel.co.jp/en/technology/oled.html (accessed June 6, 2020).

[11] Lodahl P, Mahmoodian S, Stobbe S. Interfacing single photons and single quantum dots with photonic nanostructures. Rev Mod Phys 2015;87:347–400. https://doi.org/10.1103/RevModPhys.87.347.

[12] Shortall AC, Palin WM, Jacquot B, Pelissier B. Advances in light-curing units: four generations of LED lights and clinical implications for optimizing their use: Part 2. From present to future. Dent Update 2012;39:13–7, 20–2. https://doi.org/10.12968/denu.2012.39.1.13.

[13] Comte M, Vouaux P. A new method of light emission by certain organic compounds. Journal de Chimie Physique 1953;50:64.

[14] Fallahi A, Taromi FA, Mohebbi A, Yuen JD, Shahinpoor M. A novel ambipolar polymer: from organic thin-film transistors to enhanced air-stable blue light emitting diodes. J Mater Chem 2014;2:6491–501. https://doi.org/10.1039/C4TC00684D.

[15] Garcia IM, Leitune VCB, Kist TL, Takimi A, Samuel SMW, Collares FM. Quantum Dots as Nonagglomerated Nanofillers for Adhesive Resins. J Dent Res 2016;95:1401–

7. https://doi.org/10.1177/0022034516656838.
[16] Organic Light-Emitting Diode, Graded Heterojunction Architecture, Quantum Efficiency, Solid_State Lighting - Office for Technology Commercialization, Express_license, University_of_Minnesota, Technology_Marketing_Site n.d. https://web.archive.org/web/20120324152059/http://www.license.umn.edu/Products/Organic-Light-Emitting-Diodes-Based-on-Graded-Heterojunction-Architecture-Has-Greater-Quantum-Efficiency__20100200.aspx (accessed June 6, 2020).
[17] Kim SO, Lee KH, Kim GY, Seo JH, Kim YK, Yoon SS. A highly efficient deep blue fluorescent OLED based on diphenylaminofluorenylstyrene-containing emitting materials. Synthetic Metals 2010;160:1259–65. https://doi.org/10.1016/j.synthmet.2010.03.020.
[18] What you need to know about OLED lighting. The Washington Post 2015.
[19] Carter SA, Angelopoulos M, Karg S, Brock PJ, Scott JC. Polymeric anodes for improved polymer light-emitting diode performance. Applied Physics Letters 1997;70:2067–9. https://doi.org/10.1063/1.118953.
[20] Ravinthar K, Others. Recent Advancements in Laminates and Veneers in Dentistry. Research Journal of Pharmacy and Technology 2018;11:785–7.
[21] Jabbour GE, Kawabe Y, Shaheen SE, Wang JF, Morrell MM, Kippelen B, et al. Highly efficient and bright organic electroluminescent devices with an aluminum cathode. Applied Physics Letters 1997;71:1762–4. https://doi.org/10.1063/1.119392.
[22] Daokar S, Hadole P. Light-curing unit (devices). International Journal of Orthodontic Rehabilitation 2019;10:121. https://doi.org/10.4103/ijor.ijor_1_19.
[23] Siddique R, Sureshbabu NM, Somasundaram J, Jacob B, Selvam D. Qualitative and quantitative analysis of precipitate formation following interaction of chlorhexidine with sodium hypochlorite, neem, and tulsi. J Conserv Dent 2019;22:40–7. https://doi.org/10.4103/JCD.JCD_284_18.
[24] Noor SSSE, S Syed Shihaab, Pradeep. Chlorhexidine: Its properties and effects. Research Journal of Pharmacy and Technology 2016;9:1755. https://doi.org/10.5958/0974-360x.2016.00353.x.
[25] R R, Rajakeerthi R, Ms N. Natural Product as the Storage medium for an avulsed tooth – A Systematic Review. Cumhuriyet Dental Journal 2019;22:249–56. https://doi.org/10.7126/cumudj.525182.
[26] Garcia IM, Leitune VCB, Visioli F, Samuel SMW, Collares FM. Influence of zinc oxide quantum dots in the antibacterial activity and cytotoxicity of an experimental adhesive resin. J Dent 2018;73:57–60. https://doi.org/10.1016/j.jdent.2018.04.003.
[27] Hsu S-H, Lin YY, Huang S, Lem KW, Nguyen DH, Lee DS. Synthesis of water-dispersible zinc oxide quantum dots with antibacterial activity and low cytotoxicity for cell labeling. Nanotechnology 2013;24:475102. https://doi.org/10.1088/0957-4484/24/47/475102.
[28] Palaniappan S, Bharadwaj D, Mattar DL, Peumans M, Van Meerbeek B, Lambrechts P. Nanofilled and microhybrid composite restorations: Five-year clinical wear performances. Dent Mater 2011;27:692–700. https://doi.org/10.1016/j.dental.2011.03.012.
[29] Padovani GC, Feitosa VP, Sauro S, Tay FR, Durán G, Paula AJ, et al. Advances in Dental Materials through Nanotechnology: Facts, Perspectives and Toxicological Aspects. Trends Biotechnol 2015;33:621–36. https://doi.org/10.1016/j.tibtech.2015.09.005.
[30] Senellart P, Solomon G, White A. High-performance semiconductor quantum-dot single-photon sources. Nat Nanotechnol 2017;12:1026–39. https://doi.org/10.1038/nnano.2017.218.
[31] Bertassoni LE, Orgel JPR, Antipova O, Swain MV. The dentin organic matrix –

limitations of restorative dentistry hidden on the nanometer scale. Acta Biomaterialia 2012;8:2419–33. https://doi.org/10.1016/j.actbio.2012.02.022.
[32] Teja KV, Ramesh S, Priya V. Regulation of matrix metalloproteinase-3 gene expression in inflammation: A molecular study. J Conserv Dent 2018;21:592–6. https://doi.org/10.4103/JCD.JCD_154_18.
[33] Janani K, Palanivelu A, Sandhya R. Diagnostic accuracy of dental pulse oximeter with customized sensor holder, thermal test and electric pulp test for the evaluation of pulp vitality: an in vivo study. Brazilian Dental Science 2020;23:8.
[34] Carvalho RM, Manso AP, Geraldeli S, Tay FR, Pashley DH. Durability of bonds and clinical success of adhesive restorations. Dent Mater 2012;28:72–86. https://doi.org/10.1016/j.dental.2011.09.011.
[35] Rajendran R, Kunjusankaran RN, Sandhya R, Anilkumar A, Santhosh R, Patil SR. Comparative Evaluation of Remineralizing Potential of a Paste Containing Bioactive Glass and a Topical Cream Containing Casein Phosphopeptide-Amorphous Calcium Phosphate: An in Vitro Study. Pesqui Bras OdontopediatriaClinIntegr 2019;19.