wjpmr, 2024, 10(11), 103-106

SJIF Impact Factor: 6.842

WORLD JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.wjpmr.com

Review Article

ISSN 2455-3301

WJPMR

IMPACT OF OXYGEN INHIBITION LAYER ON DENTAL COMPOSITE RESTORATIONS: A REVIEW OF CURRENT UNDERSTANDING AND APPROACHES

Dr. Aida James*, [1]Dr. Jain Mathew, [2]Dr. Robin Theruvil, [3]Dr. Saira George, [4]Dr. Allu Baby and [5]Dr. Niya Mariam Joseph

*,[5]PG Student, Dept. of Conservative Dentistry and Endodontics St. Gregorios Dental College, Chelad.
[1]Professor and HOD, Dept. of Conservative Dentistry and Endodontics St. Gregorios Dental College, Chelad.
[2,3]Professor, Dept. of Conservative Dentistry and Endodontics St. Gregorios Dental College, Chelad.
[4]Reader, Dept. of Conservative Dentistry and Endodontics St. Gregorios Dental College, Chelad.

***Corresponding Author: Dr. Aida James**

PG Student, Dept. of Conservative Dentistry and Endodontics St. Gregorios Dental College, Chelad.

Article Received on 14/09/2024 **Article Revised on 04/10/2024** **Article Accepted on 25/10/2024**

ABSTRACT

The oxygen inhibition layer (OIL), a byproduct of polymerization in light-cured composites, can significantly affect the surface characteristics and curing efficiency of restorations. This review explores the impact of the OIL on dental composite restorations, focusing on its formation and properties, effects on bond strength, and strategies employed to mitigate its negative impacts. By synthesizing these findings, we provide insights into optimizing dental composite restorations for enhanced durability and improved clinical outcomes.

KEYWORDS: Oxygen Inhibition Layer, Polymerization, Bond Strength, Resin Based Composite.

INTRODUCTION

Dental composite resin (DCRs) have revolutionized modern dental care by enabling minimally invasive treatments and offering excellent esthetic results. These composites consist of two main components: dental resins and inorganic fillers. The resins, which are a blend of monomers, are formulated to balance flowability before curing and high strength after curing. However, a notable challenge with DCRs is the oxygen inhibition that affects the free-radical polymerization process during curing.

This oxygen inhibition layer (OIL) occurs because oxygen reacts with the free radicals, preventing full polymerization at the surface. While deeper layers may fully cure, the outermost layer can remain tacky and under-polymerized. While this layer may be thin, it can have significant implications for the properties of the resin. In some cases, it provides a beneficial feature, allowing chemical bonding between successive layers in multi-step restorative procedures. However, when unintentional or uncontrolled, the oxygen inhibition layer formed can lead to reduced surface hardness, increased wear, and higher susceptibility to staining or plaque accumulation. Understanding and mitigating this oxygen inhibition layer is crucial for improving the performance of DCRs and ensuring the long-term success of dental restorations.

FORMATION DYNAMICS OF THE OXYGEN INHIBITION LAYER

The oxygen inhibition layer is formed when resin-based materials are exposed to oxygen during curing. This thin layer consists of monomer that remains uncured or only partially cured due to the presence of oxygen, which disrupts the normal polymerization process. Free radicals that are generated during polymerization have a higher affinity for oxygen molecules than for the methacrylate carbon-carbon double bonds. As a result, the oxygen reacts with the free radicals, forming peroxy radicals that are less reactive, thus rendering them unavailable to participate effectively in the polymerization process. This retards or prevents full polymerization at the surface, creating the oxygen-inhibition layer.[1]

VARIABLES AFFECTING OIL IN RESIN-BASED COMPOSITES

The thickness of the oxygen-inhibition layer is influenced by several factors. This includes the type of monomer used, the initiator-activator system, the particle morphology, the concentration of free radicals, and the rate of oxygen consumption.[2]

Resin viscosity

In a study by Finger et al., various ratios of BisGMA and hydroxyethylmethacrylate (HEMA) were mixed to assess their effect on oxygen inhibited layer formation. The researchers found that a resin with 100% BisGMA

developed an OIL thickness of 4 μm, which increased significantly to 14 μm for the 40:60 mix. This indicates that the thickness of the oxygen inhibition layer increases with the HEMA content, a low-viscosity methacrylate monomer. These findings are consistent with a study by Gauthier et al., which also showed that the OIL grows as resin viscosity decreases.[3]

A study by Essam S. Shawkat et al. concluded that a reduction in composite viscosity caused by higher diluent monomer content in the matrix leads to an increase in the thickness of the OIL.[4]

Filler load

Gauthier et al (2005) found that when the filler load exceeded 40%, the amount of oxygen inhibition in the resin-based composites (RBCs) decreased. The authors attributed this to the increased diffusivity of atmospheric oxygen at the resin-filler interface, which was not counterbalanced completely by the higher viscosity resulting from the increased filler content.

There are several factors which complicates the pathway of oxygen diffusion with the addition of filler materials to adhesive resin.

Filler particles can

1. **Act as Obstacles**: They can obstruct the movement of oxygen through the resin.
2. **Adsorb Oxygen**: They can capture and hold oxygen on their surface.
3. **Facilitate Diffusion**: They can create pathways along their surfaces that allow oxygen to diffuse more easily.[5]

IMPACT OF OIL ON COMPOSITE SHEAR BOND STRENGTH

Truffier-Boutry et al. (2003) proposed that samples without OIL (cured under mylar strip) were less likely to show mechanical irregularities. In contrast, samples with oxygen-inhibited layer had more surface irregularities, which enhanced mechanical retention when a second layer of resin-based composite (RBC) was applied.[6] Additionally, Rueggeberg and Margeson (1990) suggested that the unpolymerized inhibited surface layer could intermix and integrate with the newly applied RBC, forming a hybrid layer that increased mechanical retention.[7]

Panchal et al. stated in their study that the presence of oxygen inhibited layer improved the shear bond strength (SBS) between two adjacent composite layers and resulted in more durable adhesion. The absence of an oxygen inhibited layer negatively impacted bond strength, leading to adhesive interfacial failures.[8]

Contradicting these findings, a study by Essam S. Shawkat et al. compared the incremental shear bond strength of composite resin cured in air and nitrogen atmospheres. The researchers found no significant differences in bond strength between the two conditions, leading them to conclude that incremental bond strength is not dependent on surface inhibition.[4] This conclusion was supported by the study conducted by Ghivari et al.[9]

IMPACT OF OIL ON COMPOSITE REPAIR STRENGTH

The hypothesis suggesting a positive correlation between the presence of an oxygen-inhibition layer and composite repair strength is based on the principle of molecular interaction. According to this principle, interfacial bonding between two contacting polymers can be enhanced by the sticky, soft, and liquid-like consistency of the oxygen-inhibition layer, which increased the contact area between the polymers.[6]The oxygen-inhibition layer facilitates the formation of an "intermixed" or "interdiffused" zone between polymers, leading to the creation of chemical bonds through copolymerization.[7] However, Eliades and Caputo reported higher composite repair strength when bonding to surfaces in the absence of oxygen-inhibition layer. They attributed these results to the fact that the oxygen-inhibition layer contained a reduced amount of photoinitiator, which resulted in suboptimal polymerization within that layer.[10] Some studies reported no significant differences in shear bond or microtensile bond strengths, when composites were repaired with or without OIL.[1]

IMPACT OF OIL OF UNIVERSAL ADHESIVES ON ENAMEL BOND FATIGUE DURABILITY

According to a study by Ouchi et al., the enamel bonding with an oxygen inhibition layer exhibited higher initial shear bond and shear fatigue strengths than those without, regardless of the adhesive type and etching mode. Moreover, the water contact angles on the specimens with oxygen inhibition layer were significantly lower than those without, regardless of etching mode. Thus the oxygen inhibition layer of universal adhesives significantly increased the enamel bond fatigue durability and greatly changed interfacial characteristics.[11]

IMPACT OF OIL ON DEGREE OF CONVERSION AND COLOR STABILITY

The degree of conversion (DC) of monomers was determined by the percentage of carbon double bonds consumed during the polymerization process. Oxygen inhibited the polymerization, thus decreasing the DC.[2]

Schroeder et al. reported that the color stability of composite resins was not improved by applying a hydrosoluble gel before the final polymerization, suggesting that the dependence of color stability on protection from OIL was not clearly established.[12]

Polishing the composite restoration, irrespective of the presence of the oxygen-inhibition layer, resulted in a comparable reduction in surface roughness and, consequently, improvements in color stability.[13]

Although post-polymerization polishing improved color stability, regardless of the presence of oxygen-inhibition layer, it resulted in a lower degree of conversion when compared to using an oxygen inhibitor agent.[2] The degree of conversion was directly linked to the surface hardness. A lower DC% typically resulted in a less rigid and softer surface.[14]

METHODS TO REDUCE OIL

Finishing and polishing

Post-polymerization polishing removed OIL to an extent, thereby improving the color stability of composite restorations, which would otherwise have been affected by the soft, sticky layer of unpolymerized resin.[2,13]

Oxygen exclusion -Mylar strips & glycerin

Barrier techniques, such as the application of glycerin or Mylar strip, reduced the formation of OIL. The Mylar strip prevents direct contact with air. Thus, the only contribution of oxygen is from within the composite in the formation of OIL, thereby minimizing its formation. However, when glycerin is used, the minute amount of oxygen in the glycerin, along with the oxygen already on the composite surface, contribute to OIL formation. Hence, this method creates more OIL formation when compared to the Mylar strip method.[15]

Thermal Activation of Radicals

Activation of oxidized radicals occurs at 110-120°C. Visible-light curing cannot reach this temperature and hence cannot directly heat the sample. The observation that polymers reaching 110°C showed no inhibition suggested that post-curing with visible light could help remove surface inhibition. This method effectively addressed the oxygen inhibition issues without altering the resin's chemical composition.[5]

Phosphine derivatives to overcome the OIL

Incorporating a copolymerizable phosphorine derivative like triphenylphosphine (TPP) or 4- (diphenylphosphino) styrene (DPPS) into a camphorquinone/amine photoinitiator system enhanced the polymerization efficiency even in the presence of air, accelerated the curing speed, and improved the storage stability. This system also prevented the coloration issues in the final polymer material. TPP raises toxicological concerns that disqualify its use in dental materials where as DPPS is safe for dental use due to it's extremely low migration. The high efficiency of this novel system meant that the presence of oxygen did not significantly hinder the photocuring process.[16]

FINAL THOUGHTS ON THE OXYGEN INHIBITED LAYER (OIL): REMOVAL VS. RETENTION

Although, there was no conclusive evidence to justify the need for removing or retaining the oxygen inhibited layer (OIL) on surfaces that would be covered with additional layers of material, considering all factors, removing the OIL from intermediate layers was not necessary. However, It is beneficial to protect the surface layer from OIL, as this can improve the degree of conversion.

REFERENCES

1. Dall'Oca S, Papacchini F, Goracci C, Cury ÁH, Suh BI, Tay FR, Polimeni A, Ferrari M. Effect of oxygen inhibition on composite repair strength over time. Journal of Biomedical Materials Research Part B: Applied Biomaterials: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials, May. 2007; 81(2): 493-8.
2. Borges MG, Silva GR, Neves FT, Soares CJ, Faria-e-Silva AL, Carvalho RF, Menezes MS. Oxygen inhibition of surface composites and its correlation with degree of conversion and color stability. Brazilian Dental Journal, Apr. 2, 2021; 32(1): 91-7.
3. Finger WJ, Lee KS, Podszun W. Monomers with low oxygen inhibition as enamel/dentin adhesives. Dental Materials, 1996; 12(4): 256-61.
4. Shawkat ES, Shortall AC, Addison O, Palin WM. Oxygen inhibition and incremental layer bond strengths of resin composites. Dental Materials, Nov. 1, 2009; 25(11): 1338-46.
5. Gauthier MA, Stangel I, Ellis TH, Zhu XX. Oxygen inhibition in dental resins. Journal of dental research, Aug. 2005; 84(8): 725-9.
6. Truffier-Boutry D, Place E, Devaux J, Leloup G. Interfacial layer characterization in dental composite. Journal of oral rehabilitation, Jan. 2003; 30(1): 74-7.
7. Rueggeberg FA, Margeson DH. The effect of oxygen inhibition on an unfilled/filled composite system. Journal of dental research, Oct. 1990; 69(10): 1652-8.
8. Panchal AC, Asthana G. Oxygen inhibition layer: A dilemma to be solved. Journal of Conservative Dentistry, May 1, 2020; 23(3): 254-8.
9. Ghivari S, Chandak M, Manvar N. Role of oxygen inhibited layer on shear bond strength of composites. Journal of Conservative Dentistry and Endodontics, Jan. 1, 2010; 13(1): 39-41.
10. Eliades GC, Caputo AA. The strength of layering technique in visible light-cured composites. The Journal of prosthetic dentistry, Jan. 1, 1989; 61(1): 31-8.
11. Ouchi H, Tsujimoto A, Nojiri K, Hirai K, Takamizawa T, Barkmeier WW, Latta MA, Miyazaki M. Effect of oxygen inhibition layer of universal adhesives on enamel bond fatigue durability and interfacial characteristics with different etching modes. Operative dentistry, Nov. 1, 2017; 42(6): 636-45.
12. Schroeder T, da Silva PB, Basso GR, Franco MC, Maske TT, Cenci MS. Factors affecting the color stability and staining of esthetic restorations. Odontology, Oct. 2019; 107: 507-12.
13. Gaviria-Martinez A, Castro-Ramirez L, Ladera-

Castañeda M, Cervantes-Ganoza L, Cachay-Criado H, Alvino-Vales M, Garcia-Luna G, López-Gurreonero C, Cornejo-Pinto A, Cayo-Rojas CF. Surface roughness and oxygen inhibited layer control in bulk-fill and conventional nanohybrid resin composites with and without polishing: In vitro study. BMC Oral Health, Jun. 26, 2022; 22(1): 258.

14. Aromaa MK, Vallittu PK. Delayed post-curing stage and oxygen inhibition of free-radical polymerization of dimethacrylate resin. Dental Materials, Sep. 1, 2018; 34(9): 1247-52.
15. Park HH, Lee IB. Effect of glycerin on the surface hardness of composites after curing. Journal of Korean Academy of Conservative Dentistry, Nov. 1, 2011; 36(6): 483-9.
16. Bouzrati-Zerelli M, Maier M, Fik CP, Dietlin C, Morlet-Savary F, Fouassier JP, Klee JE, Lalevée J. A low migration phosphine to overcome the oxygen inhibition in new high performance photoinitiating systems for photocurable dental type resins. Polymer International, Apr. 2017; 66(4): 504-11.