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A Comparative Analysis Of Oxygen Inhibition Layer Thickness In Conventional And Self-Adhesive Composite Resins: An In Vitro Study

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Abstract:
Background:
Composite resin has become indispensable in modern restorative dentistry, but its polymerization process in air leads to the formation of an oxygen inhibition layer (OIL), affecting interlayer bond strength. The thickness of the OIL is crucial, influencing interfacial homogeneity, composite interdiffusion, and mechanical strength. Despite advancements in composite technology, variations in OIL thickness persist among different composite types, attributed to filler content, resin matrix, and diluent composition. While an OIL has traditionally been deemed necessary for composite layering, its impact on bond strength remains inconsistent. Glycerin application has been proposed to prevent OIL formation by blocking oxygen's interaction with free radicals, thus enhancing polymerization quality and surface properties. This study compares the influence of glycerin on OIL thickness in conventional and self-adhesive composite resins, aiming to elucidate its role in composite performance.
Materials and Methods:
Sixty specimens, 30 each of conventional composite resin (OMNICHROMA Composite - Tokuyama Dental) and self-adhesive composite resin (DMG Constic), were prepared and subdivided into subgroups based on surface treatments. The control group received no treatment, while the glycerine group had glycerine applied followed by light activation. After surface modifications, the thickness of the oxygen inhibition layer (OIL) was remeasured in each subgroup. Composite resin was applied onto glass microscope slides, with spacers maintaining a consistent thickness. Specimens were polymerized, ensuring OIL formation only at outer surfaces. OIL depth was measured using a calibrated disk and a stereomicroscope at ×40 magnification, with micrographs captured for visual records.
Results:
The study determined the thickness of the oxygen inhibition layer (OIL) for each composite resin type. Conventional composite resin exhibited a higher OIL thickness compared to self-adhesive composites. Statistical analysis revealed significant effects of both composite type and surface treatment on OIL thickness ($P < 0.001$), highlighting the importance of material composition and surface modification in influencing OIL characteristics.
Conclusion:
This study demonstrates the persistence of the oxygen inhibition layer (OIL) on composite resin surfaces even after glycerin treatment, albeit with lower formation in self-adhesive composites. Despite differences between groups, OIL formation was evident across all specimens. The clinical significance lies in the potential to enhance the degree of conversion of composite resin surfaces by reducing oxygen presence through glycerin application. This optimization holds promise for improving interlayer bond strength, managing polymerization shrinkage, and ensuring restoration integrity. By mitigating post-operative sensitivity, marginal leakage, and secondary caries risks, tailored techniques for OIL management offer the potential for more durable and satisfactory composite restorations. This research underscores the importance of personalized approaches to optimize OIL formation, ultimately enhancing clinical outcomes and patient satisfaction in restorative dentistry.

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I. Introduction

Modern restorative dentistry now uses composite resin as a fundamental component. When a bonding or composite resin is polymerized in air, an uncured layer known as the oxygen inhibition layer (OIL) is always present.[1] It is sticky and rich in resin. Because oxygen is more reactive with radicals than monomers are, airborne oxygen disrupts the polymerization reaction during the light-curing process. This results in the formation of an OIL on the surface of the composite.

The OIL can also be referred to as an unpolymerized (uncured) layer of resin since its composition is comparable to that of an uncured resin with consumed or reduced amounts of photo-initiator [1,2,3,4] Since OIL is known to (i) impair interfacial homogeneity,[2] (ii) permit complete interdiffusion of the freshly overlaid composite through the oxygen inhibition zone (if OIL is thin),[1] and (iii) compromise mechanical strength (if OIL is thick), its thickness may have an impact on the interlayer bond strengths of the composite resins.[5] The integrity of the layer and the caliber of the interlayer bonding are therefore dependent on the thickness of the OIL.

OIL generated on the preceding layer easily adjusts to the material on top when a fresh increase of the composite is introduced. As a result, it broadens the region of contact and makes it possible for incremental composite on both sides of the oil to blend and cross the interface to create an interdiffused zone, which is where chemical bonding through copolymerization can occur. The layer-layer contact will be strengthened by all of these acts.[3]

With improvements in adhesive systems, polymerization devices, filler particles, and monomer matrices, composites are becoming more robust. [2,4,6,7,8]

Variations have been noted in the OIL thickness of different dimethacrylate-based composites. This might be caused by the type and quantity of filler used as well as the resin composite's network density. The oxygen inhibition depth (in this study, as in microhybrid and short glass fiber-reinforced (SGFR) composite) is also influenced by the amount of diluent (TEGDMA). When fibers are used to reinforce a composite, the direction and size of the fibers may also affect the depth of oxygen inhibition.[10,11,12, 13]

The dentistry world has long believed that an OIL is necessary prior to applying more glued composite layers. Despite a lot of effort being put into the topic, reports on how the OIL influences bond strength have been inconsistent.[13, 14]Oxygen inhibits the polymerization process by outcompeting resin composite monomers for reaction with free radicals. During this inhibition, oxygen reacts with the resin liquid and is consumed by the radicals formed [2, 10,]. Glycerin, on the other hand, transforms these highly reactive radicals on the surface into relatively stable hydroperoxides. This conversion helps achieve better light-curing quality in the outermost layer of resin composites, thereby preventing the formation of the oxygen inhibition layer [15]. Hence, glycerin was employed in this study to prevent atmospheric oxygen from contacting the resin composite surface, thereby averting its reaction with free radicals and enhancing both the degree of conversion and surface mechanical properties.

In liquid or gel form, glycerin—a polyhydric alcohol compound—makes a useful surface coating material. Its three hydroxyl groups in its trivalent alcohol structure serve as a barrier to prevent composite resins from polymerizing. through obstructing the exchange of oxygen with free radicals. Glycerine application could be a useful strategy to prevent the production of OIL.Some clinicians have applied glycerin gel or water-soluble gel over the last increment light-curing trough the transparent layer avoiding the oxygen inhibition of composite resin surface [15,16].The present study aimed to compare the influence of glycerin on the Oxygen Inhibition Layer thickness in a conventional composite resin and a self-adhesive composite resin.

II. Materials And Methods

Preparation of the specimen

A total number of 60 specimens(15 in each group) were prepared for this study, which were divided into 2 main groups of 30 specimens each (Group-1 - a conventional composite resin (OMNICHROMA Composite - Tokuyama Dental), Group-2 a self-adhesive composite resin (DMG Constic) .

Each of the two groups were further subdivided into subgroups A and B according to the surface treatments given to the specimen.

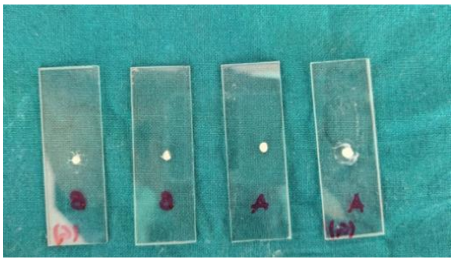

Figure.1 : Microscopic slide with specimen with surface treatment (G) and non-surface treated.

Control group : No surface treatment was given to the specimen.

Glycerine group : Glycerine was applied on the surface of composite resin specimens followed by additional light activation for 20 s.

Following the specimen's surface modifications, OIL thickness was once more measured in each of the two subgroups, A and B.

Evaluation of the thickness of oxygen inhibition layer:

An equal amount of each type of composite resin was applied onto the middle of a horizontally placed glass microscope slides.

Two glass plates (20 mm × 20 mm) were placed on either side of the composite resin, which was covered with a coverslip made of another microscope slide, to act as spacers and maintain a consistent sample thickness of 0.1 mm.

Using a light-emitting diode light-curing equipment, the specimens were polymerized through the coverslip for 40 seconds. Because air-resin contact was only feasible at the resin border between the spacers and the polymerized composite material, this approach only insured the development of OIL at the outer surfaces of the specimens.

Using a calibrated disk and a stereomicroscope with a magnification of ×40, the depth of the OIL was measured around the periphery of each specimen. Using the computer imaging tool, micrographs of every specimen were captured to give a visual record of the inhibitory layer. Using a Stereomicroscope, measurements will be taken around the edge of subgroup I and II specimens from each group. The depth of the inhibition layer will be measured, using a calibrated micrometre disk. The interface between the polymerized and unpolymerized resin and the specimen's outer boundary will be where the results are recorded.

III. Results

Oxygen inhibition layer thickness

The optically measurable thickness of the OIL was determined for each composite utilized in the study. The results are presented in Table 1. Conventional composite (Group 1) showed a maximum thickness of OIL, as compared to self adhesive composites (Group 2).

Table 1

All materials' oxygen inhibition layer thickness values as observed with a stereomicroscope

Group 1 – Conventional composite
Thickness of oxygen inhibition layer (micron)
Subgroup 1A (untreated surface) - 19.8 (5.5)*
Subgroup 1B (Glycerine treated surface) - 19.0 (5.7)*
Group 2 – Self adhesive composite
Thickness of oxygen inhibition layer (micron)
Subgroup 2A (untreated surface) - 17.78 (5.5)*
Subgroup 2B (Glycerine-treated surface) - 17.19 (5.7)*

Values are given as mean (SD). The superscript symbols (*) within a value represent a homogenous subset (P>0.05) among the groups for each material individually. SD: Standard deviation

Paired T test showed that both the type of material and the surface treatment had significant effects ($P < 0.001$) on the thickness of the OIL.

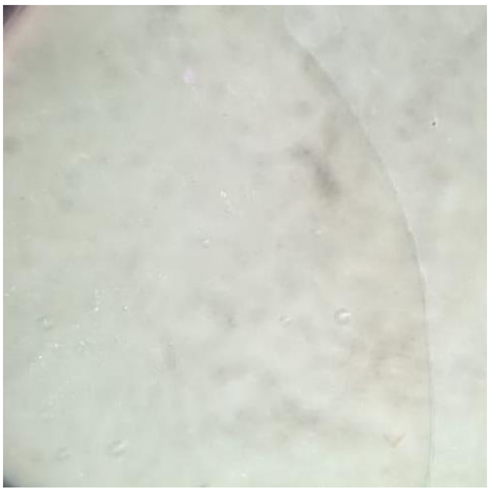

Figure.2 : Group 1A

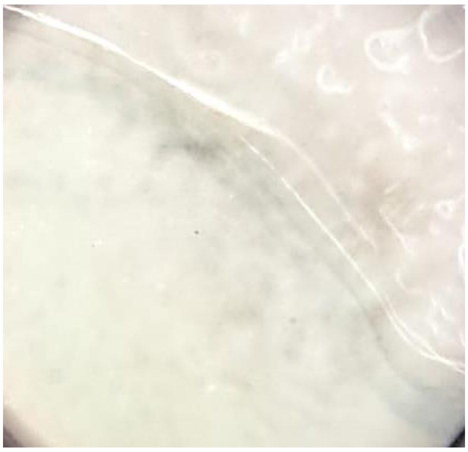

Figure.3 : Group 1B

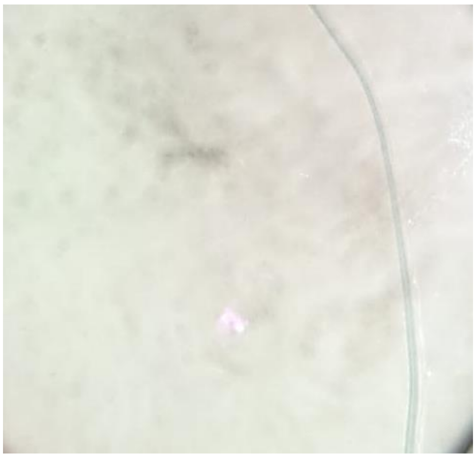

Figure.4 : Group 2A

Figure.5 : Group 2B

IV. Discussion

Dental composites get cured by free-radical-induced polymerization reaction which is strongly inhibited by free-radical scavengers such as oxygen in the air. Free oxygen diffuses and suppresses the polymerization reaction when it comes into contact with composite resin, creating peroxide radicals that are less reactive toward monomers.[1] The monomer layer that is still unbound on the surface after curing is known as the oxygen-inhibited layer. $R + O_2 \rightarrow R - OO$ (stable radicals).[15]

The interlayer bond strength achieved becomes crucial to take into account because multilayer techniques are advised to reduce polymerization shrinkage and raise the degree of conversion of dental composites. A positive connection was reported in several research examining the effect of OIL on bond strength, suggesting that OIL strengthened bonds.[16] Kim et al. (2006) came to the conclusion that in cases where the oil was either too thin or absent, there may have been insufficient unreacted monomers to establish a chemical bond between the two surfaces.also failed to resist the shrinkage stress.[17]

The present study shows results in accordance with the study of Koga *et al*.,[18] which showed that both the physical and chemical surface properties of the OIL depend on its thickness if relatively thin, the OIL allows diffusion of the photoinitiator into the overlaying composite, thus improving the bond strength.

The ethanol and water spray treatments employed in this investigation are more useful from a therapeutic standpoint. After applying them for a regulated duration of 20 seconds, neither surface treatment showed any unfavourable impacts on bonding.[19]

Investigating the impact of oxygen inhibition layers on composite resin color stability, our study sheds light on the crucial role played by polymerization conditions and post-restoration surface treatments, in line with the findings of Azevedo *et al.* (2021). Their study highlighted how the presence of oxygen during polymerization significantly influences the degree of conversion and surface staining of composite resins, emphasizing the importance of optimizing these factors to enhance the longevity of dental restorations. [20]

While Lassilla et al. (2020) and Strnad et al. (2015) suggest employing celluloid tape to address oxygen inhibition layer (OIL), they caution against its complete eradication due to the risk of bubble entrapment. Therefore, our study complements this method by introducing glycerin application. Furthermore, our findings are consistent with Tsujimoto et al. (2016), indicating insignificant differences in roughness regardless of OIL control. Nevertheless, our results differ from those of Borges et al. (2021) and Meita et al. (2019), potentially attributed to variations in resin composite composition and polishing methodologies utilized. [21]

The degree of conversion (DC) of monomers is the proportion of single carbon-carbon bonds in a polymer matrix to double carbon bonds between monomers (1). It has been shown that the clinical performance [18] of dental composites can be affected by mechanical properties that are influenced mainly by the DC [19], filler content and type of matrix [18,20].

Low DC values may have detrimental effects on compressive strength, wear resistance, fracture resistance, and may necessitate the early replacement of long-term restorations due to discolouration or separation around the adhesive interfaces. [20]. Low DC values can also increase the release of toxic monomers and initiators in the oral environment [22]. A higher DC was observed for groups with oxygen inhibition surface treatment by glycerin, regardless of composite resins tested by Marcela Gonçalves Borges et al. [20] Oxygen slows down the polymerization process because it reacts quickly with free oxidized radicals. Oxygen inhibition improved polymerization of the surface layer [15,16]. Our findings were in line the findings of Borges MG et al[20].

This result confirms that the physical characteristics of the OIL's surface have an impact on both the failure mode and the binding strength between successively placed composite layers. Consequently, it can be inferred that the adhering surface's adherence depends critically on the surface wettability that the OIL provides. Wettability is influenced by variables like the liquid's surface tension and the solid's surface free energy. [18]

V. Conclusion

Within the constraints of this research, these results were attained:

The OIL, which acts as an intermediate layer, is retained on the surface of the composite even after treatment with glycerine. Though the Self-adhesive composite had lower OIL formation. It is an undeniable fact that the layer was definitely formed on both the groups and their subgroups. The clinical significance of this study is that the degree of conversion of the composite resins surface can be improved by using glycerin to reduce the oxygen presence. [20] The clinical significance of our research findings on the formation of the oxygen inhibition layer (OIL) during composite resin polymerization is profound in the context of restorative dentistry. Our study demonstrates that effective management of OIL formation, particularly through glycerin application, holds potential to optimize the degree of conversion of composite resin surfaces. This optimization is crucial for enhancing interlayer bond strength, managing polymerization shrinkage, and ensuring marginal integrity of restorations. By reducing post-operative sensitivity and mitigating the risk of marginal leakage and secondary caries development, [23] clinicians can provide patients with more durable and long-lasting composite restorations. Our research underscores the importance of tailored techniques to optimize OIL formation, ultimately leading to improved clinical outcomes and patient satisfaction in restorative dental procedures.

List of abbreviations: OIL-Oxygen inhibition layer, SD -standard deviation, DC- degree of conversion, s-seconds

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