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Main approaches of biofilm formation in composite resins: a concise systematic review

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Abstract

Introduction: Composite resins are widely used in clinical dental practice to restore the structure lost by caries and dental defects, achieving aesthetic and functional results. Failures in the photoactivation process can cause problems in the mechanical resistance to wear in regions of direct occlusal contact on the restorative material. This occurs due to the reduction in the degree of conversion of monomers into polymers, compromising the clinical performance of the composite resin. Polymerization shrinkage leads to microleakage of the restoration, leading to staining and the development of bacterial biofilms. **Objective:** It was to carry out a systematic review of the main scientific evidence of biofilm formation on composite resin veneers, identifying potential predictors, as well as proposals to mitigate this problem. **Methods:** The systematic review rules of the PRISMA Platform were followed. The search was carried out from December 2022 to March 2023 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases, using articles from 2015 to 2022. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed accordingly, according to the Cochrane instrument. **Results and Conclusion:** A total of 125 articles were found, 25 articles were evaluated and 20 were included and developed in this systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 10 studies with a high risk of bias and 70 studies that did not meet GRADE. It was concluded that the surface properties of resin-based composite materials, as well as surface treatments, can strongly affect bacterial adhesion and biofilm formation. In addition, scientific evidence highlights that cariogenic biofilm formation can alter the surface properties of materials, thus stimulating bacterial adhesion and biofilm formation. Photoactivation allows the curing and crosslinking of polymer chains, essential for the clinical longevity of the composite resin. Insufficient photoactivation culminates in marginal microleakage in restorations and biofilm accumulation on surfaces exposed to the oral environment.

Keywords: Composite resins. Biofilms. Resin veneers. Polymerization retraction.

Introduction

In the scenario of biofilm formation on composite resin veneers, the surface properties of resin-based composite materials, as well as surface treatments, can strongly affect bacterial adhesion and biofilm formation. In addition, scientific evidence highlights that cariogenic biofilm formation can alter the surface properties of materials, thus stimulating bacterial adhesion and biofilm formation [1].

In this context, composite resins are widely used in clinical dental practice to restore the structure lost by caries and dental defects, achieving aesthetic and functional results. They differ from each other according to the type, size, amount of filler particles, and type of organic matrix. Size variations of inorganic particles classify composites into macroparticles, microparticles, and nanoparticles [2].

In this sense, the improvement of composite resins improved the mechanical properties, increasing the resistance to abrasion and compression of these materials, as well as a low polymerization contraction [2,3]. A crucial factor to ensure the quality of the restorative procedure is the degree of conversion of the composite resins, which can be influenced by the characteristics of the composites, such as the chemical composition of the matrix, photoinitiator concentration, type, size, and quantity of filler particles, color, and degree of translucency/opacity and by factors related to the activation light [4-7]. Proper polymerization maximizes the physical, mechanical, and biological properties that determine the clinical success of the restorative treatment [8-10].

In this regard, the photoactivation process promotes the conversion of monomers into polymers, and begins with the light-sensitivity of a photopolymerizing molecule, usually camphorquinone, through the absorption of photons irradiated by visible light within the spectral range between 450 nm and 500 nm, promoting the change from the viscous to a solid state of the composite resin. However, there are still some limitations in the photoactivation cycles of resins, which may fail the expected result [11].

Added to this, failures in the photoactivation process can cause problems in the mechanical resistance to wear in regions of direct occlusal contact on the restorative material. This occurs due to the reduction in the degree of conversion of monomers into polymers, compromising the clinical performance of the composite resin. In addition, polymerization contraction causes microleakage of the restoration, leading to staining and the development of bacterial biofilms, which is the main cause of replacement restorations [11].

Furthermore, polymerization shrinkage during restorative material curing is one of the most important factors in achieving a seal at the tooth-composite interface; another factor is the extent of polymerization, especially in places that are difficult to access, such as the gingival margin of class II restorations. Insufficient curing of this material leads to early degradation of the organic matrix when in contact with the aqueous medium, causing instability of the polymeric matrix and leaving open spaces for plaque retention. Many of the undocumented failures of later composites are attributed to the flawed process of curing the material during insertion [12,13].

Among the photoactivation techniques, the continuous and switched ones stand out, which differ in terms of the time of emission and interruption of the light beam – implying differences in terms of heating the tooth [1,7,11]. The oral cavity is a complex environment, with high humidity, moderate temperature, and a large number of nutrients that favor the formation of differentiated microorganisms and microbial biofilms [7].

Besides, oral biofilms adhere to the surfaces of teeth and dental materials in the oral cavity. Material surfaces exposed to oral conditions can influence pellicle coverage, initial bacterial adhesion, and biofilm formation due to their specific physical and chemical characteristics. The irregular topography, the low degree of conversion of monomers into polymers, and the rough surfaces of the restorative material provide a favorable interface for bacterial colonization that can develop pathologies such as secondary caries, and periodontal and endodontic diseases [5,7].

Therefore, this study carried out a systematic review of the main scientific evidence of biofilm formation on composite resin veneers, identifying potential predictors, as well as proposals to mitigate this problem.

Methods

Study Design

This was followed by a systematic literature review model on the main clinical findings of mandible fractures, according to the PRISMA rules.

Data Sources and Research Strategy

The literary search process was carried out from December 2022 to March 2023 and was developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar, using scientific articles from 2015 to 2022, using the descriptors (MeSH Terms): *Composite resins. Biofilms. Resin veneers. Polymerization retraction,* and using the Booleans "and" between the descriptors (MeSH Terms) and "or" between the historical findings.

Study Quality and Risk of Bias

The quality of the studies was based on the GRADE instrument, with randomized controlled clinical studies, prospective controlled clinical studies, and studies of systematic review and meta-analysis listed as the studies with the greatest scientific evidence. The risk of bias was analyzed according to the Cochrane instrument.

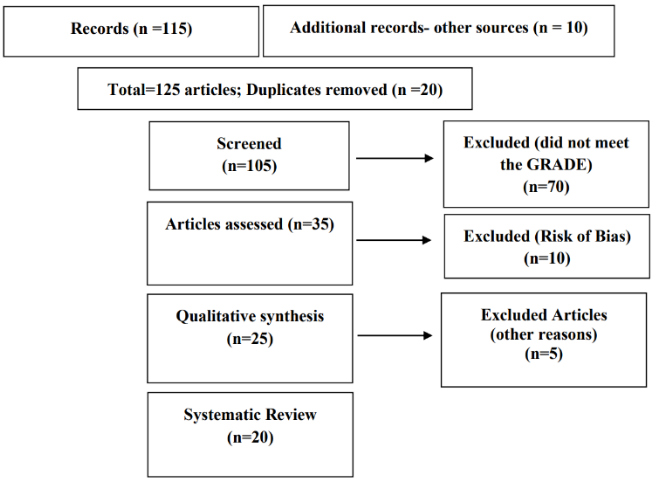
Results and Discussion

Summary of Literary Findings

A total of 125 articles were found. Initially, duplication of articles was excluded. After this process, the abstracts were evaluated and a new exclusion was performed, removing the articles that did not include the theme of this article, resulting in 35 articles. A total of 25 articles were evaluated and 20 were included and developed in this systematic review study (Figure 1).

Considering the Cochrane tool for risk of bias, the overall assessment resulted in 10 studies with a high risk of bias and 70 studies that did not meet GRADE.

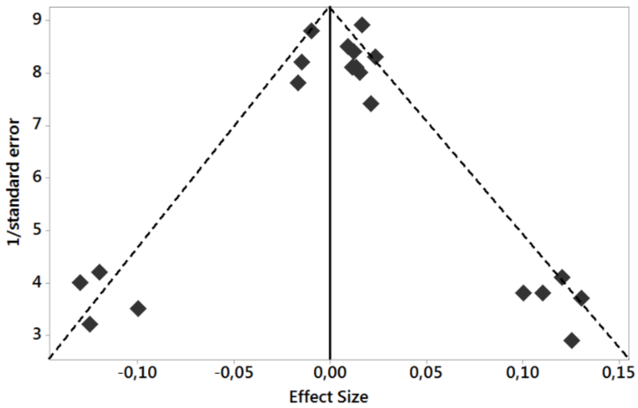
Figure 1. Selection of studies.



Source: Own authorship.

Figure 2 presents the results of the risk of bias in the studies using the Funnel Plot, through the calculation of the Effect Size (Cohen's Test). The sample size was determined indirectly by the inverse of the standard error. The graph showed symmetric behavior, not suggesting a significant risk of bias in studies with small sample sizes, which are shown at the bottom of the graph.

Figure 2. The symmetric funnel plot does not suggest a risk of bias between the small sample size studies that are shown at the bottom of the graph (N = 20 studies).



Source: Own authorship.

Major Findings - Composite Resin and Biofilm

According to the main scientific evidence that was obtained through the analysis of the articles selected in this study, photoactivated composite resins were introduced in dentistry in the past decades, and are the first choice materials for direct restorations due to the evolution of their properties, such as color, brightness, surface smoothness, translucency and opacity that enable the aesthetic reconstruction of dental structures [14]. Initially, the restorative material was photoactivated by ultraviolet light, however, because of the harmful effects of radiation, this type of photoactivation fell into disuse [15].

After that, it was replaced by visible light sources such as light-emitting diodes (LED) in the blue range of the visible radiation spectrum [14]. Photoactivation allows the curing and crosslinking of polymer chains, essential for the clinical longevity of the composite resin. Some studies have emphasized that when there are failures in photopolymerization, the resins suffer a high degree of degradation of the organic matrix, leading to a loss of mechanical and biological performance [16,17].

In addition, the literature reports that deficiencies resulting from the polymerization contraction of composite resins persist [7,18]. Shrinkage is a physical process inherent to the healing reaction and causes tension at the tooth-restoration interface that can lead to marginal microleakage of oral fluids and microorganisms. The curing reaction of composite resins occurs through the conversion of monomers into polymers, a process called photopolymerization [11].

In this context, photoactivation occurs when photoinitiator substances absorb energy at a certain wavelength and activate this process. Camphorquinone and trimethylbenzene-diphenylphosphine oxide, known as TPO, are associated so that, after photoinitiation, the material does not become yellowish [7,11]. Insufficient photoactivation culminates in marginal microleakage in restorations and biofilm accumulation on surfaces exposed to the oral environment. The enrichment of aciduric and acidogenic bacterial species and the rates of uncured monomers can be determining factors to facilitate the formation of gaps with bacterial penetration into the resins [11].

One of the most important parameters that influence the ideal cure is the radiation exposure, delivering enough energy to be absorbed by the restoration, making the cure depend on the degree of conversion, this varying from 50% to 70%, with better mechanical properties, greater stability, and greater durability [2,7,11]. Complete and effective light curing of composite resins is one of the most important factors for successful restorations. There are several models of curing light devices on the dental market, from the simplest ones based on halogen light to LED systems (light emitting diode) with high power and emission of multiple wavelengths. These devices are distinguished by the type of light source used, the variation of emitted wavelengths, the type of pulse, and light intensity [11].

Moreover, in the conventional photoactivation cycle, or by continuous light emission, the emitted light intensity is kept constant on the restorative material from beginning to end, using the maximum power of the light curing unit for a longer time. This action induces a rapid polymerization reaction, with a smaller pre-gel phase and a greater tension at the tooth-restoration interface, which may compromise marginal sealing [19,20].

Also, research on photoactivation cycles has shown that the switched technique (also called pulsed) promotes advantages, such as the reduction of tensions arising from contraction, when compared to the continuous irradiation technique, the one without a break between light applications. After the first pulse of light energy, an interval is given without light activation so that there is a greater flow of internal forces generated inside the resin.

This phase, called the pre-gel phase, in which the material manages to dissipate the generated internal forces, is evidenced in this time interval and, only after that moment, is a new pulse of light given. The authors evaluated different types of composite resin and different polymerization techniques, observing the polymerization quality of the composite resins, and concluded that the effectiveness of polymerization on the surface of the composite resins tested was not affected by the different polymerization modes [7,11].

Thus, the dental surgeon is free to choose which photoactivation cycle to use. On the other hand, it should be noted that other factors must be considered when choosing the photoactivation cycle, such as the increase in pulp bed temperature. The increased exposure time to the LED seems to be the factor most likely to cause tissue damage, one of the other aspects that the dental surgeon must take into account when photoactivation the composite resin [19,20].

Conclusion

It was concluded that the surface properties of resin-based composite materials, as well as surface treatments, can strongly affect bacterial adhesion and biofilm formation. In addition, scientific evidence highlights that cariogenic biofilm formation can alter the surface properties of materials, thus stimulating bacterial adhesion and biofilm formation. Photoactivation allows the curing and crosslinking of polymer chains, essential for the clinical longevity of the composite resin. Insufficient photoactivation culminates in marginal microleakage in restorations and biofilm accumulation on surfaces exposed to the oral environment.

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Conflict of interest
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