BIOFILM ACCUMULATION IN DENTAL MATERIALS AND ITS REPERCUSSIONS ON ORAL HEALTH: CRITICAL REVIEW OF LITERATURE

ACÚMULO DE BIOFILME EM MATERIAIS DENTÁRIOS E SUAS REPERCUSSÕES NA SAÚDE BUCAL: REVISÃO CRÍTICA DE LITERATURA

Allana Marcela Cavalcanti Barbosa *
Anny Caroline Rodrigues Acioli **
Gabriela Vasconcelos Cruz ***
Marcos Antônio Japiassú Resende Montes ****

Uniterms:

Biofilms;
Dental plaque;
Dental materials;
Oral health.

ABSTRACT

Purpose: This article aims to conduct a literature review about the impact that biofilm accumulation on different types of dental materials can cause on oral health, according to its characteristics. Methods: Original articles about the accumulation of biofilm on the surface of different restorative and rehabilitative dental materials and their repercussions on oral health were gathered in journals in the PubMed and Lilacs databases using the search terms "Biofilm", "Dentistry", "Dental materials", through the logical operator "AND". An individual analysis of the articles that contemplated this study´s subject was performed. Results: As a result of the search, 439 articles were found, 416 from Pubmed and 23 from Lilacs, however only 23 studies (Pubmed: 20 and Lilacs: 3) were selected for content analysis. The majority of the selected articles discussed dental biofilm formation in the different restorative and rehabilitative dental materials and how their characteristics interfere in this accumulation. Final considerations: Bacterial adhesion and biofilm formation are strongly influenced by the surface characteristics of dental materials, such as their chemical compositions, surface roughness and surface free energy, what can lead to negative repercussions to the individual´s oral health.

* Acadêmica de Odontologia da Faculdade de Odontologia de Pernambuco, Universidade de Pernambuco. ORCID: https://orcid.org/0000-0003-2580-5238
** Acadêmica de Odontologia da Faculdade de Odontologia de Pernambuco, Universidade de Pernambuco. ORCID: https://orcid.org/0000-0002-5868-2871
*** Acadêmica de Odontologia da Faculdade de Odontologia de Pernambuco, Universidade de Pernambuco. ORCID: https://orcid.org/0000-0001-6313-5904
**** Professor Associado, Materiais Dentários, Universidade de Pernambuco. ORCID: https://orcid.org/0000-0002-1197-9985

Unitermos:

Biofilmes;
Placa dentária;
Materiais odontológicos;
Saúde buccal.

RESUMO

Objetivo: Este estudo tem o objetivo realizar uma revisão crítica de literatura sobre a repercussão que o acúmulo de biofilme em diferentes tipos de materiais dentários pode ter na saúde bucal, de acordo com suas características. Materiais e Métodos: Foram pesquisados artigos nas bases de dados PubMed e Lilacs acerca do acúmulo de biofilme na superfície de diferentes materiais dentários restauradores e reabilitadores e suas consequências na saúde bucal. Foram utilizados os termos "Biofilm", "Dentistry", "Dental Materials", através da operadora lógica "AND". Foi realizada uma análise individual dos artigos que contemplaram o tema deste estudo. Resultados: Como resultado da pesquisa, foram encontrados 439 artigos, sendo 416 de Pubmed e 23 de Lilacs, porém apenas 23 estudos (Pubmed: 20 e Lilacs: 3) foram selecionados para análise de conteúdo. A maioria dos artigos selecionados discutiu a formação de biofilme nos diferentes materiais dentários restauradores e reabilitadores e como suas características interferem nesse acúmulo. Conclusão: A adesão bacteriana e a formação de biofilmes são fortemente influenciadas pelas características de superfície dos materiais dentários, como suas composições químicas, rugosidade superficial e energia livre de superfície, o que pode levar a repercussões negativas à saúde bucal do indivíduo.

INTRODUCTION

The oral cavity is a complex environment, due to its high humidity, moderate temperature, which has an average of 36,8ºC, and the high abundance of nutrients that promote the development of differentiated microorganisms, and, therefore, the biofilm formation [1]. A prerequisite for the formation of this biofilm is the development of acquired pellicle, which occurs through the deposition of salivary glycoproteins, phosphoproteins, lipids and gingival fluid components on the dental surface, considering that bacterial adhesion to biotic or abiotic surfaces of the oral cavity depends on its formation [2]. Bacterial biofilms are complex, functional and structurally organized microbial communities, characterized by a diversity of microbial species that are mainly related to dental surfaces or gingival epithelial cells [3].

The biofilm is formed from an imbalance of complex interactions involving microorganisms, which because of a diet based on sugars, produce metabolites that cause demineralization [4]. The development of biofilm can be divided into four stages, where the first phase consists of the formation of acquired pellicle. The adhesion of the primary microorganisms to this pellicle corresponds to the second phase. The third stage is due to secondary colonization; and, finally, there is the fourth and final stage corresponding to the maturation of biofilm plaque [5]. Salivary pellicle receptors provide attachment sites for the cells of initial floating bacteria to connect to these surfaces and form microcolonies [1]. Over time, bacterial cells aggregate, proliferate and grow into a mature biofilm, firmly attached to these surfaces [1].

Several factors can influence the development and accumulation of oral biofilm, such as poor oral hygiene, smoking, restorations with rough surfaces and genetic factors [6]. These aspects can cause consequences for oral health such as recurrent cavity, gingivitis, periodontitis, peri-implantitis and prosthetic stomatitis[7]. Some methods can be used to control the formation of biofilm in the oral cavity, aiming to avoid the consequences of triggering factors, such as tooth brushing, that is a mechanical method and the use of toothpastes and mouthrinses, which are chemical methods [7]. The formation of oral biofilm has repercussions for oral health, also interfering in the longevity of dental materials.

Scientific evidence demonstrates the existence of an active interaction at the interface of dental materials and oral biofilm, which may affect the mechanical and aesthetic characteristics of these materials, such as Methacrylate-based resin composites and polymers, which are currently the main components of dental restorative materials used for the restoration of tooth decay and absent teeth [7]. The present work aims to conduct a literature review about the impact that biofilm accumulation on different types of dental materials can cause on oral health, according to its characteristics.

METHODS

This study is characterized by a literature review with the objective of gathering the main information of articles on the accumulation of biofilm on the surface of different restorative and rehabilitative dental materials and their repercussions on oral health.

The articles were searched in the first semester of 2021, using the strategy of "advanced search" in the databases: PubMed and Lilacs, through the logical operator "AND" with the combinations of the following terms: "Biofilm", "Dentistry", "Dental materials". It was selected articles that were published in the years between 2010 and 2020.

The studies were selected from the reading of the title, in order to verify if they were in accordance with the chosen subject. After this initial selection, it was observed whether the article had been published in portuguese or english and whether it addressed some content about the consequences of oral biofilm accumulation for longevity and functionality of the material, as well as for oral health. The exclusion criteria were the correspondence of the articles to the theme addressed in this study and the authenticity of the information collected, that was verified by the scientific platform where the article was found and if it was trustworthy.

Finally, with the selected studies, the articles were fully read and essays were written with the main points of discussion, in order to facilitate the individual analysis of the articles that contemplated this article's subject.

RESULTS

As a result of the search, 439 articles were found, 416 from Pubmed and 23 from Lilacs, however only 23 studies (Pubmed: 20 and Lilacs: 3) were selected for content analysis.

From the selected studies, ten bring the formation of dental plaque in the different restorative and rehabilitative dental materials and how their characteristics interfere in this accumulation, two articles address the relationship between diet and the development of oral biofilm, two analyze biofilm formation capacity in orthodontic materials and nine articles discuss the different antimicrobial compounds that can be added to dental materials in order to reduce biofilm accumulation and consequently improve their performance. (Table 1).

Table1. Summary of collected articles

Authors	Year	Title	Objective	Conclusion
Moreau JL, XU HHK	2010	Fluoride releasing restorative materials: effects of ph on mechanical properties and ion release	Investigate the effects of solution pH and immersion time on the mechanical properties and F release of restorative materials	The restoratives tested were able to greatly increase the F release at acidic, cariogenic pH, when these ions are most needed to inhibit caries. However, mechanical properties of these F-releasing restoratives degraded significantly in immersion.
Marra J, Paleari AG, Rodriguez LS, Leite ARP, Pero AC, Compagnoni MA	2011	Antimicrobial activity of an acrylic resin for prosthetic base combined with an antimicrobial polymer on the formation of biofilm	Evaluation of antimicrobial activity of a thermopolymerizable acrylic resin for a prosthetic basis combined with poly(2 tert-butylaminoetil) methacrylate (PTBAEMA) antimicrobial activity on staphyloccocus aureus biofilm formation, *Streptococcus mutans* and *Candida albicans*.	The results showed that the group containing 25% PTBAEMA completely inhibited the biofilm formation of *S. aureus* and *S. mutans.*
Pereira CA, Eskelson E, Cavalli V, Liporoni PCS, Jorge AOC, Rego MA	2011	*Streptococcus mutans* biofilm adhesion on composite resin surfaces after different finishing and polishing techniques	Evaluate *S. mutans* biofilm adherence on the surface of nanofilled, nanohybrid, and microhybrid composites submitted to different polishing and finishing techniques.	Human saliva pellicle increased S mutans adhesion to all composite restorative materials tested. Also, Nanofilled composite resin presented the lowest bacterial adhesion among composites.
Gil, AMC	2015	Effect of the main materials used in dental practice against the formation of bacterial dental plaque	Identify the effect of the materials most commonly used in dental practice against the formation of bacterial dental plaque.	According to the bibliographic review conducted, the materials that most commonly enable the formation of bacterial dental plaque are composite resins, followed by silver amalgam.
Silva FL, Rodrigues F, Pamato S, Pereira JR	2016	Implant surface treatment: a literature review	Expose the types of surface treatment of dental implants, as well as cellular interactions related to these materials and how this affects the speed and quality of osseointegration.	Studies show that implants with surface rough ness have a greater area of contact between the tissue and the external part of the implants, the literature does not present a consensus as to the best type of surface treatment.
Souza JCM, Mota RRC, Sordi MB, Passoni BB, Benfatti CAM, Magini RS	2016	Biofilm formation on different materials used in oral rehabilitation	Evaluation of the density and morphological aspects of in vitro biofilms cultivated in different materials used in oral rehabilitation supported by dental implants.	After 24h, results reveal statistically significant values, biofilm density higher on CoCr surfaces than in zirconia, titanium or feldspar-based porcelain.

Table1. Summary of collected articles. (Continuation)

Authors	Year	Title	Objective	Conclusion
Kim KH, Waddell JN, Tompkins G, Schwass D	2017	Surface characteristics and biofilm development on selected dental ceramic materials	The objectives were to characterize the surface and roughness of four ceramic materials and to evaluate the development of biofilm following clinical intraoral polishing protocol.	A higher degree of surface roughness of ceramic restorations often generates greater wear on the opposite dentition, compromises the aesthetics of the restoration and increases biofilm´s adhesiveness and growth.
Peralta SL, Leles SB, Dutra AL, Silva VB, Piva E, Lund RG	2017	Evaluation of physical-mechanical properties, antibacterial effect, and cytotoxicity of temporary restorative materials	Investigate the physical-mechanical properties, antibacterial effects and cytotoxicity of seven temporary restorative materials.	Temporary restorative materials sealant capacity is extremely important, due to the fact that microleakage can lead to secondary infections, threatening the treatment.
A. Balhaddada A, A. Kansaraa A, Hidan D, D. Weir M, H.K. Xu H, Anne S. Melo M	2018	Toward dental caries: exploring nanoparticle-based platforms and calcium phosphate compounds for dental restorative materials	Discuss the process of cavity formation and the role of pathogenic biofilm in this process, the increasing incidence of recurrent cavity and the recent efforts made to incorporate bioactive nanoparticles into restorative materials, as strategies for the prevention and management of caries-related bacteria.	The incorporation of metallic nanoparticles has become a field of interest in dentistry and several studies have demonstrated their ability to improve mechanical and physical properties, and also improve the antimicrobial properties of materials against certain oral species.
Hao Y, Huang X, Zhou X, et al	2018	Influence of dental prosthesis and restorative materials interface on oral biofilms	The objective was to discuss the influence of biofilm formation on the tooth interface with restorative materials and prostheses.	Each chemical composition of dental materials (organic matrix, inorganic filling, fluoride and various metal ions) can improve or inhibit the formation of biofilms.
Silva, T.S., Freitas, A.R., Pinheiro, M.L., do Nascimento, C., Watanabe, E., Albuquerque, R.F	2018	Oral biofilm formation on different materials for dental implants	The objective was to evaluate and compare the accumulation of biofilm in implant materials.	Clinical studies demonstrate a cause-and-effect relationship between biofilm accumulation in teeth or dental implants and the development of peri-implant gingivitis. The progression of the inflammatory process leads to peri-implantitis and consequent loss of the implant.
Zhang N, Zhang K, Xie X, et al	2018	Nanostructured polymeric materials with protein-repellent and anti-caries properties for dental applications	Review the new generation of nanostructured, bioactive and therapeutic dental polymeric materials with protein repellent properties and anti-cariogenic properties.	The combined use of MPC with DMAHDM resulted in a more effective reduction of colony formation units and more effective deaths than each agent alone.
Conrads G, Wendt LK, Hetrodt F, Deng Z-L, Pieper D, Abdelbary MMH, et al	2019	Deep sequencing of biofilm microbiomes on dental composite materials	To evaluate in detail the composition of dental biofilm in resinous dental materials.	Bacteria adhere more strongly to composites, this interferes with their biostability and consequently longevity.
Kim D, Lee M, Kim J, Lee D, Kwon J, Choi S	2019	Incorporation of zwitterionic materials into light-curable fluoride varnish for biofilm inhibition and cavity prevention	This study aimed to evaluate the incorporation of three different zwitterionic materials — Polymers MPC, CBMA and SBMA — in LCFV in relation to inhibition of biofilm accumulation.	The depth of enamel demineralization was significantly lower in LCFV incorporated with zwitterionic materials in relation to the control group, demonstrating that the incorporation of these compounds has a greater inhibitory effect on cavity.
Bozkurt AP, U¨nlu O, Demirci M	2020	Comparison of microbial adhesion and biofilm formation on orthodontic wax materials; an in vitro study	Experimentally analyze microbial adhesion and biofilm formation capacity of *S. mutans* and *L. acidophilus* individually and together in orthodontic wax materials and on different surfaces.	Considering the ability to form biofilms of *S. mutans* and *L. acidophilus* together in different orthodontic waxes, it was found that more biofilm was formed in the 48th hours in Orthodots CLEAR (OrVance) compared to Brace Gard (Infa-Lab Inc.).
Brum RS, Labes LG, Volpato CAM, Benfatti CAM, Pimenta AL	2020	Strategies to reduce biofilm formation in peek materials applied to implant dentistry: a comprehensive review	Discuss strategies capable of improving the antibiofilm and antimicrobial properties of poly(ether-ether-ketone) materials.	Pure Poly(ether-ether-ketone) polymer has been shown to be susceptible to colonization by biofilms.
Carrouel F, Viennot S, Ottolenghi L, Gaillard C, Bourgeois D	2020	Nanoparticles as anti-microbial, anti-inflammatory,and remineralizing agents in oral care cosmetics: a review of the current situation	Provide a synthesis of the progress made by nanomaterials and their use in the oral hygiene market as antimicrobial and remineralizer agents in oral care cosmetics.	To combat bacterial infections, metals, metal oxide and other nanoparticles seem to be promising alternatives due to their distinct physicochemical properties. Even though some materials have a naturally antibacterial activity, their antibacterial activity is increased when their dimensions are reduced to nanometric regimens.
Engel AS, Kranz HT, Schneider M, et al	2020	Biofilm formation on different dental restorative materials in the oral cavity	Compare biofilm adhesion and formation in different dental restorative materials with those in human enamel to detect differences in bacterial composition, growth rate and morphology of the oral biofilms formed, all in vivo.	The accumulation of proteins and the thickness of the acquired pellicle seem to depend on the underlying material.
Leyva del Rio D, Sartori N, Barton Tomblin N, et al	2020	Bioactive dental adhesive system with tt-farnesol: effects on dental biofilm and bonding properties	The aim of this study was to investigate the antimicrobial properties of experimental adhesives incorporating different concentrations of tt-farnesol in a universal adhesive system, in order to analyze its effect on the viability of *S. mutans* biofilm.	The antibacterial effect of experimental adhesives containing tt-farnesol was observed, but a more accurate evaluation of the adequate concentration of antibacterial agent was required to overcome the harmful effects on the mechanical properties, which decreased the material´s adhesive capacity to the dental substrate.

Table1. Summary of collected articles. (Continuation)

Authors	Year	Title	Objective	Conclusion
Mangal U, Kwon JS, Choi SH	2020	Bio-interactive zwitterionic dental biomaterials for improving biofilm resistance: characteristics and applications	The objective was to evaluate the performance of Zwitterionic polymers in its resistance to protein adhesion and prevention of biofilm formation, maintaining biocompatibility.	The study discussed the potency of Zwitterionic polymers, when alone or associated with other compounds, in preventing the adsorption of proteins and bacteria to the surfaces of composites, adhesive systems and varnishes.
Mitwalli H, Alsahafi R, A. Balhaddad A, D. Weir M, H. K. Xu H, Anne S. Melo M	2020	Emerging contact-killing antibacterial strategies for developing anti-biofilm dental polymeric restorative materials	Evaluate the recent strategies of antibacterial agents in the control of infections related to biofilm accumulation in dental restorations.	The addition of light-curing quaternary ammonium-based monomers that can covalently bind to resin-based dental materials has shown a strong antibacterial effect that does not diminish over time.
Staszczyk M, Jurczak A, Magacz M, et al	2020	Effect of polyols and selected dental materials on the ability to create a cariogenic biofilm–on children caries-associated *streptococcus mutans* isolates	The objective of this study was to evaluate the effect of sweeteners on the *Streptococcus mutans´* ability to form biofilm in dental materials.	Due to the impact of cariogenic biofilms on resinous materials, the substitution of sugars by non-cariogenic sweeteners seems to be important not only from the point of view of the development of new outbreaks of demineralization, but also to protect the physical-chemical properties of these materials and to more effectively prevent secondary cavity.
Tektas S, Thurnheer T, Eliades T, et al	2020	Initial bacterial adhesion and biofilm formation on aligner materials	It aims to evaluate the initial bacterial adhesion and the formation of biofilm in different alignment materials.	Aligners have advantages over fixed appliance in relation to oral health, since they accumulate less biofilm.

DISCUSSION

The oral cavity is an extremely dynamic environment[8]. Finding restorative and rehabilitative materials that can preserve their chemical and physical characteristics, despite humidity, pH and temperature variations is a major challenge. In addition to these factors, the oral cavity serves as a habitat for the development and proliferation of various species of microorganisms. However, this oral microbiome consisting of pathogenic, symbiotic and commensal microorganisms living in a community, can become dysbiotic due to some factors such as an unbalanced diet, lack of oral hygiene protocols and intrinsic factors of the individual. Thus, biofilm is formed on the oral surfaces. As a result, there is the emergence of oral diseases and the most prevalent are dental cavity and periodontitis, which have as their main etiological factor the accumulation of pathogenic bacteria attached to biofilm. Together, they represent the most common infectious human disease in the world [9,10].

Dental materials may have characteristics that influence a higher or lower rate of biofilm accumulation. Surface roughness, for example, makes it difficult to remove the biofilm by conventional oral hygiene methods, as it can create niches in which bacteria are protected from brushing and cutting forces [7]. Another characteristic is the surface free energy, because the higher this energy is, the greater the wetting capacity becomes, consequently making the surface more hydrophilic which intensifies the adhesion of the salivary pellicle, providing greater colonization of bacteria in the region due to the presence of binding proteins [1, 2, 11, 12].The process of biofilm formation on the surface of dental materials also depends on the chemical composition of this material, some even have substances such as fluoride, chlorhexidine, quaternary ammonium salts [13].

Among the dental materials used in restorative dentistry, composite resin restorations have gained the dental market due to their aesthetic, mechanical properties and minimally invasive approach, due to adhesive systems [14]. However, there are a few attributes on these composites that provide intense growth of biofilm and can affect its longevity [11, 14, 15]. The resin, being a light curing material, does not achieve total conversion of its monomers, which can lead to the development of bacterial colonies by the leaching of their components, and this colonization ends up being responsible for accelerating the degradation process of restorations [4].

Another factor would be the surface roughness of the resins, which is closely linked to increased plaque formation on the dental surface [16]. In a study by Pereira et al. a reduction in biofilm formation in nanoparticulated resins has been demonstrated compared to nanohybrid and microhybrid resins [17]. This occurs because the nanoparticulate resins have smoother surfaces after the same finishing and polishing procedures, consequently decreasing the adhesion of microorganisms [1]. In addition, composite resins make use of adhesive systems that form a

microscopic interface between the tooth and restoration and, if this material tends to degradation, it can lead to infiltration and subsequent secondary diseases. The dissolution of the adhesive is mainly attributed to the acidic environment created by the microorganisms present in the biofilm [9].

One of the major concerns about biofilm accumulation is its deposition on the surface of composite resin restorations leading to the development of secondary cavity, mostly formed at the tooth and restoration interface, a place of greater fragility, and also the main cause of failure of the restorative procedure[14,15,18]. Restoration longevity is linked to susceptibility towards bacterial colonization [13], which leads to the need for a restoration replacement, which may cause a greater loss of dental structure [13,15,18]. The pellicle formed under the composite resins not only degrades the material, but also results in infection at the resin-tooth interface, which can cause caries disease or pulpitis [11].

Prior to the development of composite resins, the frequently used material for direct restorations was amalgam. However, amalgam restorations are becoming obsolete due to the risk of environmental pollution, unfavorable aesthetic results and the need for greater removal of dental tissue during cavity preparation, compared to resins, despite having excellent mechanical properties, good longevity and low cost. The longevity of amalgam is closely related to a lower incidence of secondary cavity, since the reduction of biofilm deposition on amalgam surfaces probably comes from the release of ions with bactericidal activity, mainly mercury (Hg) and silver (Ag), in addition to the copper present in its composition, which has a strong and rapid bactericidal effect, known as "contact killing". The amalgam also has the self sealing property, resulting from the corrosion of the metal alloy and oxide deposition in the tooth-restoration interface. However, the roughness caused by corrosion tends to accelerate the deterioration process and ultimately induce the failure of amalgam restoration. [1]

Glass Ionomer Cement (GIC), used as a provisional restoration material, presents some satisfactory characteristics such as its ability to chemically adhere to enamel and dentin, as well as its ability to release fluoride in the oral environment [1,11]. Acidic conditions can increase the constant release of fluoride due to its high bioavailability at low pH, but the highest rate of release of these ions is found when the pH is around 4. It is known that the cariogenic pH is between 5.5–4, that is, when these ions are most needed to inhibit the demineralization process [1,19]. Therefore, the efficiency of fluoride ions depends not only on their concentration, but also on the pH threshold value for their release. However, although this material has the ability to inhibit enamel demineralization through fluoride release, low pH and microbial environment can provoke changes in the morphology of the GIC and accelerate the aging of the material by increasing surface roughness, which causes greater bacterial adhesion and biofilm formation [1].

Indirect restorations with adhesively cemented ceramic, such as inlays/onlays, facets and crowns, are mainly used due to their biocompatibility, low thermal conductivity, color stability and aesthetics. Clinical failure is related to a number of factors, such as lack of marginal sealing, superficial irregularities and cement excess, which may favor the accumulation of microorganisms, compromising the restoration´s longevity. Both surface roughness and free surface energy are able to decisively influence initial microbial adhesion[1,20]. A material widely used for this type of procedure is zirconia, which has shown lower accumulation of biofilm on its surface [1].

The physical and chemical characteristics of dental prostheses can also influence the coating of the acquired salivary pellicle, initial bacterial adhesion and biofilm formation, which is aggravated by the presence of roughness and pores on the surface of the acrylic resin prosthetic base, limiting the material's longevity [1,2,12]. The poor adaptation of prostheses associated with local factors such as poor oral hygiene, continuous use of the prosthesis and changes in saliva pH are inducing agents for the development of prosthetic stomatitis, a clinical condition characterized by hyperemia, edema, pruritus and pain. Although its etiology is considered multifactorial, *Candida spp* infection, also present in oral microcolonies, especially *Candida albicans*, is still the main responsible agent [12].

There are other materials that have retentive characteristics for the dental plaque, such as orthodontic appliances and aligners, which may be responsible for the formation of incipient cavity lesions and inflammatory processes in gingival tissue. This occurs, since these devices can prevent patients from performing adequate hygiene, and their components can cause changes in the oral microbiota, reducing the pH and increasing the retention areas for microorganisms [8]. Orthodontic adhesives used in the direct fixation of brackets to enamel are also highly susceptible to

plaque accumulation [7].

Implants, although commonly used in the rehabilitation of tooth loss, easily become infectious due mainly to the accumulation of biofilm on their surface, what can lead to the development of peri-implantitis. That is a heterogeneous infection, in which periodontal pathogens and opportunistic microorganisms act simultaneously. Patients rehabilitated from periodontal disease with dental implants are more predisposed to develop peri-implant diseases, for which the inadequate control of plaque also acts as a primary etiological factor [21]. What occurs is that the initial accumulation of biofilm in implant abutments causes peri-implant mucositis, which may evolve to peri-implantitis, and may lead to the implant´s loss in the future. Zirconia is a widely used material due to its aesthetic property and lower bacterial adhesion capacity, demonstrating itself as a possible substitute for titanium abutments [1,3].

Understanding all the repercussions that biofilm can bring to oral health and to the longevity of dental materials, it is necessary to take some precautions in order to prevent such consequences. Only the control of plaque accumulation made through fluoride prophylaxis is not a sufficient method to prevent cavity, therefore, knowledge about the relationship between the development of this disease and diet, as well as the reduction of consumption of cariogenic sugars, for example sucrose, is important to develop new strategies to prevent this disease. That being said, the substitution of cariogenic sugars by polyols such as sorbitol and erythritol, which are substances naturally found in many fruits and manufactured from natural raw materials, proves to be a good option for reducing the growth of dental plaque. These can be found in the form of chewing gums, toothpastes and dental floss [13].

In the mouth, the surface of a restoration is quickly coated by a film of saliva containing salivary proteins. These proteins are fundamental for the adhesion of bacteria on the dental surface, and the first step towards the formation of the biofilm is the adhesion of primary colonizers such as streptococcus to these salivary proteins. Thus, making a composite able to repel binding proteins would contribute to the reduction or elimination of the biofilm. Following this point of view, several studies have been conducted aiming to develop dental materials with antimicrobial properties, consequently aiming at an improvement in their longevity and functionality in the oral environment[22].

As an example, there are zwitterionic polymers that are a group of materials with positive and negative charges included in its structure, which have the property of repelling bacteria. This is due to the formation of a physical and energetic barrier on the hydration layers on the surface of the material reducing the attachment of salivary proteins and bacteria, while maintaining biocompatibility [7,15]. There are also polymers formed by quaternary ammonium methacrylates, which act by preventing the formation of biofilm from the connection between the quaternary amine present in its structure, which is positively charged, with the negatively charged bacterial membrane, resulting in its rupture by altering the electrical balance [15,22].

However, quaternary ammonium methacrylates' contact killing mechanism could be limited by the presence of salivary proteins on the composite surface, since these proteins prevent the direct attachment of microorganisms to the material. To overcome this limitation, studies have evaluated the addition of a polymer to quaternary ammonium methacrylates, capable of repelling these proteins, such as 2-methacryloyloxyethyl phosphorylcholine (MPC). The advantage of adding MPC in this case is the decrease in protein adsorption, which would increase the antibacterial potency of the ammonia quaternary, exposing the polymer surface with antibacterial function. This demonstrates the synergistic effect between these two polymers [15,22,23].

Therefore, further studies in this direction are necessary to prove these potential benefits in clinical practice, and thus obtain a better analysis of the behavior of these polymers incorporated into dental materials in the future, and it is necessary to ensure that this addition is not toxic and does not negatively interfere with the mechanical and chemical properties of dental materials. This demonstrates a possibility of promising progress in the area of Restorative Dentistry.

CONCLUSION

It can be concluded in this study that bacterial adhesion and biofilm formation are strongly influenced by the surface characteristics of dental materials, just as their chemical compositions, surface roughness and surface free energy. These factors lead to negative repercussions to the individual´s oral health, since biofilm accumulation can cause problems, such as secondary cavity, periodontal diseases, peri-implantitis and prosthetic stomatitis. Therefore, the development

of new dental materials with antimicrobial and remineralization properties is a good option for the advancement of restorative and rehabilitative dentistry today, and it is important to conduct further studies in this area.

REFERENCES

1. Hao Y, Huang X, Zhou X, et al. Influence of Dental Prosthesis and Restorative Materials Interface on Oral Biofilms. International Journal Of Molecular Science. 2018;19(3157):1-17.
2. Engel AS, Kranz HT, Schneider M, et al. Biofilm formation on different dental restorative materials in the oral cavity. BMC oral health. 2020;20(162):1-10.
3. Silva, T.S., Freitas, A.R., Pinheiro, M.L., do Nascimento, C., Watanabe, E., Albuquerque, R.F. Oral biofilm formation on different materials for dental implants. J. Vis. Exp. 2018 (136), e57756, doi:10.3791/57756.
4. A. Balhaddada A, A. Kansaraa A, Hidan D, D. Weir M, H.K. Xu H, Anne S. Melo M. Toward dental caries: Exploring nanoparticle-based platforms and calcium phosphate compounds for dental restorative materials. Ke Ai Advancing Research Evolving Science. 2018;43:55
5. Bozkurt AP, U¨nlu O, Demirci M. Comparison of microbial adhesion and biofilm formation on orthodontic wax materials; an in vitro study. Journal Of Dental Sciences. 2020; 15:493-499
6. Silva FL, Rodrigues F, Pamato S, Pereira JR. Implant surface treatment: a literature review. RFO. 2016;21(1):136-142
7. Mangal U, Kwon JS, Choi SH. Bio-Interactive Zwitterionic Dental Biomaterials for Improving Biofilm Resistance: Characteristics and Applications. International Journal of Molecular Science. 2020;21:9087
8. Peralta SL, Leles SB, Dutra AL, Silva VB, Piva E, Lund RG. Evaluation of physical-mechanical properties, antibacterial effect, and cytotoxicity of temporary restorative materials. Journal of Applied Oral Science. 2018 May 15;10(1):1-10.
9. Carrouel F, Viennot S, Ottolenghi L, Gaillard C, Bourgeois D. Nanoparticles as anti-microbial, anti-inflammatory,and remineralizing agents in oral care cosmetics: a review of the current situation. MDPI. 2020;10:140
10. Tektas S, Thurnheer T, Eliades T, et al. Initial Bacterial Adhesion and Biofilm Formation on Aligner Materials. MDPI. 2020; 9(908):1-11.
11. Gil, AMC. Effect of the main materials used in dental practice against the formation of bacterial dental plaque. Revista Cubana de Estomatologia. 2015;52(4):32-38.
12. Marra J, Paleari AG, Rodriguez LS, Leite ARP, Pero AC, Compagnoni MA. Effect of an acrylic resin combined with an antimicrobial polymer on biofilm formation. Journal of Applied Oral Science . 2012; 20:643–8.
13. Staszczyk M, Jurczak A, Magacz M, et al. Effect of Polyols and Selected Dental Materials on the Ability to Create a Cariogenic Biofilm–On Children Caries-Associated Streptococcus Mutans Isolates. International Journal of Environmental Research and Public Health. 2020;17(3720):1-20.
14. CONRADS, Georg. Deep sequencing of biofilm microbiomes on dental composite materials. Journal Of Oral Microbiology. 2019; 11(1617013):1-9.
15. Mitwalli H, Alsahafi R, A. Balhaddad A, D. Weir M, H. K. Xu H, Anne S. Melo M. Emerging Contact-Killing Antibacterial Strategies for Developing Anti-Biofilm Dental Polymeric Restorative Materials. MDPI. 2020;7:83
16. Souza JCM, Mota RRC, Sordi MB, Passoni BB, Benfatti CAM, Magini RS. Biofilm Formation on Different Materials Used in Oral Rehabilitation. Brazilian Dental Journal. 2016;27(2):141-147.
17. Pereira CA, Eskelson E, Cavalli V, Liporoni PCS, Jorge AOC, Rego MA. Streptococcus mutans Biofilm Adhesion on Composite Resin Surfaces After Different Finishing and Polishing Techniques. **Operative Dentistry**. Operative Dentistry. 2011; 36(3): 311-317.
18. Leyva del Rio D, Sartori N, Barton Tomblin N, et al. Bioactive Dental Adhesive System With tt-Farnesol: Effects on Dental Biofilm and Bonding Properties. Frontiers in Bioengineering and Biotechnology. 2020;8:865.
19. Moreau JL, XU HHK. Fluoride releasing restorative materials: Effects of pH on mechanical properties and ion release**. Dental Materials**. 2010; 26(11): 227-235.
20. Kim KH, Waddell JN, Tompkins G, Schwass D. Surface Characteristics and Biofilm Development on Selected Dental Ceramic Materials. International Journal of Dentistry.2017;2017:1-6.
21. Brum RS, Labes LG, Volpato CAM, Benfatti CAM, Pimenta AL. Strategies to Reduce Biofilm Formation in PEEK Materials Applied to Implant Dentistry: A Comprehensive Review. MDPI. 2020;9:609.
22. Zhang N, Zhang K, Xie X, et al. Nanostructured Polymeric Materials with Protein-Repellent and Anti-Caries Properties for Dental Applications. MDPI. 2018;8:393.

23. Kim D, Lee M, Kim J, Lee D, Kwon J, Choi S. Incorporation of zwitterionic materials into light-curable fluoride varnish for biofilm inhibition and cavity prevention. Scientific Reports Nature Research. 2019;9:19550.

.

Endereço para correspondência

Marcos Antônio Japiassú R. Montes
E-mail: marcos.japiassu@upe.br