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Scoping review of resin cements modified by antimicrobial agents: Effects of incorporation

Revisão do escopo de cimentos resinosos modificados por agentes antimicrobianos: Efeitos da incorporação

Revisión general de los cementos de resina modificados con agentes antimicrobianos: Efectos de la incorporación

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Simone Kreve
ORCID: https://orcid.org/0000-0001-5599-4450
Ribeirão Preto School of Dentistry, University of São Paulo, Brazil
E-mail: simonek@alumni.usp.br
Izabela Ferreira
ORCID: https://orcid.org/0000-0003-2774-9495
Ribeirão Preto School of Dentistry, University of São Paulo, Brazil
E-mail: izabela.ferreira@usp.br
Andréa Cândido dos Reis
ORCID: https://orcid.org/0000-0002-2307-1720
Ribeirão Preto School of Dentistry, University of São Paulo, Brazil
E-mail: andreare73@yahoo.com.br

Abstract
The purpose of this scoping review was to assess the modification effects of resin cements on antimicrobial capacity, mechanical properties, and conversion degree. Researches in the Embase, PubMed, SCOPUS, Cochrane library and Web of Science databases were enriched with manual searches, between May and June 2020, using the keywords "antibacterial resin cement" NOT "adhesive" NOT "ionomer". The criteria included articles written in English, in vitro studies assessing resin cements with the incorporation of antimicrobial agents, describing conversion degree and/or mechanical properties, and/or effect of the antimicrobial agents, and articles indexed in the Journal Citation Reports (JCR) database. A total of 100 articles were found, of which 11 were selected by title and/or abstract, according to the inclusion criteria. From the 7 articles selected for full reading, 3 articles remained in this scoping review. These had high variability in materials and methods, making it difficult to perform the data statistical analysis; thus, a descriptive analysis was performed. There is a need for a resinous adhesive cementing agent with antimicrobial action since the bacteria infiltration at the adhesive interface is directly related to secondary dental caries with reduced longevity and survival of prosthetic treatments.
Keywords: Resin cements; Anti-infective agents; Biofilms.

Resumo
O objetivo dessa revisão de escopo foi avaliar os efeitos da modificação dos cimentos resinosos na capacidade antimicrobiana, nas propriedades mecânicas e no grau de conversão. As pesquisas nos bancos de dados Embase, PubMed, SCOPUS, Cochrane library e Web of Science foram enriquecidas com buscas manuais, entre maio e junho de 2020, usando as palavras-chave "antibacterial resin cement" NOT "adhesive" NOT "ionomer". Os critérios incluíram artigos escritos em inglês, estudos in vitro que avaliaram cimentos resinosos com a incorporação de agentes antimicrobianos, descrevendo o grau de conversão e/ou as propriedades mecânicas e/ou o efeito dos agentes antimicrobianos e artigos indexados no banco de dados Journal Citation Reports (JCR). Foi encontrado um total de 100 artigos, dos quais 11 foram selecionados pelo título e/ou resumo, de acordo com os critérios de inclusão. Dos 7 artigos selecionados para leitura completa, 3 artigos permaneceram nesta revisão de escopo. Esses artigos apresentavam alta variabilidade de materiais e métodos, o que dificultou a análise estatística dos dados; portanto, foi realizada uma análise descritiva. Existe a necessidade de um agente de cimentação adesiva resinosa com ação antimicrobiana, uma vez que a infiltração de bactérias na interface adesiva está diretamente relacionada à cárie dentária secundária, com redução da longevidade e da sobrevivência dos tratamentos protéticos.
Palavras-chave: Cimentos de resina; Agentes anti-infecciosos; Biofilmes.

Resumen
El propósito de esta revisión de alcance era evaluar los efectos de modificación de los cementos de resina sobre la capacidad antimicrobiana, las propiedades mecánicas y el grado de conversión. Las investigaciones en las bases de datos Embase, PubMed, SCOPUS, Cochrane library y Web of Science se enriquecieron con búsquedas manuales, entre mayo y junio de 2020, utilizando las palabras clave «antibacterial resin cement» NOT «adhesive» NOT «ionomer». Los criterios incluyeron artículos escritos en inglés, estudios in vitro que evaluaran cementos de resina con la incorporación de agentes antimicrobianos, que describieran el grado de conversión y/o las propiedades mecánicas, y/o el efecto de los agentes antimicrobianos y artículos indexados en la base de datos Journal Citation Reports (JCR). Se encontró un total de 100 artículos, de los cuales 11 fueron seleccionados por título y/o resumen, según los criterios de inclusión. De los 7 artículos seleccionados para lectura completa, 3 artículos permanecieron en esta revisión de alcance. Éstos presentaban una gran variabilidad en cuanto a materiales y métodos, lo que dificultó el análisis estadístico de los datos, por lo que se realizó un análisis descriptivo. Existe la necesidad de un agente cementante adhesivo resinoso con acción antimicrobiana, ya que la infiltración bacteriana en la interfase adhesiva está directamente relacionada con la caries dental secundaria con reducción de la longevidad y supervivencia de los tratamientos protésicos.
Palabras clave: Cementos de resina; Antiinfecciosos; Biopelículas.

1. Introduction

Resin cements are polymer-based materials (Liu et al., 2020) that emerged to supply the need for cementation or adhesion of indirect restorations to dental structures and became the material of choice in aesthetic restorations due to its adhesive properties and low solubility ((Chen, Suh, Yang, 2018; Hiraishi et al., 2010; Oguz et al., 2020). The composition of most resin cements is similar to that of composite resins for restoration, i.e., a resin matrix, inorganic fillers, and a silane that joins the filler to the matrix (Akaki et al., 2005; Huang et al., 2018), being the proportion of diluents monomers in the matrix and the number of inorganic particles the main differences (Spazzin et al., 2016). However, the composite resin has a volumetric contraction, generated when the van der Waals gaps become narrower with the polymerization of methacrylate monomers (Ersen, Gürbüz, Özcan, 2019), and incomplete conversion of monomers to polymer chains, due to the presence of free unconverted monomers (Nedeljokovic et al., 2015). Such situations lead to infiltration over time, since the volumetric contraction produces internal stresses that can cause the rupture of the composite-tooth bond, in addition to microleakage, postoperative sensitivity, or fracture of the dental structure (Hardy et al., 2018; Nedeljokovic et al., 2015).

The main use of resin cements is the cementation of aesthetic restorations, thanks to its high adherence power to the dental structure and the aesthetic material (Hardy et al., 2018). However, this adhesive interface is one of the places of greatest infiltration and recurrence of dental caries, leading to restorations failure (Akaki et al., 2005; Ersen, Gürbüz, Özcan, 2019; Hiraishi et al., 2010; (Ahmet et al., 2014). Originally, resinous materials have no antimicrobial capacity, once the number of monomers and other leachate components is much less than the minimum concentration required for bacterial inhibition (Chen et al., 2018). Thus, the incorporation of antimicrobial agents to resin cements can be a factor to increase the longevity of cemented restorations, since this can eliminate the harmful effects caused by bacteria during microleakage (Akaki et al., 2005; Hiraishi et al., 2010).

Ahmet et al., (Ahmet et al., 2014) promoted the addition of benzalkonium chloride in self-adhesive resin cements, and although the addition of 1% seemed acceptable, changes in the tested mechanical properties were observed. The incorporation of Triclosan in resin cements did not significantly change the cement's structure; however, the formation of pores was verified (Akaki et al., 2005). And Hiraishi et al., (Hiraishi et al., 2010) observed that the chlorhexidine incorporated in resin cements based on polymethylmethacrylate (PMMA) was not effective against Enterococcus faecalis, and in addition, it was leached from the material.

The few studies available (Ahmet et al., 2014; Akaki et al., 2005; Hiraishi et al., 2010) show some achievements regarding the cements' modification, however, still with losses in mechanical properties, such as a reduction in hardness values

(Ahmet et al., 2014) and reduction in resistance to biaxial bending as the concentration of the antimicrobial agent increases (Ahmet et al., 2014).

The search in the databases presented a large number of studies that modified materials such as composite resins and adhesives. Even though resin cements and composite resins have similarities in their composition, it is not known whether the modifications made to allow adequate viscosity and adhesion to the dental structure can interfere with the performance of antimicrobials. The purpose of this study was to investigate the effects of the incorporation of antimicrobials to resin cements on antimicrobial capacity, mechanical properties, and conversion degree. We tested the null hypothesis that the incorporation of antibacterials did not change the conversion degree of resin cements.

2. Methodology

This scoping review was performed in accordance with the declaration of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Liberati, Altman, Tetzlaff, 2009; Moher et al., 2009).

We tried to answer the following question: What are the effects of modifying resin cements on antimicrobial capacity, mechanical properties, and conversion degree?

Inclusion criteria: Articles written in English, in vitro studies assessing resin cements with the incorporation of antimicrobial agents, describing conversion degree and/or mechanical properties, and/or effect of the antimicrobial agents and articles indexed in the Journl Citation Reports (JCR) database.

Exclusion criteria: In vivo studies, bibliographic reviews, studies with endodontic cements, dentin adhesives, glass ionomer cements, temporary cements, unpublished data, reviews, letters to the editor, abstract, opinion, case report/series, or book chapter.

The research was conducted using combinations of the following terms: “antibacterial resin-cement” NOT “adhesive” NOT “ionomer” which have been adapted for each of the following electronic databases: Embase, PubMed, SCOPUS, Cochrane library, and Web of Science. The bibliographical research was performed from May to June 2020 and included all relevant articles published from 1900 to 2020, from journals indexed in the Journal Citation Reports (JCR) database. Additional researches were performed, where the reference lists and citations of the relevant articles were revised to choose possible inclusions.

The initial bibliographical research was performed by the author’s (S.K. and I.F), where titles and abstracts were selected. Subsequently, the resulting titles and abstracts were reassessed by two independent authors (S.K. and I.F.), responsible for discarding studies not related to the subject according to the established inclusion and exclusion criteria. The other studies were submitted to a full text reading. Questions or discrepancies were resolved by consensus and discussion with a third author (A.C.R).

The data were extracted from the included articles tabulated in an Excel spreadsheet (Microsoft Corporation, Redmond, USA). The study, year of publication, purpose, number of samples examined, type of resin cement, antimicrobial method, and the main conclusions described in the documents were recorded

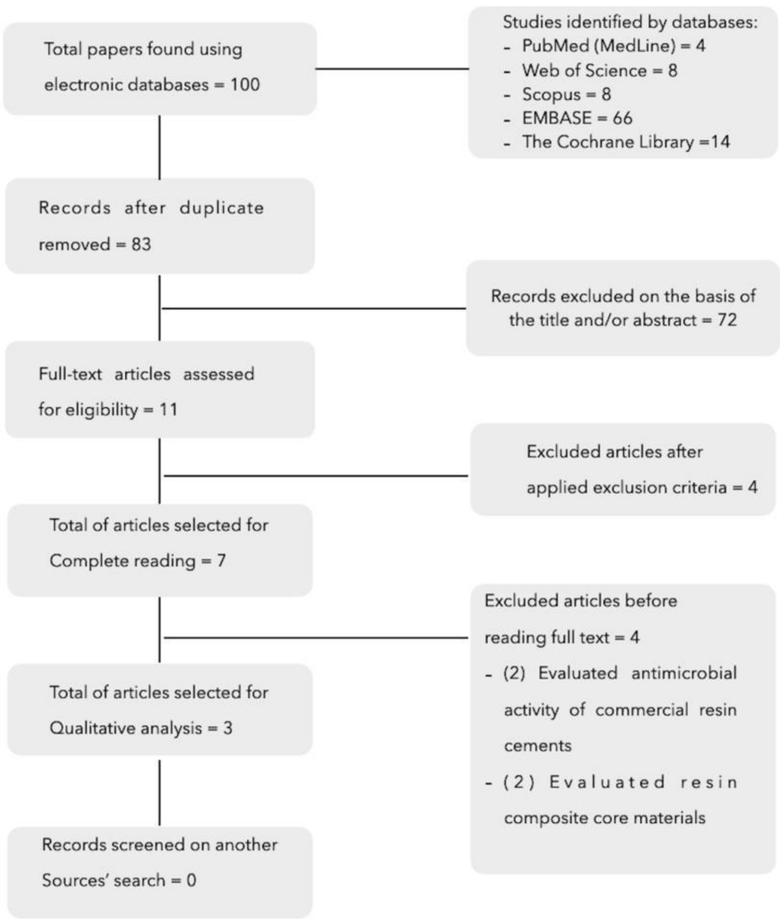
Two reviewers (S.K and I.F) independently assessed the methodological quality of each study, using a protocol adapted from a systematic in vitro review, performed by Sarkis-Onofre et al. (Sarks-Onofre et al., 2014). The following parameters were used to assess the quality of the study: number of specimens reported; sample size calculation; tests performed by a single operator; appropriate control group; the material handling followed the manufacturer’s instructions; the distribution of antimicrobials in the sample was assessed; and whether interventions were sufficiently detailed to allow reproduction. If the writer reported these items, the article received (yes). If the information could not be found, the article received (no). Articles that included only one or two of these items were considered to be at high risk for bias; three to four items, with an average risk of bias; and five to seven items, with low risk of bias (Sarkis-Onofre et al., 2014).

The articles selected for this scoping review presented great variability in the agents incorporated into the cements, in the mechanical and microbiological tests performed. This made it inappropriate to conduct a meta-analysis, however, a detailed qualitative synthesis of the results was performed, and two subcategories were described: methods used to incorporate antimicrobials into resin cements; and the importance of the conversion degree.

3. Results

Figure 1 shows a general view of the studies selection procedure. A total of 100 studies were identified in the initial research. Following the PRISMA statement, all abstracts were analyzed (Liberati, Altman, Tetzlaff, 2009; Moher et al., 2009). After excluding duplicates, and applying the inclusion criteria, 7 articles were selected for full-text evaluations, and 3 were considered in the qualitative analysis. The included articles were published between 2005 and 2014.

Figure 1 - Systematic review flowchart.



Source: Authors.

The three studies included in this review did not meet all quality requirements, so they were classified as having an average risk of bias, as described in Table 1. Also, none declared whether a single operator performed the test or reported the sample size calculation.

Table 1 - Quality assessment and risk of bias.

Study	Number of specimens reported	Sample size calculation	Assessed the antimicrobials distribution in the sample	Adequate control group	Materials used followed the manufacturers' instructions	With sufficient detail to enable replication	Tests executed by a single operator
Akaki et al.,	yes	no	yes	no	yes	yes	no
Hiraishi et al.,	yes	no	no	yes	yes	yes	no
Ahmet et al.,	yes	no	no	yes	no	yes	no

Source: Authors.

The three studies included in this review were in vitro studies. The minimum number of samples per group was 4 and the maximum number was 10. The antimicrobials used were triclosan (Akaki et al., 2005), chlorhexidine (Hiraishi et al., 2010), and benzalkonium chloride (Ahmet et al., 2014). The conversion degree (Ahmet et al., 2014), Vickers hardness (Ahmet et al., 2014), setting time measurements (Ahmet et al., 2014), biaxial bending strength measures (Ahmet et al., 2014), antibacterial agent distribution (Akaki et al., 2005), material characterization (Akaki et al., 2005), analysis of antimicrobial release (Akaki et al., 2005), and antimicrobial capacity were measured (Akaki et al., 2005). The analyzes used to assess antimicrobial capacity were agar diffusion test and direct contact test (Hiraishi et al., 2010). The main characteristics of the included studies were included in Table 2.

Table *2* - Main characteristics of the included studies.

Study	Publication year	Objective	N specimens per group	Resin cement type	Antimicrobial method	Conclusions
Akaki et al.,	2005	Incorporation of Triclosan in resin cement	5	Polymethyl methacrylate (PMMA)-based autocuring resin cement and Dual-curing self-adhesive resin cement	Leachable compounds	The antibacterial agent incorporation has not significantly altered the resin cement structure
Hiraishi et al.,	2010	Evaluated antimicrobial activity and chlorhexidine release from experimental resin cements based on polymethylmethacrylate (PMMA)	4	Polymethyl methacrylate (PMMA)-based autocuring resin cement	Leachable compounds	The 3.0 and 4.0% chlorhexidine-incorporated cement exhibited chlorhexidine release for 5 weeks; The agar diffusion test failed against Enterococcus faecalis, whereas the direct contact test revealed effect of 3.0 and 4.0% against each microbe for 2 weeks.
Ahmet et al.,	2014	Effect of different concentrations of benzalkonium chloride (BAC) on the degree of conversion (DC), vickers hardness (VH), setting time (ST) and biaxial flexural strength (FS) of two self-adhesive resin cements RC	10	Dual-curing self-adhesive resin cement	Leachable compounds	Incorporation of BAC with self-etch adhesive resins could be a good solution in order to improve the bond durability.

Source: Authors.

4. Discussion

This scoping review did not find studies with sufficient descriptions to understand the effects of modifying resin cements with the addition of antimicrobials. Most of the studies compiled in the databases have analyzed modifications in composite resins for restorations and adhesives, but there is a gap with regard to resin cements.

Resinous materials do not have an antimicrobial activity after hardened (Chen, Suh, Yang, 2018; Imazato et al., 1994), because even though the monomers and the amine compounds can act as antimicrobials, their number is much less than the minimum concentration necessary to promote bacterial inhibition (Chen, Suh, Yang, 2018). Besides, the material used as filler, usually silica, is inert and has no activity against bacteria (Imazato, 2003). In this sense, some methods were used to add antibacterial activity to resinous materials (adhesives, resins for restoration, and cements) to inhibit biofilm adhesion and reduce the incidence of secondary dental caries, which is the main reason for restorations failure (Zhang et al., 2014).

The obtaining of resinous antimicrobial compounds occurs by three main techniques, namely 1) incorporation of leachable antibacterial agents, which are generally soluble in water; 2) mixture of particles of antibacterial filler (usually metals, salts, or metal oxides, which are insoluble in water) with the fillers; 3) incorporation of polymerizable antibacterial agents (Chen, Suh, Yang, 2018; Shvero et al., 2015; Wang et al., 2018). Chlorhexidine and benzalkonium chloride (which is a quaternary ammonia) are examples of leachable antibacterial agents (Chen, Suh, Yang, 2018); bioactive glass, silver and Zn oxide are examples of antibacterial filler particles (Chan et al., 2018; Wang et al., 2018); and dimethylaminohexadecyl methacrylate and MDPB (methacryloyloxydodecylpyridiniumbromide) are examples of polymerizable antibacterial agents (Chan et al., 2018; Imazato et al., 1994).

They are used more frequently despite their short duration (Chen, Suh, Yang, 2018; Wang et al., 2018). These antimicrobials, being soluble, are mixed in the resin matrix and aim at release in a humid environment, i.e., they can be released in oral conditions (Chen, Suh, Yang, 2018; Imazato, 2003). However, they are leached in large quantities in a short period, promoting a drastic reduction in the agent’s concentration, which promotes a certain porosity in the material’s structure, changing some mechanical properties (Imazato, 2003; Zhang et al., 2014). Among the most used agents are benzalkonium chloride (BAC) and chlorhexidine (Chen, Suh, Yang, 2018; Wang et al., 2018). BAC (mixture of alkyl benzyl dimethylammonium chlorides with alkyl carbon chains) is a positively filled quaternary ammonium compound and its antibacterial activity is the result of its amphiphilicity, i.e., it has a hydrophobic part (long alkyl carbon chain) and a hydrophilic part (ammonium cationic group). The hydrophilic cationic region is responsible for destabilizing the pathogen’s surface through interactions with negatively filled components causing cell lysis (Chen, Suh, Yang, 2018). However, due to its amphiphilicity, changes in the viscosity of the mixture may occur (Ahmet et al., 2014).

Chlorhexidine is a broad-spectrum antimicrobial agent, effective against Gram-negative and Gram-positive, and which can suppress mutans streptococcal levels (Anusavice, Zhang, Shen, 2006; Chen, Suh, Yang, 2018; Zhang et al., 2014). Its antimicrobial potential acts by affecting the bacterial cell membrane integrity, which is damaged when in contact with the chlorhexidine (Cheng et al., 2017). Although it has low cytotoxicity (Zhang et al., 2014) some concerns involve the 4-chloroaniline carcinogenic impurity that is present in chlorhexidine (Chen, Suh, Yang, 2018).

Antibacterial filler particles include polymer nanoparticles, bioactive glass, and metals and their oxides (Chen, Suh, Yang, 2018). Silver is the most widely used agent and its antibacterial action is due to the interaction with the thiol group compounds found in the bacterial cell wall, resulting in the inhibition of respiratory process (Chen, Suh, Yang, 2018).

Shvero et al. (Shvero et al., 2015) found a broad antibacterial effect against oral pathogens with the incorporation of a small percentage of polymer nanoparticles of quaternized polyethyleneimine (QPEI) in resin composites. Even though nanoscale particles are more reactive than microscale particles, which produces a more efficient antibacterial effect, the disadvantages of nanoparticles include agglomeration (Shvero et al., 2015), and difficulty in color stability when using metallic particles (Chen, Suh, Yang, 2018; Imazato, 2003).

This method produces a long-lasting antibacterial effect (Imazato, 2003), since, once copolymerized with resin-based materials, i.e., after polymerization, they are not expected to leach (Chen, Suh, Yang, 2018). The antibacterial effect acts only by contact (Shvero et al., 2015), which can be beneficial, considering that, for dental materials, the antimicrobial leaching can generate several disadvantages such as porosity and loss of physical and mechanical properties (Zhang et al., 2014).

A polymerizable antibacterial agent consists of a polymerizable group, an antibacterial functional group, and among them, an alkyl chain spacer. The polymerizable group is usually a methacrylate, the functional groups are usually cationic compounds such as quaternary ammonia, pyridinium, or phosphonium (Chen, Suh, Yang, 2018; Wang et al., 2018).

Several quaternary ammonia monomers were developed in order to be polymerized together with the resin matrix, including, among others, methacryloxyethyl cetyl ammonium chloride (DMAE-CB), triethylaminododecyl acrylate (TEADDA), and MDPB (Anusavice, Zhang, Shen, 2006; Chan et al., 2018). MDPB is a combination of hydroxydodecylpyridinium bromide (a quaternary ammonia) with a methacrylate group, which allows copolymerization with other monomers so it can be added to resinous materials (Imazato, 2003; Imazato et al., 1994). While quaternary ammonia is responsible for antibacterial activity, the methacrylate group allows copolymerization with conventional monomers (Imazato et al., 2014). The MDPB monomer is incorporated into resins in the form of prepolymerized filler, and the antibacterial agents remain immobilized, as they have been chemically adhered to the resin matrix, and act as contact inhibitors against bacteria that attach to the surface (Chen, Suh, Yang, 2018; Imazato, 2003; Imazato et al., 1994). However, the effect of the antibacterial is mainly bacteriostatic, and occurs when the agent binds to cell membranes and causes cytoplasmic leakage, unlike leachable antimicrobials where penetration through the cell wall or membrane occurs (Imazato, 2003). Thus, the effects of MDPB are not as intense as the materials that release antibacterial agents.

Triethylaminododecyl acrylate (TEADDA) is another quaternary ammonium monomer that was developed with a difference in the position of functional groups (Liang et al., 2018). According to Liang et al., (Liang et al., 2018) changing the position of the functional group can help increase the mass fraction of quaternary ammonium monomers without decreasing mechanical resistance, in addition to influencing anti-biofilm capabilities.

An important parameter in the development of resinous antibacterial compounds is the effect of salivary components on surface properties. According to Imazato (Imazato, 2003), a limitation of resins containing quaternary ammonia methacrylate is that the coating of salivary proteins on the resin surface reduces the effectiveness of “contact death” by reducing the contact between bacteria and the resin. This reduction in antibacterial potential occurs because saliva is adsorbed on the surfaces of materials, which can change the surface-biofilm interaction (Shvero et al., 2015).

Resinous materials have a mechanism for polymerization by free radicals (Besegato et al., 2019; Moldovan et al., 2019), and, for self-cured systems, these are generated by a chemical reaction, and in light-cured systems, polymerization initiators are activated by visible light that react with a reducing agent to produce free radicals (Besegato et al., 2019; Moldovan et al., 2019).

In resin compounds, the polymerization of methacrylate monomers produces highly cross-linked structures, however, not all material polymerizes, which results in the surplus of some double bonds (Moldovan et al., 2019). Some factors are responsible for the degree of incomplete polymeric conversion, and among them, curing time, the chemical structure of the monomer (Lempel et al., 2019), the matrix composition (amount of diluent) (Besegato et al., 2019), the intensity of the photopolymerizing light (Besegato et al., 2019; Hayashi et al., 2019), exposure time (Hayashi et al., 2019), characteristics of the filler particles (Besegato et al., 2019; Lempel et al., 2019), and the concentration of initiator and inhibitor (Lempel et al., 2019).

The conversion degree of these double bonds determines the mechanical properties of the resulting polymer (Asmussen, Peutzfeldt, 2003). The conversion degree correlates with microhardness and diametrical compression (Ogunyinka et al., 2007), since the cement hardening time is related to changes in the polymerization reaction (Ahmet et al., 2014). Thus, the incorporation of some materials as antibacterial agents into the structure of polymers can influence the conversion degree.

Ahmet et al. (Ahmet et al., 2014) found changes in the polymerization of self-adhesive resin cements with the addition of BAC and considered that such change may be caused by the influence of cationic activity, which changes the resin viscosity and affects the polymerization.

According to Anusavice, Zhang & Shen (Anusavice, Zhang, Shen,2006), the incorporation of chlorhexidine diacetate in resin composites may impair the polymerization process and result in a higher level of residual monomers, which results in greater weight loss of the resin matrix, increasing the dissolution of organic components and elution of chlorhexidine diacetate. Such a situation has negative consequences for the mechanical or physical properties of the composite, with decreased wear resistance (Zhang et al., 2014), porous surface (Anusavice, Zhang, Shen,2006), staining propensity, and increased water absorption. The main reason for incomplete polymerization is that chlorhexidine is a salt, and it does not mix with dental monomers, but forms aggregates in the resin matrix, and the dissolution of these aggregates forms a porous surface (Zhang et al., 2014).

Incomplete polymerization in polymers forms micro-voids that serve as the pathway for water molecules. And when present among the polymer aggregates, they serve as a deposit for chlorhexidine molecules that leach when water is absorbed by the polymeric network (Hiraishi et al., 2010).

Other antimicrobial agents incorporated into resin composites also showed changes in physical, chemical, and mechanical properties. Durner et al. (Durner et al., 2011) observed that the presence of silver nanoparticles in composites influences the polymerization process because the photons may not pass through the silver nanoparticles and do not activate the photoinitiator system; thus, the polymerization does not occur properly. Also, an additional chemical reaction can occur between the silver nanoparticles and the electrons in the photoinitiator system.

Regardless of the agent used, it is difficult to find a material that has been totally effective, i.e., with antibacterial effect without harming any physical-mechanical characteristics. A concern is in relation to residual monomers (Durner et al., 2011), because the lower the conversion degree, the greater the amounts of residual elutable monomers of the polymerized compound, which can reduce the mechanical properties, cause allergic reactions or there may still be metabolization of reactive species of oxygen (Durner et al., 2011). For leachable compounds, there is a concern that the antimicrobial compound, as well as the biodegradation products, become systemic compounds and are absorbed by the body and cause potential toxicological effects, should it come off the restoration (Chan et al., 2018; Nedeljkovic et al., 2015). And not least, there is a possible impact on the oral microbiota, which can be important due to the cariogenesis aspect (Nedeljkovic et al., 2015).

5. Considerations and Future Perspectives

The antibacterial mechanism of resinous materials containing quaternary ammonium monomers is unclear, but it has been suggested that the positive filler of the quaternary amine (N+) disturbs the electrical balance when in contact with negatively filled bacteria; also, cationic groups may penetrate the membrane causing cell lysis (Chan et al., 2018).

It is difficult to immobilize an antibacterial agent in the polymeric matrix through copolymerization with monomers of the resinous material without promoting important changes in structural functions, since the length of the alkyl chain spacer can play an important role if it is modified, as well as the counter-anion of these cationic groups (Chen, Suh, Yang, 2018).

Efforts to promote antibacterial capacity to resinous materials without decreasing the mechanical resistance promoted some observations: 1) Changing the position of the alkyl chain can limit the distribution of quaternary amines and change the antibacterial effect (Liang et al., 2018); 2) Hydrolytically sensitive coupling agents, such as silane, can be replaced by a nanoparticle (mesoporous silica + antimicrobial agent (chlorexidine)), which form a physical interlocking structure that improves the mechanical strength of polymers (Zhang et al., 2014); 3) The lack of contact of the biofilm with the antibacterial agent reduces the antibacterial effectiveness, i.e., when the bacteria are located on the biofilm’s outer surface, far from the resin, they are not damaged (Zhou et al., 2016); 4) Removing the hydrophobic end of the alkyl chain reduces the antibacterial effect of quaternary ammonium monomer (Liang et al., 2018); 5) And among others, longer alkyl chains and longer dimethacrylates tend to produce stronger antibacterial effects (Wang et al., 2018).

Identifying agents that cause long-term bacterial inhibition and that are compatible with resinous materials is a challenging task. It is essential to correlate the material’s structure with the properties for future studies to be successful in modifying polymeric materials.

Analyzes with nanoscale antimicrobials can be a suggestion to be studied with the advantage of allowing a large surface area, which improves the interaction with microorganisms and results in a broad spectrum of action. Furthermore, it is important that the nanoparticles used do not agglomerate, allowing dispersion in the resin matrix without changing the conversion degree. In this sense, excellent results have been achieved for some materials such as acrylic resins (Castro et al., 2016), irreversible hydrocolloids (Castro et al., 2019), refillers (Kreve et al., 2019), and endodontic cements (Teixeira et al., 2019).

6. Conclusion

This scoping review found few studies available that evaluated resin cements with the incorporation of antimicrobials, although the authors agree with the positive effects of this modification on the adhesive interface of indirect restorations. The need for the development of a new material was evident in the results, and the use of nanotechnology is suggested.

Furthermore, based on the descriptive analysis, it was found that due to the structural characteristics of the photopolymerizable polymers, there is a difficulty in adding antimicrobial agents without promoting structural changes that reflect on the mechanical properties or even promoting a long-term antibacterial effect without the risk that agents are leached and promote systemic concerns.

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