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Review

Antibacterial dental resin composites

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ABSTRACT

Resin composite materials exhibit good esthetic properties and strength, making them the most commonly used materials for restoring hard tissue, i.e., enamel and dentin. In the last 30 years these restorative materials have been widely used for both anterior and posterior restorations. Regrettably, studies have indicated numerous failures, the main reason for which is secondary caries. Resin composites were found to accumulate more dental plaque than enamel and other restorations. Thus, to increase the service life of resin composite restorations, modifications introducing antibacterial properties are required. In this review the authors discuss the advantages and disadvantages of various released and non-released antibacterial agents incorporated in resin composites. A change in strategy based on the use of antimicrobial polymeric macromolecules is suggested, focusing on polycationic antimicrobials. Polyethyleneimine nanoparticles, in particular, are presented as a possible solution to the disadvantages of released antiseptic agents. Developing agents with strong antimicrobial activity upon contact that do not diminish over time nor affect the biocompatibility of materials should be the focus of future research.

Contents

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1. Introduction

Dental resin composites typically consist of a dispersed phase composed of glass filler particles that are distributed to reinforce a polymerizable resin matrix, and silane coupling agents. Usually the inorganic glass filler particles, which are zirconium/silica-based, are dispersed in an organic matrix of resin components such as bisphenol, there usually are a glycidyl methacrylate (BIS-GMA), urethane dimethacrylate (UDMA), and triethylene glycol dimethacrylate (TEGDMA), which are cured during application. These composites have good esthetic properties and strength, making them the most commonly used materials for restoring hard tissue, i.e., enamel and dentin. In the past 30 years these restorative materials have been used widely for both anterior and posterior restorations. Regrettably, studies have indicated numerous failures, the main reason which is secondary decay. Numerous studies have investigated the antibacterial properties of various resin composites as well as their constituents, reporting that restorative composite materials fail to display any inhibition after being polymerized [1–4].

Moreover, resin composites have been found to accumulate more dental biofilm in the long run, when compared with enamel and other restorations. There is strong evidence that biofilm formation contributes to the chemical and mechanical degradation of resin composites [5], i.e., the lack of inhibitory effect against cariogenic bacteria such as *Streptococci mutans*. Furthermore, adhered bacteria infect the neighboring soft and hard tissues, including the enamel, dentin and gingiva. Consequently, recurrent caries evolve around these restorations which, as a matter of course, are treated by restoration replacement, resulting in additional tissue loss. Therefore, one of the strategies to elongate the survival time of dental resin composites focuses on antimicrobial treatment.

2. Antibacterial resin composites

The definition of an antimicrobial agent is a chemical compound capable of killing pathogenic microorganisms [6]. In resin composite materials the addition of an antibacterial component can be achieved through modifications made to the filler particles [7–9] or the resin matrix [10]. The strategies that have provided resin composites possessing antibacterial activity can be divided into two main groups: a released soluble antimicrobial agent, or a stationary non-released antibacterial agent (Table 1). A soluble agent is gradually released over time, discharging the antibacterial agent from the bulk of the material. Although an antibacterial effect is achieved, the agent's release has several disadvantages: an adverse influence on the mechanical properties of the base material, the release of the agent possibly generating a porous structure, time-limited efficacy, and possible toxicity to the adjacent tissues given that the rate of diffusion can be difficult to monitor. Soluble antibacterial agents that have been introduced are of low molecular weight, such as antibiotics, fluoride, chlorhexidine, silver ions, iodine and quaternary ammonium compounds.

3. Filler particle modification

Resin composites consist of 70–90% (w/w) glass filler, various modifications of the filler components have been reported to achieve antibacterial composites using soluble or stationary agents.

3.1. Released antibacterial agents

Released agents are soluble components capable of diffusing in an aqueous environment. A well known anticariogenic agent component is fluoride. The anticariogenic effect of fluoride is attributed to various mechanisms, such as, reduction of the demineralization process, enhancement of the remineralization, interference with pellicle and biofilm formation, and, the inhibition of microbial growth and metabolism. Thus, it has been reported that fluoride-releasing filler systems, such as strontium fluoride (SrF2), ytterbium trifluoride (YbF3) or leachable glass fillers, produce an antibacterial effect [11–13]. The filler systems release fluoride by means of an exchange reaction of water diffusion into the resin composite and fluoride release from the particles. One of the major disadvantages of fluoride release is that it may cause voids in the matrix, as the fluoride leaches out of the material. Furthermore, most of the fluoride is already released during the setting reaction, followed by a smaller amount of long-term fluoride release.

Additional antibacterial components widely used in medicine and pharmacology are silver and zink oxide [8,14]. Resin composites modified by silver components added to the filler particles, have been evaluated in numerous studies. Pure silver ions implanted in SiO_2 filler particles exhibit an antibacterial effect on oral streptococci [8]. Other studies, showing leaching of silver ions from resin composites loaded with high concentrations of silver-containing fillers, report antibacterial activity attributed to the anti-adherence activity of the silver-supported substratum [9,15]. Antibacterial activity has also been demonstrated in Ag–silica glass prepared by the sol–gel method [11].

3.2. Non-released antibacterial agents

Non-released antibacterial agents can be used to modify the filler particles and to produce an antibacterial effect. For example, Yoshida et al. [9] report that an experimental restorative composite containing silver supported fillers inhibit the growth of *S. mutans*. According to the authors the antibacterial effect is achieved through direct contact of the bacteria with the silver-composites. An additional contact inhibition bactericide-immobilized filler [16] contain 12-methacryloyloxydodecylpyridinium bromide (MDPB). The MDPB component, which maintain favorable mechanical properties in resin composites after aging, is more advantageous than agent-releasing composites. Furthermore, MDPB is more preferable than

Table 1
Antimicrobial agents incorporated into resin composites.

	Filler particle modification	Resin matrix modification
Released antibacterial agents	• Strontium fluoride (SrF2) ytterbium trifluoride (YbF3) [12,13] • Silver ions [8] • Ag–silica glass [11] • Zinc Oxide (ZnO) [14]	• Acrylic-amine-HF salts [17] • Methacryloyl acid-fluoride [18] • Acrylic-amine-BF3 [15] • Chlorhexidine [19] • Benzalkonium chloride [23] • Cetylpyridinium chloride [21] • Chitosan [22]
Non-released antibacterial agents	• Silver supported fillers [9] • 12-Methacryloyloxydodecylpyridinium bromide (MDPB) [16]	• Triclosan [24] • Quaternary ammonium polyethyleneimine (QPEI) [41]