DENTAL MATERIALS XXX (2018) XXX–XXX

Available online at www.sciencedirect.com

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Antibacterial quaternary ammonium compounds in dental materials: A systematic review

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ARTICLE INFO

Article history:
Received 14 July 2017
Received in revised form
20 March 2018
Accepted 23 March 2018
Available online xxx

Keyword:
Antimicrobial
Dental adhesive
Nanocomposite
Restorative dentistry
Nanofiller
Surface modification

ABSTRACT

Objective. Quaternary ammonium compounds (QACs) represent one of the most effective classes of disinfectant agents in dental materials and resin nanocomposites. This reviews aims to give a wide overview on the research in the field of antibacterial QACs in dental materials and nanocomposites.

Method. An introduction to dental materials components as well as the microorganisms and methods of evaluation for the antimicrobial assays are presented. Then, the properties and synthesis route of QACs, as monomer and filler, are shown. Finally, antimicrobial monomers and fillers, specifically those contain quaternary ammonium salts (QASs), in dental materials are reviewed.

Results. QACs have been used as monomer and micro/nanofiller in restorative dentistry. They possess one or more methacrylate functional groups to participate in polymerization reactions. QACs with multiple methacrylate groups can also be used as crosslinking agents. Furthermore, QACs with chain length from ~12 to 16 have higher antimicrobial activity in cured dental resins. In general, increasing the chain length leads to a threshold value (critical point) and then it causes decrease in the antimicrobial activity.

Abbreviations: BEMA, 2-bromoethyl methacrylate; HEMA, 2-hydroxyethylmethacrylate; MAE-HB, 2-methacryloxylethyl hexadecyl methyl ammonium bromide; MPS, 3-methacryloxypropyltrimethoxysilane; BC, benzyl chloride; IDMA-1, *bis*(2-ethacryloyloxyethyl)dimethylammonium bromide; *bis*-EMA, bisphenol A ethoxylated dimethacrylate; *bis*-GMA, bisphenol-glycerolate dimethacrylate; BB, butyl bromide; CFU, colony-forming unit; CSLM, confocal laser scanning microscopy; DC, degree of conversion; DMADDM, dimethylaminododecylmethacrylate; DMAEMA, dimethylaminoethyl methacrylate; DB, dodecyl bromide; SEM, electron microscopy; EDMAB, ethyl-4-dimethylaminobenzoate; HB, hexadecyl bromide; MAE-DB, methacryloxylethyl dodecyl methyl ammonium bromide; MDPB, methacryloyloxydodecylpyridinium bromide; DMAE-BC, methacryloxylethyl benzyl dimethyl ammonium chloride; DMAE-CB, methacryloxylethyl cetyl ammonium chloride; DMAE-m-CBC, methacryloxylethyl m-chloro benzyl dimethyl ammonium chloride; MBC, minimum bactericidal concentration; MIC, minimum inhibitory concentrations; DMAH, *N*,*N*-dimethylaminohexane; OTMS, octyltrimethoxysilane; PBS, phosphate buffered saline; OPPI, *P*-octyloxy-phenyl-phenyl iodonium hexafluoroantimonate; QAM, quaternary ammonium monomer; QABGMA, quaternary ammonium *bis*-phenol A glycerolate dimethacrylate; QACS, quaternary ammonium compounds; QASs, quaternary ammonium salts; QPEI, quaternary ammonium poly(ethylenimine) nanoparticles; SBM, Scotchbond multi-purpose; SWCNTs, single-walled carbon nanotubes; TEGDMA, triethylene glycol dimethacrylate; TPO, trimethylbenzoyl-diphenyl-phosphine oxide; TPO, trimethylbenzoyl-diphenyl-phosphine oxide; UDMA, urethane dimethacrylate; UDMS, urethane dimethacrylate silane; ZnO-NPs, zinc oxide nanoparticles.

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https://doi.org/10.1016/j.dental.2018.03.014

Please cite this article in press as: Makvandi P, et al. Antibacterial quaternary ammonium compounds in dental materials: A systematic review. Dent Mater (2018), https://doi.org/10.1016/j.dental.2018.03.014

Significance. The current state of the art of dental materials and resin nanocomposites includes a wide variety of antimicrobial materials. Among them, QACs presents low cytotoxicity and excellent long-term antimicrobial activity without leaching out over time.

Contents

1. Introduction

Composite resin materials are widely used in the dental clinic for replacing of hard tissues [1]. They have been used to replace dental amalgam restorations because of the esthetic (tooth-colored) property of composites and the safety concern for mercury in amalgam [2]. Human dental plaque is a complex biofilm that is present on tooth tissues as well as on restorative materials [3]. The oral biofilm may harbor many bacteria that are involved in the development of disease conditions such as secondary caries and demineralization process of marginal enamel and dentin [4]. The growth of some microorganisms such as *Streptococcus mutans* and *Candida albicans* on acrylic appliances and devices is one of the most discussable questions in using them [5,6]. Therefore, the bacterial adhesion, and then growth on the surface of composite resins and other dental restorative materials is an important parameter in the aetiology of secondary caries formation [7].

To overcome the problems in this field, many researchers have focused on the preparation new materials which possess antibacterial and antifungal activity. Therefore, this review will focus on the antibacterial effects of dental materials and resin composites. The properties, progresses, and limitations of the materials investigated so far are described. In the following sections, first, we present dental materials components, types of microorganisms involved in biofilm formation and then the methods used to evaluate the antimicrobial properties. Finally, antimicrobial materials, particularly QACs, in dental resin composites will be presented.

2. Dental materials components

2.1. *Monomers*

Amalgam has been used in dentistry since about 150 years and is still being used due to its low cost, ease of application, bacteriostatic effect, strength, and durability. Besides all, it has other advantages like if placed under ideal conditions, it is more durable and long-lasting as well as least technique sensitive of all restorative materials, but, concern has been raised that amalgam causes mercury toxicity [8], health effects, aesthetics, and environmental pollution [9]. The main exposure to mercury in human individuals with amalgam restoration occurs during the placement or removal of dental restorations. Once the reaction is complete, less amount of mercury is released, that is far below the current health standard [10].

Please cite this article in press as: Makvandi P, et al. Antibacterial quaternary ammonium compounds in dental materials: A systematic review. Dent Mater (2018), https://doi.org/10.1016/j.dental.2018.03.014