Elimination of oral pathogens using antibacterial hybrid mesoporous silica material templated with surfactant polyion complex (SPIC) micelles

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Mesoporous silica (MS) materials have attracted significant attention due to their unique properties, such as high specific surface area, tuneable mesoporous structure, and facile post-functionalization, making them highly advantageous for use in drug delivery systems (DDS). For instance, mesoporous silica nanoparticles (MSNs) can carry antibacterial drugs and show potential for use in dental applications [1]. Recent developments in mesoporous DDS aim not only to carry drugs but also to incorporate additional drug release control mechanisms, e.g, pH-stimuli, to reduce drug toxicity and improve treatment efficacy [2].

New hybrid mesoporous silica (MS) material with a monomodal pore size distribution was successfully synthetized by the sol-gel method using Surfactant PolyIon Complex (SPIC) micelles [2]. They were formed through the electrostatic complexation of a cationic surfactant, cetylpyridinium chloride (CPC), characteristic by broad-spectrum antimicrobial properties, and double hydrophilic block copolymer (DHBC), which consists of a weak polyacid block of poly(acrylic acid) (PAA)) and a neutral comb block of poly(oligo(ethylene glycol)) methyl ether acrylate (PEOGA). This material is intrinsically functionalized with PEOGA blocks anchored in silica walls via H-bonding, and weak polyacid blocks complexed with antibacterial CPC within the mesopores.

CPC release studies conducted at different pH values (7.4, 4.2, and 3) confirmed selective CPC release under the acidic conditions commonly found in orodental pathologies and remarkable stability of the anchored DHBC.
In this work, we demonstrated the antibacterial effect of a hybrid MS against four types of bacteria associated with the most common oral diseases. This hybrid MS was tested against both aerobic (Staphylococcus aureus, Enterococcus faecalis) and anaerobic (Streptococcus mutans, Porphyromonas gingivalis) bacteria using several methods, confirming its ability to inhibit bacterial growth and affect the metabolism of tested microorganisms. Minimal inhibition concentration (MIC) and minimal bactericidal concentration (MBC) for the different bacteria, expressed in μg/ml, were 16/32, 32/32, 8/16 and 2/4 (MIC/MBC) for S. aureus, E. faecalis, S. mutans and P. gingivalis, respectively. When monitoring the 48-hour survival of bacteria without (pH(-))and with a pH stimuli (pH<3), the MICs were as follows 16/16, 32/16, 16/16 and 4/1 μg/ml for S. aureus, E. faecalis, S. mutans and P. gingivalis, respectively.

The obtained results confirmed that hybrid MS templated and functionalized with SPIC systems represent tuneable pHstimuli responsive DDS with excellent antimicrobial properties against various oral pathogens.

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References

[1] Brezhnev A., 2023, doi.org/10.1021/acsabm.2c01080
[2] Witecka A., 2024, doi.org/10.1016/j.micromeso.2023.112913