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Superhydrophobic, nanotextured polyvinyl chloride films for delaying *Pseudomonas aeruginosa* attachment to intubation tubes and medical plastics

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ABSTRACT

Bacterial attachment onto the surface of polymers in medical devices such as polyvinyl chloride (PVC) is influenced by the physicochemical properties of the polymer, including its surface hydrophobicity and roughness. In this study, to prevent biofilm formation onto PVC devices, the PVC surface was modified using a combination of solvent (tetrahydrofuran) and non-solvents (i.e. ethanol and methanol). The surface of unmodified PVC was smooth and relatively hydrophobic (water contact angle (CA) = 80°). Ethanol-treated PVCs revealed the presence of micron-sized particulates and porous structures as the concentration of ethanol was increased. Surface hydrophobicity (measured in terms of CA) increased from 73° to 150° as the ethanol concentration increased from 15% to 35% (v/v). In general, methanol-treated PVCs were more hydrophilic compared to those treated with ethanol. The colonization of *Pseudomonas aeruginosa* PAO1 onto unmodified PVC surface was rapid, and individual bacterial cells could be seen after 6 h incubation. On the surface of treated PVC, the secretion of extracellular matrix layers was evident at 18 h and *P. aeruginosa* PAO1 start to form microcolonies at 24 h of incubation. The initial attachment of *P. aeruginosa* PAO1 was delayed to 18 and 24 h, respectively in the PVCs treated with 25% (v/v) and 35% (v/v) ethanol. It can be concluded that the treatment used in this study to prepare superhydrophobic PVC surface prevented the colonization of bacteria up to 24 h after culture.

1. Introduction

Polymer-based medical devices such as endotracheal tubes and catheters are indispensable for the treatment of critically ill patients. Indeed, it was estimated that in the US alone, ~20 million urinary catheters are used annually [1]. Therefore, the high incidence of infection associated with the use of these medical devices is of grave concern. For instance, endotracheal tubes inserted into patients who need mechanical ventilation, bypass the body's primary host defenses, and provide initial sites for bacterial colonization. When intubated for prolonged periods, these colonies are capable of developing into life-threatening biofilm-based infections. Statistics have shown that ventilator-associated pneumonia (VAP), a common hospital-acquired infection, affects up to 28% of patients who use endotracheal tubes for ventilation [2]. *Pseudomonas aeruginosa* and *Staphylococcus aureus* are often responsible for such endotracheal tube associated infections with 41.7% and 36.7%, respectively, of VAP cases being attributed to these microorganisms [3]. Due to the high morbidity rate (24–50%) of VAP [4], work has focused on the design of endotracheal tubes with higher resistance and/or delayed bacterial colonization. By increasing the time for initial bacterial adhesion and proliferation, VAP may be significantly reduced since infection is highest in the early days of intubation: ~3% infection/day for the first 5 days of intubation, decreasing to 2% per day between day 5 to day 10 [5].

To reduce bacterial colonization and infection, several modifications to endotracheal tubes have been studied. These include modifying inflatable cuffs that provide a physical barrier to prevent oral secretion from trachea from flowing into the lungs [6,7], and immobilization of antimicrobial agents onto the tube surface. For example, Roe et al. reported that the impregnation of 600 μg of silver nanoparticles into a endotracheal tube was sufficient to inhibit both growth and biofilm formation of *Escherichia coli* and *S. aureus* for more than 72 h [8]. In another study, the release of zinc oxide nanoparticles from polyvinyl chloride (PVC)-based endotracheal tubes resulted in at least a 50% reduction in *S. aureus* biofilm formation [9].

It is believed that initial contact of microorganisms with the surface of materials is crucial for successful colonization [10]. The interactions between the microorganism and material are

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