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Light-activated antibacterial screen protectors for mobile telephones and tablet computers

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ABSTRACT

Novel light-activated antibacterial screen protectors were produced from commercially available protectors by a simple dye functionalization process. The screen protectors were shown to be effective against *Escherichia coli* and an epidemic strain of methicillin-resistant *Staphylococcus aureus*, EMRSA-16 under white light conditions. UV–vis spectroscopy and Fourier transform infrared spectroscopy showed that the principal light activated antimicrobial agent present was crystal violet. The antibacterial screen protectors represent a simple and inexpensive means by which microbial contamination of mobile phone and tablet computer screens may be reduced in healthcare and non-healthcare environments, where device cleaning compliance has been shown to be very low.

1. Introduction

The use of portable electronic devices, in particular mobile telephones has become increasingly common place within the healthcare environment, with healthcare workers and patients using them regularly. Use of cellular devices was initially restricted in many healthcare environments because of concerns over electromagnetic interference with equipment – although this is now relaxed and devices are used more freely both in the delivery of care and by patients themselves. Indeed, many patients now consider access to, and use of, their mobile telephone as vital to their stay in a healthcare environment [1].

There has been much interest in the microbial contamination of the inanimate environment within a healthcare setting and the effect this may have on the epidemiology of hospital-acquired infections. This, and the application of antimicrobial surface technologies to mitigate this contamination, has been reviewed elsewhere [2]. Studies have previously shown contamination of door furniture [3,4], ward fabrics and plastics [5], pens [6], keyboards [7], stethoscopes [8] and telephones [9] with pathogenic micro-organisms. However, mobile devices were not considered at the time. With the advent of touchscreen technology and its increased availability and use, researchers began to consider the potential of these touchscreen surfaces to act as reservoirs of nosocomial pathogens. Recent studies have surveyed patients and staff within hospital environments and have recovered microorganisms from mobile devices [1,10–13]. One review shows that in the period 2005–2009 all studies in this field reported contamination of devices with microorganisms, with up to 40% of studied devices having *Staphylococcus aureus* present – a microbe of clinical significance in nosocomial infections [12]. Clearly there is mounting evidence for the case that mobile device screens can be a reservoir of nosocomial pathogens. Despite this knowledge amongst surveyed healthcare professionals – 78% being aware of the issue – only 8% admitted to cleaning their device [11]. It has been shown that cleaning protocols such as a 70% isopropanol wipe, bleach or even a simple wet microfibre cloth can be effective in reducing the microbial load on device displays, in some cases to below detection limits [11,13], but this is of little use if cleaning compliance amongst healthcare workers is so poor. Amongst mobile device users in the general public, cleaning compliance is likely to be even lower than amongst medical professionals. To assist in reducing the microbial contamination of device screens and hence their potential to act as reservoirs of

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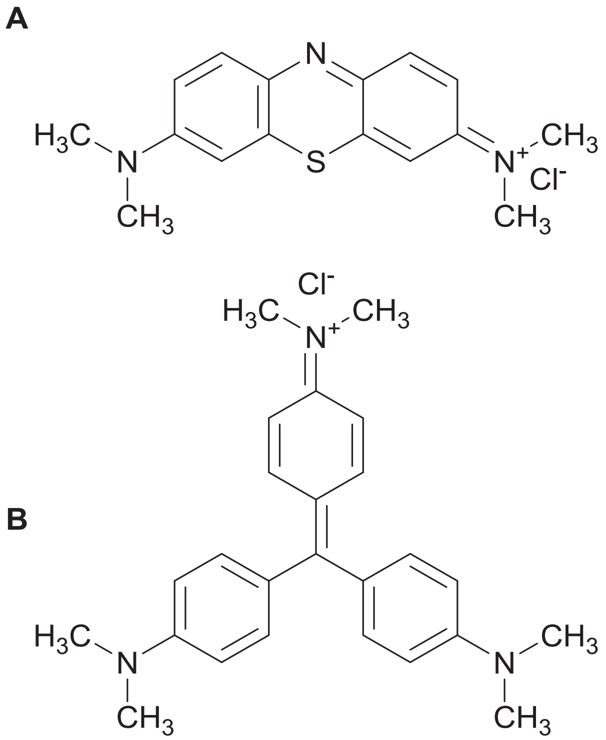

Fig. 1. Methylene blue (A) and crystal violet (B) – two commonly used light-activated antimicrobial agents.

pathogenic micro-organisms, a self-disinfecting screen which requires little or no user compliance would be of great benefit.

Recently an antimicrobial display glass technology was unveiled by Corning Inc. [14,15] and is, as far as we are aware, the only current technology in this field. This is a chemically toughened glass into which silver ions have been ion exchanged [16]. The antimicrobial activity of Ag^+ ions is well documented and reviewed [17] and has been applied in a number of commercial products [18–20]. In the case of the antimicrobial glass, Ag^+ ions are slowly released from the surface, resulting in the antimicrobial action. Detailed data on the antimicrobial efficacy are not currently available, but a three log reduction in microbial numbers is quoted in the product information sheet when studied using the JIS Z 2801 standardised test for antimicrobial surfaces [14]. This test examines the efficacy over a 24 h period, with microbes in a nutritive medium and a moist environment.

An alternative approach to the disinfection of surfaces is to incorporate light-activated antimicrobial agents (LAAAs) within the surface. LAAAs are a class of materials which display an antimicrobial effect, activated by exposure of the material to light of an appropriate wavelength. Typically these materials generate reactive radical species, which have a broad antimicrobial effect [21,22]. These LAAAs can be divided into inorganic materials such as the photocatalyst TiO_2 and materials containing organic photosensitising dyes [2,23].

In our research group we have extensively studied the encapsulation of numerous photosensitiser dyes into various polymers to produce surfaces with inherent antimicrobial activity [23–34]. For this study the dyes selected were methylene blue and crystal violet as shown in Fig. 1.

The photosensitisers are excited by light into a singlet excited state, which in turn undergoes an intersystem crossing to a triplet excited state. This excited state may directly generate radicals such as superoxide and hydroxyl radicals (Type I process), or may interact with molecular oxygen to produce singlet oxygen (Type II process). All of these reactive oxygen species are potent microbicides, with no specific target within a microbe – making an ideal antimicrobial approach. It is however thought that the singlet oxygen production is the predominant process for these materials [35].

Due to their broad antimicrobial efficacy and the ability to integrate the LAAAs within a polymer film, photosensitiser dyes were chosen for this study. An approach using the organic photosensitising dyes is also more appropriate than using a photocatalyst material, since these function using visible light and application of the photosensitiser does not require excessively elevated temperatures as is needed to deposit TiO_2. We demonstrate, using representative Gram-positive and Gram-negative bacteria, that microbial contamination of mobile phone screen protectors may be effectively addressed by functionalisation of a commercially available screen protector foil with photosensitiser-based LAAAs.

2. Experimental

2.1. Materials synthesis

Commercially available screen protector foils were applied to a sheet of clean glass according to the manufacturer's instructions. This was done to enable coating of only the topmost touch surface, without affecting the adhesive side of the foil. An aqueous solution of methylene blue and crystal violet (Sigma–Aldrich, Gillingham

Fig. 2. Dye treated mobile phone screen protector foils, after 5 min, 20 min and 60 min of dye treatment (viewed left to right).