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Durability and stability of antimicrobial coated surfaces

Abstract: Antimicrobial surface coating of i.e. medical devices could contribute to infection prevention and reduction of hospital acquired infections (HAI). Recent studies showed a significant reduction in the microbial contamination of antimicrobial coated surfaces in clinical setups. Nevertheless, there are only few publications available that deal with the durability and stability of these coatings under routine clinical conditions. In this work different antimicrobial coating compositions were tested on different surfaces for their durability and remaining antimicrobial activity. Our results show that the durability and stability of a subsequent applied antimicrobial coating is strongly dependent on the chemical formulation of the coating and also the underlying surface condition. Whereas we could still detect remaining antimicrobial coating and activity on some samples after repeated abrasion testing, some other samples lost their coating and activity after only a few abrasion cycles. Interestingly the integrated antimicrobial substance in the 3-D printed samples showed strong antimicrobial activity even after rough treatment of the surfaces (brushing, scratching).

Keywords: antimicrobial activity, surfaces, medical device, abrasion, durability, stability.

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1 Introduction

The number of cases of nosocomial infections in the USA is estimated at 1.7 million, of which approximately 99,000 are fatal. [1] The cost caused by these infections amount to about 10 billion US $. [2] Antimicrobially active coatings, when used correctly, could possibly reduce the transmission of pathogens of any kind via surface contacts, thus counteracting these alarming numbers. There are multiple types of antimicrobial coatings from a wide variety of suppliers. Most are based on silver, copper or zinc. In the past, these substances have proven to be effective against bacteria, and in some cases also against fungi and viruses. [3] Research is also underway regarding coatings based on transition metal acids, titanium or titanium dioxide. [4] The advantage of the tested titanium dioxide based TiTANO coating (HECOSOL GmbH, Bamberg) is its application procedure. With the so called electrospray technique the antimicrobially active coating can be applied to nearly every surface. The principal effectiveness of these surface technologies can be demonstrated by standard methods such as the Japanese Industrial Standard or ISO (JIS Z 2801/ISO 22196). However, there are only few studies to date regarding the activity of antimicrobial technologies after reprocessing, cleaning and disinfection as well as permanent use in the finished product.

2 Material and Methods

In previous studies we could already show strong antimicrobial activity of the TiTANO coating (HECOSOL GmbH, Bamberg). Since abrasion behaviour of the substances has not yet been investigated, some preliminary tests were necessary to find out which compositions and substance ratios are appropriate. Different compositions of this antimicrobial technology were formulated and applied on underlying test samples (glass, plastic, metal) by electrospray technique. Furthermore, the antimicrobial substance was introduced into 3-D printed ABS plastic samples. Subsequently durability of the antimicrobial activity was assessed after abrasion tests with the test samples using a standardized test protocol (JIS Z 2801/ISO 22196) and device (Fig.1 Elcometer 1720, Elcometer Instruments GmbH, Aalen). This device can be used for testing washing, brushing and abrasion resistance of various materials. All available tools can be used according to ASTM, DIN, EN and ISO standards. Stroke length, slide speed and number of cycles are freely adjustable. Via special supply lines it is possible to constantly supply the abrasion simulation with different solutions (water, disinfection etc.). Test samples are clamped under the wiping mechanism and then treated over predetermined cycles.

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Figure 1: Elcometer 1720 abrasion test device

After the abrasion testing, the test samples are examined microscopically and electron microscopically. Here, possible depletion and complete removal of the coating were recorded and documented. Test samples that showed no or only low abrasion in the abrasion tests were then tested for their antimicrobial activity according to the above mentioned procedure (JIS Z 2801/ISO 22196).

3 Results

Our results show significant differences in the durability of the different coating compositions of the test samples. For example, a large proportion showed severe damage to the coatings after only a few abrasion cycles. While some of the coatings were still able to show an antimicrobial activity even after repeated abrasion cycles, the coating on other test samples got visibly damaged after single wiping with distilled water. (Fig. 2)

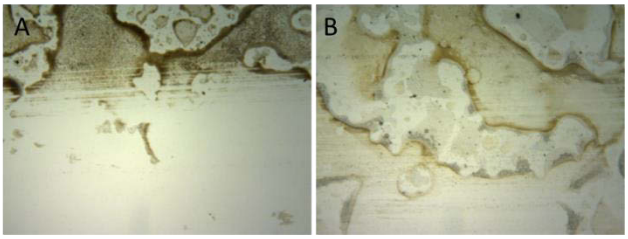

Figure 2: Different coating compositions after abrasion testing with (A) weak and (B) strong durability and stability

Interestingly also the material of the test samples showed strong impact on the abrasion behavior. On the microscopic images it can be seen that although small parts of the film are occasionally loosened even with >500 times of abrasion cycles most of the substance adhere to the glass slides. After the microscopic examination of the abrasion behavior standardized JIS Z 2801/ISO 22196 tests of the surfaces were performed in order to identify the residual antimicrobial activity. (Fig. 3)

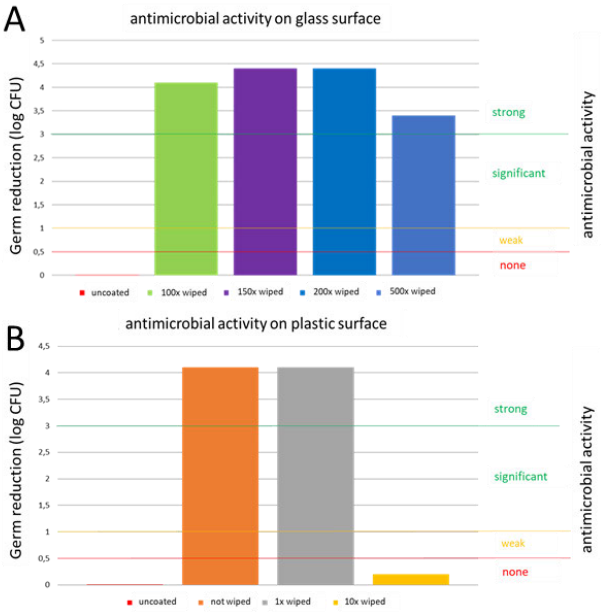

Figure 3: results of the JIS Z 2801/ISO 22196 for (A) glass and (B) plastic surfaces

These results showed a strong advantage of the glass surfaces compared to the plastic samples regarding remaining antimicrobial activity after abrasion testing. The test samples in which the antimicrobial agent was integrated directly into the plastic did not show any loss of antimicrobial activity even after heavy physical exposure (brushing, scratching).

4 Conclusion

The benefits of antimicrobial surface technologies in the clinical environment has not yet been comprehensively investigated. However, first studies show a significant reduction of microbial burden of surfaces in routine clinical settings. [5] Likewise, many questions regarding the mechanisms of action and their modification in routine use have not yet been clarified. Possible losses of efficacy through repeated reprocessing by cleaning and disinfection could be caused by chemical reactions of the antimicrobial coating with the disinfectant or simply the wear of the surface created by mechanical forces during cleaning and disinfection. A change of nanostructures and thus a reduction of the antimicrobial potential by routine cleaning and disinfection measures cannot be excluded either.

Antimicrobial coating of surfaces in medical facilities and of medical devices could be an additional measure of infection prevention. In our work we could show that abrasion behavior and antimicrobial activity is strongly dependent on the underlying surface composition, the treated surface itself and the cleaning detergents. Therefore, the assessment of the interplay of these factors is critical for the design and the development of antimicrobially equipped products for daily routine use in clinical settings. Our findings suggest that special attention should be payed to the formulation of the coating, the surface material and the application procedure. Whereas some applications show more durable properties others are even not resistant to standard cleaning and disinfecting measures and thus not effective and robust in the clinical routine. Further research is necessary to better understand interactions of coatings, materials and application procedures as well as to define requirements and to standardize application procedures and chemical formulas of antimicrobially active surface technologies.

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