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Integration of antimicrobial substances in 3-D printed plastics

Abstract: The risk of healthcare associated infections (HAI) is rising with the utilization of more complex medical devices. Cleaning and disinfecting measures of such devices are often insufficient leading to an increased microbiological contamination on these devices. Recent studies imply that antimicrobial coatings could present a solution for this topic. In this work a novel approach for the introduction of an antimicrobial technology into plastic granulate was tested. After 3-D printing the antimicrobial activity of the test samples was analysed. Our results show that the integration of an antimicrobial substance to ABS plastic is feasible only with sophisticated plastic processing technologies. Simple heating or mixing of the substance did not allow integration of the antimicrobial substance into the 3-D printed sample, but it was possible to integrate the antimicrobial ingredient into the raw material by compounding. The printed test samples showed strong antimicrobial activity in the standardized test procedures.

Keywords: antimicrobial activity, plastics, medical device, 3D printing.

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1 Introduction

Antimicrobial surface coatings cannot replace cleaning and disinfection measures, but they can be a very useful supplement. The general function principles either prevents the adhering of microbiological contaminations to the surface or degrades it when in contact with the surface, thus reducing the level of contamination. Various technologies with different modes of action are used for the antimicrobial activity of surfaces. Ideally, they keep their antimicrobial effectiveness over the entire product life cycle. The antimicrobial coatings can be applied in or on products by different approaches, for example by extrusion or electrospray technique. [1] In particular, everyday clinical objects such as work area surfaces, equipment covers, cannulas, catheters or implants that are equipped with "antimicrobial plastics" could make a major contribution to prevention of healthcare associated infections. Reducing the number of pathogenic microorganisms i.e. on high touch surfaces in hygiene-sensitive areas could help minimize the infection risk for patients. In the case of antimicrobial plastics, the active ingredient could be introduced directly during the manufacturing process. In contrast antimicrobial coatings, require post-processing of devices to achieve a long-term antimicrobial effect. [2] Since the 1980s, a novel manufacturing approach has been developed which has become increasingly important in recent years and which is finding its way more and more also into medical engineering processes: Additive manufacturing also known as 3-D printing. This is a highly specialized technology that allows the production of complex, high-precision, precisely fitting, stable and at the same time very light objects. In the field of medical engineering, this process can be used to manufacture personalized individual implants, prostheses and tools, which offer advantages over standard implants, particularly with regards to individuality and accuracy of fit. [3] For this reason, this work aims at developing a process by which the antimicrobially active agent can be incorporated directly into a plastic material production process and thus not requiring post processing but still being effective over a long period of time. Since 3-D printing is becoming increasingly important, this approach was used for this issue.

2 Material and Methods

In previous studies we could already demonstrate a strong antimicrobial activity of the TiTANO coating (HECOSOL GmbH, Bamberg). Different approaches (mixing, heating, compounding) were performed to combine an ABS plastic granulate with the antimicrobial substance. After each step standardized test samples were 3-D printed by using the freeformer 3-D printer system (Fig.1, ARBURG GmBH, Loßburg). This 3-D printer was chosen, because of the option to use standard plastic raw material as source for the printing and processing. The various antimicrobial agents were provided partly in liquid and partly in powder form. Preliminary tests were carried out on how the active ingredient can be easily incorporated into the existing plastic granulate.

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Figure 1: Freeformer 3-D Printer

In order to examine the antibacterial effectiveness, the Japanese Industrial Standard Z 2801 Test, was performed for all samples. This test is standardized in ISO 22196 for the measurement of antibacterial activity of plastics and other non-porous surfaces. [4] The advantage of the test method is its high reproducibility and repeatability. Samples were always tested in triplicates and reference samples of unprocessed ABS were used.

In preliminary studies, techniques for the integration of antimicrobially active ingredients into the plastic granulate were systematically tested. This was done by simply mixing components (solid and liquid) with and without heating. In addition, a method of integration under pressure was tested (1bar pressure at 121°C). Finally, the active ingredient was compounded with the raw material, which is the standard processing technology in such procedures. (Fig 2)

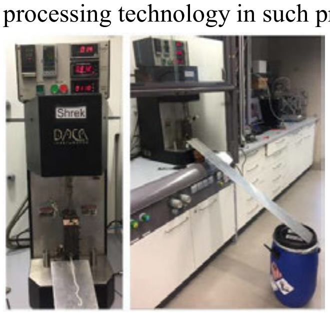

Figure 2: Microcompounder from DACA with metal rail

The dry ABS granulate (raw/mixed/compounded) was then used in the freeformer 3-D printer as material and standardized samples were printed as described and required for the antimicrobial tests according to ISO 22196. (Figure 3).

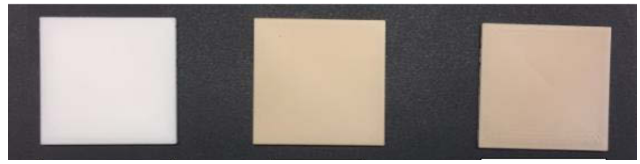

Figure 3: Test samples for antimicrobial activity tests of different material mixtures

3 Results

Our aim was to produce antimicrobially active granulate that could be easily processed by the freeformer 3-D printer and showed an antibacterial effect in the antibacterial effectiveness test. Our results showed that it is not possible to just introduce the antimicrobial agent into the ABS granulate by simply mixing or melting it down. Even the performance of the 3-D printing process with some of the test approaches sometimes led to a blockage of the printer. This may be due to poor mixing of the material and thus to insufficient melting in the 3-D printer. (Fig. 4)

Figure 4: Examples of insufficient mixtures of antimicrobial substance and plastic granulate

However, with some of the approaches it was possible to produce test samples, only without antimicrobial activity thus showing insufficient and ineffective introduction of the active ingredient into the test sample. Only the standard procedure by compounding showed the desired result. These test samples could be printed without any problems and repeatedly showed a strong antimicrobial activity. (Fig. 5)

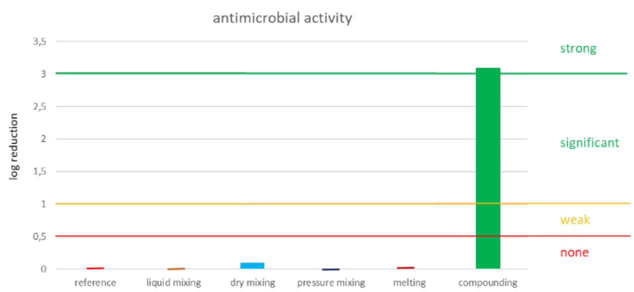

Figure 5: antimicrobial activity of test samples according to ISO 22196 testing

4 Conclusion

Contaminated medical devices can contribute to an increased risk of healthcare associated infections (HAI). Recent studies already proved that antimicrobial coatings can reduce bacterial contamination of these surfaces potentially reducing infection risks. [5] We could demonstrate that introduction of antimicrobially active substances into 3-D printing material is feasible and enables production of antimicrobially active plastic components for nearly every purpose and application. We were able to print any geometric structure with an incorporated thus genuine antimicrobial activity. Combinations of this technique with other methods like 3D scanning could lead to new concepts and solutions for the advancement of personalized medicine and orthopedics. However, further studies are needed to assess the clinical impact of such devices for the risk reduction and prevention of HAI.

Author Statement

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