Antimicrobial Surface By Thin Coating With Ag-silicate Platelet Nanohybrids And Waterborne Polyurethane on Metal plate

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Introduction: Stainless steel has been widely used as the standard material in the fracture patients due to its mechanical properties and corrosion resistance. However, one of the major drawbacks of using such a material as orthopedic plates is accessibility of possible bacterial infection. In the conventional treatment, antibiotics are used to overcome the problem of bacterial invasion. It is advantageous to coat the antimicrobial material on stainless steel to reduce the risk of infections from open wounds and surgical conditions during and after the surgery.

Methods: Coating of AgNP/NSP-PU on metal plates
The waterborne PU was used to blend with an aliquot of AgNP/NSP dispersion at the designated weight ratio. Eight formulations of AgNP/NSP-PU were prepared from the mixing of AgNP/NSP and PU at different weight ratios of 1 : 0.1, 1 : 0.5, 1 : 1, 1 : 3, 1 : 5, 1 : 7, 1 : 9 and 1 : 10. The drop-coating method of applying the nanohybrid dispersion on stainless steel plate surface was developed. By using the same procedure, various films were generated in different thickness by casting the nanohybrid/PU slurry solution on a 3×3 or 1×1 cm² stainless steel (316L) and dried at room temperature for 24 h.

Antibacterial analysis and SEM of AgNP/NSP-PU surface
The antimicrobial efficacy of the AgNP coated surface was investigated by using different pathogenic bacterial strains Staphylococcus aureus (American Type Culture Collection (ATCC) 6538) and Enterobacter cloacae (ATCC, 13047), obtained from Department of Clinical Laboratory, Sciences and Medical Biotechnology, College of Medicine, National Taiwan University, Taipei, Taiwan. By employing the standard micro-dilution method, the bactericidal concentration was defined as the lowest concentration of an antimicrobial agent to prevent the growth of microorganism after subculture onto the antibiotic-free media. The inhibition of bacterial growth was measured on the basis of the National Committee for Clinical Laboratory Standards. Typically, bacteria were incubated overnight inoculated into 5 mL fresh medium to restart the cell cycle. After 3 h incubation at 37 oC, the cells were synchronized at the log phase of the growth curve, featured with the optical density at 600 nm (OD600) of 0.3~0.5. After 1,000 fold dilution, an aliquot of solution (2 mL) at approximate 1×10⁵ CFU mL⁻¹ (colony formation unit mL⁻¹) was spread on Luria-Bertani (LB) agars, in which the tested materials were added at the designed concentrations. Colony numbers were counted after overnight incubation at 37 oC.

Results: In this study, we aimed to develop a facile method of coating the optimized tri-component AgNP/NSP-PU dispersion onto the steel metal plates and demonstrated the surface functions of antimicrobial and lower cytotoxicity. The SEM, TEM and AFM (Atomic Force Microscope) were used to monitor the surface of morphology. The cross-cut test was used to show good physical adhesion force
between our matrix and metal plate. Biofilm test and bactericidal test were performed and showed bactericidal properties of the coated plate film.

The thin coating of nanohybrid was demonstrated the optimized "golden ratio" at 1:1 by weight for best antibacterial and coating ability and safe ratio (1:5) with marginal antibacterial ability. Our study showed great improvement in the silver coating method on the metal plate. First, we employ the silver nanosilicate platelets (AgNP/NSP). AgNP/NSP has great benefit for least silver release to avoid cytotoxicity from nano silver particle. At the same time, it keeps its bactericidal property well. AgNP/NSP has good property to distribute the silver particle evenly. Second, we developed the AgNP/NSP polyurethane matrix.

**Discussion:** AgNP/NSP-PU matrix can be coated on the metal surface by dropping method easily with good physical coherence strength. The results showed great improvement of antibacterial function and the least cytotoxicity.

In conclusion, the novel nanohybrid of tri-component AgNP/NSP-PU may exhibit high efficacy of antimicrobial, good adhesion, low toxicity and robustness of the implant.

**Significance:** The golden ratio of AgNP/NSP-PU (1/1) was found to be suitable for obtaining the thin film coating process lower cytotoxicity and good biocide property. This research will impact the field of designing medical devices with antimicrobial function and medical safety.

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