Surface Characterization of Metallic Implants Created with a Novel Biofilm-Resistant Surface Modification Process

Caroline E. Bales[1], Sarah M. Helms[1], John D. DesJardins[1]

1. Clemson University, Department of Bioengineering, Clemson, SC

Introduction: The accumulation of proteins and bacteria on implant surfaces is a critical concern in the biomedical field, especially with respect to the potential of biofilm formation on implant surfaces. Material surface wettability is often used as a predictor of surface interactions between a material and specific bacterial strains. In particular, the more hydrophobic a material is, the higher the chance of bacterial adhesion on the surface. Surface roughness has also been shown to have a relationship with biofilm formation, as rougher surfaces tend to have a stronger affinity to harbor bacterial colonies. The modification of implant surfaces to impart a biofilm resistant layer can come at the expense of increasing surface roughness, however, and it is therefore important to determine how the variables of wettability and roughness are affected by any new surface coating technologies. However, proteins will adhere to the surface of materials milliseconds after they enter the body, changing the surface properties of a material and its interactions with proteins. This study investigate the impact of surface roughness, surface wettability, and protein adhesion on the formation of biofilms on metallic implants.

Materials and Methods: Titanium coupons with a 1 cm diameter modified with both CoBlast™ and BioDep™ processes were used. They were first cleaned to eliminate surface debris. Surface topography was analyzed with a Wyko NT2000 Profiling System and surface wettability was analyzed with a KRÜSS EasyDrop System using 2 µL drops of deionized water and 1 µL drops of diiodomethane. Surface energy was calculated with Fowkes theory. Samples were fouled with 10 mg/mL of human serum albumin and wettability was retested. Statistical analysis was tested through a Student's t-test.

Results and Discussion: Roughness of each sample was taken at multiple points. Statistically significant differences were found between multiple sample types, most notably between the blanks and samples CoBlasted with 90 µm grit alumina particles. Surface energy was calculated for both non-fouled and protein-fouled samples. For non-fouled samples, no significant difference was found between the blank samples, and the surface energies of the 90 µm grit PTFE/alumina-coated samples were significantly lower than any other type (Fig. 1a). In addition, for all CoBlasted samples, there were significant differences between the blank and vancomycin-coated samples. Protein-fouled samples showed similar trends, but there were significant differences in the blank samples (Fig. 1b). In addition, though the 90 µm grit PTFE/alumina-coated samples had lower surface energies than the other sample types, the values were higher than those seen in the non-fouled samples. Overall, protein-fouled samples had higher surface energies than the non-fouled samples.

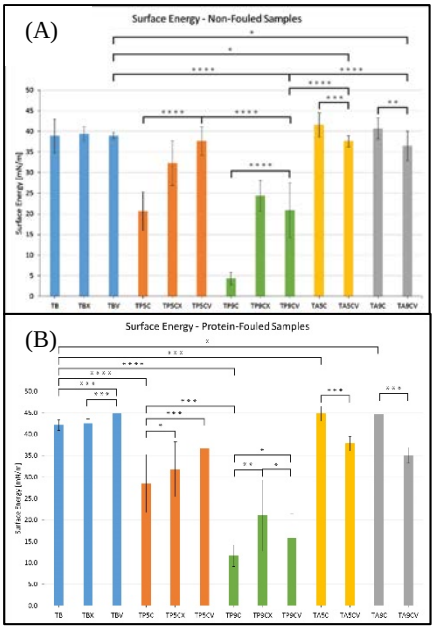

Figure 1. Surface energy of (a) non-fouled samples and (b) protein-fouled samples.

Conclusion: It was shown through this study that changing the coating of a material can change the surface topography and the wettability of the surface, which can be beneficial for different applications. Following this, the PTFE-coated samples would be best to use when preventing a hydrophobic substance from binding to the material, while alumina-coated samples would be best to use when preventing a hydrophilic substance from binding to the material. When trying to prevent *S. aureus* from adhering to the surface of a material and forming a biofilm, an alumina-coated sample, preferably with a lower grit (TA5C or TA5CV) would be best to use. Other testing, such as wear tests and cell cultures, should be performed to confirm this conclusion.

Acknowledgements: This work was funded through the Department of Defense and CDMRP, under grant number W81XWH-14-1-0438. Contact angle testing was performed in the SC BioCRAFT Bioengineering and Bioimaging Core Facility, supported by an IDeA from the NIGMS of the NIH under grant number 5P20GM103444-07.