Metallic Implant Surface Modification Process for Enhanced Biofilm Resistance

Caroline E. Bales[1], Sarah M. Helms[1], Liam O'Neill[2], John D. DesJardins[1]
1. Clemson University, Department of Bioengineering, Clemson, SC
2. TheraDep™ Technologies, Inc., Palo Alto, CA

Statement of Purpose: The accumulation of proteins and bacteria on implant surfaces is a critical concern in the healthcare field, as these accumulations can impair the patient healing process[1]. One of the most widely used predictors of surface interaction with bacteria is material surface wettability, which can be used to predict interactions between a material and the surrounding environment, and, thus, predict potential colonization of bacterial strains on the material. While different bacterial strains respond differently to the hydrophobic or hydrophilic nature of the surface, most bacteria adhere more to surfaces which are more hydrophobic[6]. Surface modifications typically affect both surface wettability and surface roughness of a material, altering the potential interaction of the material with bacteria. It is therefore important to determine how the variables of wettability and roughness are affected by new surface coating technologies. However, when a material is implanted *in vivo*, proteins quickly adhere to the surface and change the material's surface characteristics. This study compares the wettability of two novel surface modification methods on simulated protein fouling exposure.

Methods: Ti-6Al-4V coupons (n=100) 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. Effective 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: Surface chemistry of the coupons was measured following the CoBlast™ treatment, but prior to deposition of any chitosan and vancomycin layers. When the surface was bombarded with both alumina and PTFE particles, the inclusion of oxide particles was minimized and the process effectively deposited a fluoride rich layer onto the metal surface. Roughness of each sample was taken at multiple points. Statistically significant differences were found between multiple sample types, most notably between the unmodified Ti-6Al-4V and coupons modified with 90 µm alumina CoBlast™. Surface energy was calculated for both non-protein-fouled and protein-fouled coupons. For non-fouled samples, no significant difference was found between Ti-6Al-4V coupons not modified with CoBlast™, and the surface energies of the coupons modified with 90 µm grit alumina / PTFE were significantly lower than any other type (Fig. 1a). For all samples modified CoBlast™, there were significant differences between the coupons not modified using BioDep™ and those with vancomycin on the surface. Protein-fouled samples showed similar trends, but there were significant differences in the Ti-6Al-4V coupons not modified with CoBlast™ (Fig. 1b). In addition, though the coupons modified 90 µm grit alumina / PTFE 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.

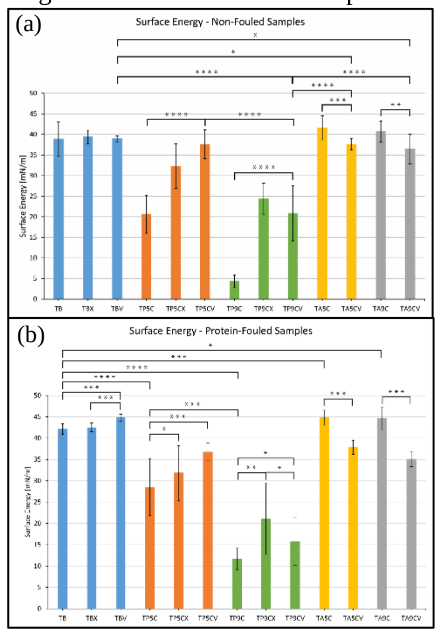

Figure 1. Surface energy of (a) non-protein-fouled samples and (b) protein-fouled samples.

Conclusion: It was shown that the surface modifications altered both the surface roughness and the wettability of the surface, which may impact bacterial response to the surface. In addition, this work showed that adhesion of proteins to implant surfaces can change the wettability of the implant over time. These results imply that the response of bacteria to these surfaces in the days and weeks after implantation will differ. Results indicated that surfaces modified with PTFE would be best to use when preventing a hydrophobic substance from binding to the material, while alumina-blasted sample types would be best to use when preventing a hydrophilic substance from binding.

References: 1. (Veerachamy, S. J. Proc Inst Mech Eng H. 2014;228:1083-1099.) 2. (Darouiche, RO. N Engl J Med. 2004;350:1422-1429.)

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