Predictive Assessment of Implant Bio-Response: The Role of Streaming Potential

The quest for the ideal biomaterial to perfectly address a specific application continues. With the exception of autologous graft transplantation, every other biomaterial is “good enough” at best. Solutions diverging from the absolute ideal anatomical and physiological standard lead to associated complications initiated by our natural defenses. The question remains – how could we design better biomaterials? A fundamental component of biomaterial design is understanding and quantifying biomaterial surface properties that, upon implantation, dictate the body response. Elucidating the correlation between surface properties and the “race to the surface” of various ions and proteins provides the basis for improving the predictability of material biocompatibility.

Currently, the battery of evaluations spans many dimensions, from surface chemistry to physical roughness and wettability. Since surface charge has been recognized to be an important indicator of contact surface behavior, reliable quantification protocols are needed, especially in addressing complex surface charge measurements of conductive and porous materials. Dr. Lorenzetti and her colleagues at the Jožef Stefan Institute have embarked on the quest to address the need for improved surface charge quantification protocols. In their article entitled “Electrokinetic behaviour of porous TiO2-coated implants” (http://link.springer.com/article/10.1007/s10856-015-5521-4), they propose a quantification of surface charge protocol for conductive and porous surfaces using a novel streaming potential approach. This approach corrects for the role of the metallic or ionic conductance in computing surface charge.

This work peels off another layer in the process of revealing the surface contact behavior of physiological proteins. Not enough is actually known about protein behavior once exposed to a surface, including 3D domain-specific folding/unfolding and structural changes leading to “abnormal” functional behavior. Therefore, the average biomaterial surface charge together with the average protein charge, while providing some understanding of possible behavior, address a non-contact state in which the material and the protein are considered separately. Quantification of the streaming potential at the biomaterial surface takes the next step in understanding protein-surface interaction. In combination with surface wettability and roughness, streaming potential contributes to a better understanding of the contact surface behavior towards proteins, and more broadly, towards biological entities. Specifically, through their research, Dr. Lorenzetti and colleagues warn about these local effects on the surface, and propose an efficient technique to distinguish among certain topographical or metallic contributions to the charge.

In this preliminary discovery phase, Dr. Lorenzetti and her colleagues evaluate the streaming potential using Phosphate Buffered Saline (PBS). The protocol maintained the PBS at 20°C, in the absence of proteins. As a next step, the protocol will be adjusted to evaluate streaming potential in the presence of physiological proteins (independent as well as in combination), while measurements will be performed at physiologically relevant temperatures. The research group proposes that the presence of multivalent ions (i.e. phosphate groups in PBS) affects the surface charge when adsorbed on a surface. Therefore, as a first step, PBS was considered relevant. This apparently “simple’ yet very effective approach sought to investigate the non-uniform distribution of charge on the contact on a nano-patterned surface.

The group at the Jožef Stefan Institute is working towards building a contact surface enhanced matrix to improve prediction of biocompatible behavior in situ. The surface properties are viewed as “…complementary to each other and even interconnected”, Dr. Lorenzetti believes. These three interconnected parameters supplement the material-focused determining factors of biocompatibility including overall chemical composition and mechanical properties, and (where appropriate) local chemical and mechanical behavior.

The continuing efforts in contact surface characterization by Dr. Lorenzetti and others move the understanding of surface biocompatibility towards the development of predictive modeling. Such an approach will shift the current accuracy, speed, and cost of preliminary material evaluations, thereby de-risking and accelerating the process of biomaterials innovation.

I would like to thank Dr. Lorenzetti and her colleagues for kindly agreeing to offer her research group’s vision on the importance of streaming potential beyond the confines of the published scientific work. Dr. Lorenzetti would like to recognize the support of the Jožef Stefan International Postgraduate School in completing this work.
To our readers: I am looking forward to your comments that can be sent to gabriela.voskerician@case.edu using the heading “Editors’ Choice”. We hope to develop this feature into a dynamic forum think-tank.