A Summary-
Adhesion force of *staphylococcus aureus* on various biomaterial surfaces

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1 Introduction and Concepts

Staphylococcus aureus (S. aureus) is known cause infections being one of the major causes behind failure of implants. It forms a resistant biofilms (immobile colonies of bacteria protected by a self produced polysaccharide matrix) on the implant surface. The risk of infection can be reduced if the bacteria does not adhere to the surface of the biomaterial and also if the viability of the bacteria is low on the surface.

The most common biomaterials used in making bone implants are tested- . ultra-high molecular weight poly ethylene (UHMWPE), stainless steel (SS), Ti–6Al–4V alloy, hydroxyapatite (HA). The parametres influencing the adhesion and viability are wettability and surface roughness of the material.

We know that wettability is directly related to surface energy. Higher the surface energy, more is the wettability and we expect the if the wettability is high, adhesion force will be more and the implant will be more susceptible to infection. So, we the hypothesis is that the material with least surface energy will be best suited for the impant.

Surface roughness will have two opposing effects. One, it will enhance the effect of surface energy by increasing it for hydrophillic surfaces (high surface energy, high wettability) and decreasing it for the hydrophobic ones. So, we would expect the higher roughness with our most hydrophobic material to have lest adhesion. But, roughness also increases the available surface area for the bacteria to adhere thereby increasing the number of bacteria that adhere as well as their adhesion. θ^* is less than θ in the hydrophilic case and more in the hydrophobic case. Reference to Figure 1.

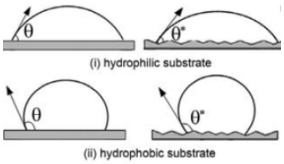

Figure 1: Surface roughness enhancing the surface energy substrate response

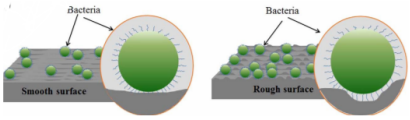

Figure 2: Surface roughness enhancing adhesion of the bacteria

2 Methods and Results

Atomic Force Microscopy technique is used to quantify the adhesion force. The bacteria is attached to the cantilever and brought close to the substrate. The bacterial cell wall proteins bond with the surface and when the cantilever is retracted, the pull off distance (the distance away from the surface when the force of adhesion vanishes a few 100nm), the pull off force (the maximum adhesion force peak a few nm) and the number of bond rupture events (quantifies the adhesion strength by counting the number of bonds formed between the ligand and the substrate) The viability test used provides the number of dead and living bacterial cells on the surface.

Material	Surface Energy (mJ/m^2)	Surface roughness(nm)	Pull off distance(nm)	Pull off force(nN)	Bond rupture number	Number of CFUs (control 93)
UHMWPE	29.86	70	131	4.10	3	63
SS	32.43	219	425	15.21	4	77
Ti–6Al–4V	30.13	289	242	11.12	4	87
HA	26.15	229	221	7.66	3	37

UHMWPE has lower surface energy , a smooth surface with high contact angle and hence, less adhesion force is observed whereas SS and Ti–6Al–4V showed higher adhesion forces. In case of HA, the roughness is high but the wettability and surface energy is low, hence, lower adhesion force was observed when compared to that of SS and Ti–6Al–4V. Bacterial viability, confirmed by $3M^{TM}$ petrifilm and TSB agar plate on all samples are near or similar to control, except HA. This implies that bacterial colonies form and proliferate normally in UHMWPE, SS and Ti alloy. Lower bacterial adhesion on HA was further confirmed by fluorescent microscopy.

3 Conclusion

Although both UHMWPE and HA show least adhesion force and least number of bonds formed, HA shows better anti bacterial properties by having the maximum number of dead bacteria. Hence, HA is most suitable to form bone implants as far as reducing the risk of infections in concerned.

In this study, the bio-response of materials is not considered. When introduced to the inner body environment, amino acids immediately get adsorbed on the surface and according to the material type the cells may or may not interact. So, in reality the implanted material has a different surface chemistry and it depends highly on the in vivo environment. The bacterial adhesion will be different for surfaces with different adsorbed amino acids and wrapped in different body cells and fibres. It is also hypothesised that when the bacterial cell approaches the impant surface with adsorbed proteins, the confirmations change and it alters the adhesion strength. This can be the future direction of study.