Design Concerns and Degradation Mechanisms in Biomaterials

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The dawn of 21st century has seen a widespread of materials in many biomedical applications. This explosion in the application of materials in medicine dates back no more than twenty years. It is foreseen that biomaterials market shall rise up to an annual 15-20 b€ globally by 2025.

Traditional materials such as stainless steel 316L has given its place especially in orthopedics, to advanced metal alloys, ceramics, combinations of ceramics and metals, highly efficient polymers and lately high performance graphite composites. Other areas of medicine have been also benefited from the advances in materials science of the last few decades. Smart polymers and shape memory alloys are widely adopted in cardiology and lastly in urology too. Needless to mention that a major outcome of the thriving applications of materials in medicine is the existence materials in which no long performance life cycle studies have been performed; i.e. orthopedic prosthesis which last more than 10-15 years in average prior to restitution surgery. So, a major issue is the damage response or durability assessment in biomedical materials.

Many different and complex damage mechanisms can be observed in systems of biomaterials or prosthetics. Often more than two are combined together with severe results in the prosthesis performance. Fatigue [1] is a major issue in hip prosthetics as it has been found to crack ceramic hip heads. In addition to that, phase transformation comes into play when zirconia ceramics are used in orthopedic prosthesis or dental restorations. Aseptic loosening of a hip prosthesis due to osteolysis can be caused by polymethyl(methacrylate) orthopedic cements. Orthopedic Implants can also fail by overloading [2]. Ultra high molecular weight polyethylene (UHMWPE) acetabular caps and knee plateaus are plagued by mechanical wear corroborated by material oxidation due to the presence of free radicals in the human body fluids. Polymer urology stents are degraded and embrittlened due to sorption of body fluids and salt encrustations [3]. Maxillofacial silicones are prone to degradation due to environmental aging [4] and carbon or glass fiber reinforced dental posts can either invoke interfacial debonding or tooth cracking [5].

Designing in such a way that complex damage mechanisms in systems of biomaterials is a demanding process and it requires multidisciplinary approach i.e. materials science and engineering, fracture mechanics, damage mechanics, finite element modeling etc. However, it proves itself as one of the most interesting and challenging scientific and economic fields of our time.

References

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