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Advanced polymeric biomaterials: clinical panacea or modern dilemma?

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Over recent years modern medicine has benefited from the varied use of polymeric-based biomaterials. Unfortunately, the design of many of these biomaterials is inadequate and reduced clinical efficacy or complications associated with the use of such systems, will result. Through an understanding of the mechanisms of these problems, we have examined the formulation, characterization, optimisation of design and evaluation of advanced biomaterial systems for use as medical devices and implantable drug delivery systems.

Biomaterials as medical devices

The major complication associated with medical devices is infection, resulting in considerable morbidity and mortality in patients. Following attachment to the biomaterial, micro-organisms rapidly become encapsulated in an exopolymeric matrix to form a microbial biofilm, that acts as a focus for dissemination and hence infection. In the development of improved biomaterials, it is important to understand the contributions of the surface properties of both micro-organism and biomaterial to the initial colonization process. To this end, our studies have examined and identified the complex roles of microbial cell surface hydrophobicity, zeta potential and cell surface biochemistry and, additionally, biomaterial surface energy, surface charge and microrugosity on the attachment process. Furthermore, the modulating effects of the physiological conditioning film, deposited from biological fluids, on the surface properties of both micro-organisms and biomaterials, and their subsequent interaction have been demonstrated.

Deposition of inorganic encrustation on the surface of medical devices has widespread implications for device performance, including obstruction and blockage. In our laboratories, a model that simulates encrustation in-vivo has been developed. This has enabled both the mechanism of encrustation, and the roles of biomaterial surface properties and physiological conditioning films on encrustation to be defined.

Based on our understanding of these processes, successful strategies have been developed to produce novel biomaterials or biomaterial coatings that resist both microbial attachment and encrustation, including the use of novel hydrogel coatings containing chemically bonded therapeutic agents, the use of biodegradable coatings that facilitate shedding of the attached micro-organisms, incorporation of non-antibiotic, antimicrobial agents into either modified biomaterials or biomaterial coatings that offer controlled release of the antimicrobial agent directly into the microbial biofilm, the deposition of inert, inorganic coatings onto medical devices using plasma deposition techniques, and the development of novel biodegradable interpenetrating networks based on biomimetic, biopolymers.

These biomaterials have shown considerable promise in-vitro and are currently undergoing clinical assessment by several medical device companies.

Biopolymers as implantable drug delivery systems

Modern implantable drug delivery systems are frequently composed of biopolymers. Using appropriate analytical methods, we have facilitated an improved understanding of the physicochemical properties of such systems, and their relationships with clinical performance. One aspect of this research programme has focused on the improved design of implantable drug delivery systems for the treatment of periodontal diseases. Two improved formulation strategies have been developed–a tooth-bonded, biodegradable chlorhexidine-containing implant, and, a bioadhesive, syringeable tetracycline-containing semi-solid system. The former system offers acceptable mechanical properties and diffusion-controlled release of chlorhexidine for a prolonged period, thus preventing microbial recolonization of the periodontal pocket, whereas, the second strategy is designed to release tetracycline into the periodontal pocket at a controlled rate for several weeks. The bioadhesive properties ensure direct interaction of the formulation with the periodontal tissues and hence the formulation is retained within the pocket. The mechanical and rheological properties of both delivery systems directly influence their performance. For example, correlations between various viscoelastic parameters and drug release, syringeability, bioadhesion and resistance to fracture have been identified. Both formulation strategies have undergone clinical evaluation and were shown to be beneficial for the treatment of periodontal diseases.