Recent progress in inorganic and composite coatings with bactericidal capability for orthopaedic applications

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Abstract

This review covers the most recent developments of inorganic and organic-inorganic composite coatings for orthopedic implants, providing the interface with living tissue and with potential for drug delivery to combat infections. Conventional systemic delivery of drugs is an inefficient procedure that may cause toxicity and may require a patient’s hospitalization for monitoring. Local delivery of antibiotics and other bioactive molecules maximizes their effect where they are required, reduces potential systemic toxicity and increases timeliness and cost efficiency. In addition, local delivery has broad applications in combating infection-related diseases. Polymeric coatings may present some disadvantages. These disadvantages include limited chemical stability, local inflammatory reactions, uncontrolled drug-release kinetics, late thrombosis and restenosis. As a result, embedding of bioactive compounds and biomolecules within inorganic coatings (bioceramics, bioactive glasses) is attracting significant attention. Recently nanoceramics have attracted interest because surface nanostructuring allows for improved cellular adhesion, enhances osteoblast proliferation and differentiation, and increases biomineralization. Organic-inorganic composite coatings, which combine biopolymers and bioactive ceramics that mimic bone structure to induce biomineralization, with the addition of biomolecules, represent alternative systems and ideal materials for “smart” implants. In this review, emphasis is placed on materials and processing techniques developed to advance the therapeutic use of biomolecules-eluting coatings, based on nanostructured ceramics. One part of this report is dedicated to inorganic and composite coatings with antibacterial functionality.

From the Clinical Editor: Inorganic and composite nanotechnology-based coating methods have recently been developed for orthopedic applications, with the main goal to provide bactericide and other enhanced properties, which may result in reduced need for pharmaceutical interventions and overall more cost effective orthopedic procedures. This review discusses key aspects of the above developments.

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Over the past half century, advancements in the manufacture of synthetic biomaterials and in surgical techniques have led to an explosive growth in the use of biomaterials in the form of implants and medical devices. The biomaterials market is estimated to be worth more than $300 billion US Dollars and to be increasing 20% per year.\(^1\) Medical specialists treat millions of patients each year by implanting devices as diverse as pacemakers, artificial hip joints, breast implants, dental implants and hearing aids.\(^2\) By 2010 more than 4.4 million people are expected to have at least one internal fixation device, and 1.3 million people will have an artificial joint.\(^3\)

An artificial implant must possess both structural and surface compatibility with the host tissue. With particular reference to bone implants, mechanical and physicochemical compatibility is necessary. Each type of material used in orthopaedic devices has its own advantages that are particularly suitable for specific applications. Nevertheless, it is difficult for a single material to have all the required properties. For instance, metal alloys and ceramics such as alumina and zirconia, can be chosen for hard tissue replacement due to their mechanical competence. However, a mismatch between the stiffness of the implant and the host tissue may lead to bone atrophy due to the stress-shielding effect.\(^4\) Moreover, these materials are classified as bioinert because they do not actively stimulate the bone-formation process. On the other hand, the introduction of an implant into the body is always associated with the risk of microbial infection, particularly for the fixation of open-fractured bones and joint-revision surgeries.\(^5\)

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