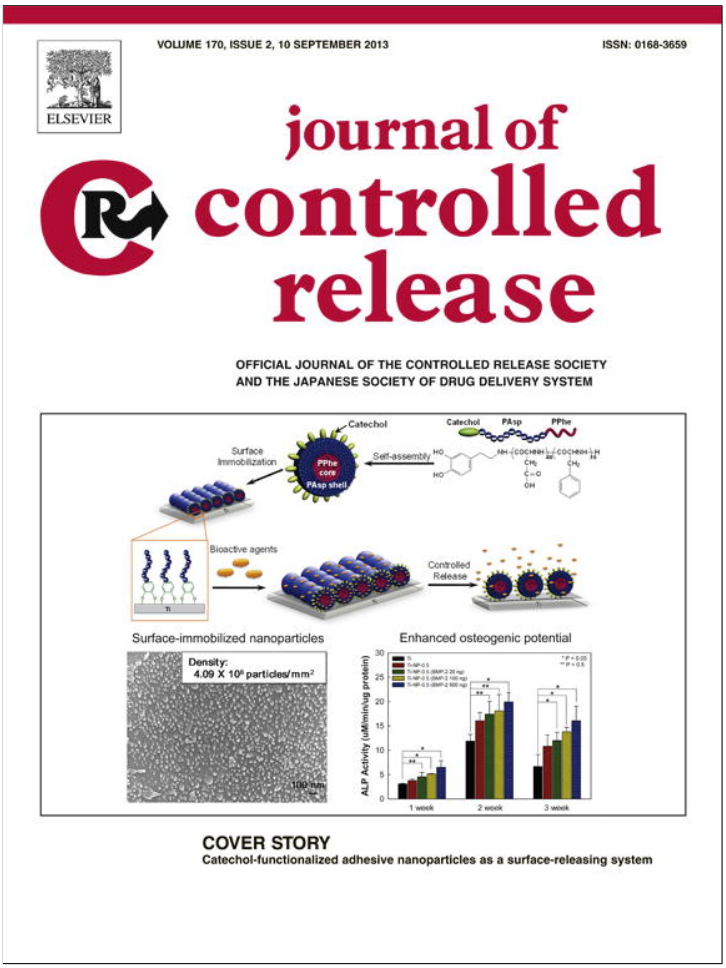

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Cover Story

Catechol-functionalized adhesive nanoparticles as a surface-releasing system

One of the major factors determining a successful outcome of implanted biomedical devices is their surface property. The surface of a variety of medical devices has been treated for enhanced biocompatibility, bioactivity, and therapeutic activities. For example, the surface of titanium implants used in orthopedic and dental fields are frequently treated to improve adhesion between an implant surface and the host bone tissue, and to lower the risk of implant failure [1]. Diverse modification approaches have been developed for controlling the surface roughness, nano- or micro-structure, calcium phosphate coatings, and conjugation of biological species. Recently, surface treatments have focused on controlled release of bioactive agents, and there are rooms to improve for better implant performances. Current coating processes frequently require organic solvents that can induce harmful effects on bioactive agents. The drop solvent coating, where the coating solution is dropped on the implant surface and allowed to dry, cannot produce the uniform coating layer with a homogeneous thickness. This irregularity may affect the local drug release properties, and thus an overall function of implanted devices. In addition, the interfacial adhesion between the polymer coating and the implant surface may be low, causing removal of the coating from the implant surface. It is desirable to develop a new coating method that allows stable coating and uniform release of bioactive agents.

In this issue, Professor Sang Cheon Lee and his colleagues proposed an adhesive nanoparticle system that may serve as a stable coating layer for drug release from various medical devices [2]. Interestingly, the rationally designed catechol-functionalized poly(L-aspartic acid)-b-poly(L-phenylalanine) (Cat-PAsp-PPhe) copolymer self-assembled in water to form core–shell polymer nanoparticles with three well-defined, distinct domains: the peripheral Ti-adhesive catechol moiety, the anionic PAsp shell, and the hydrophobic PPhe core. The selection of main components is based on combination of biocompatible, non-immunogenic poly(amino acid)s. Their nanoparticles can meet the requirement for strong surface adhesion by employing catechol groups, a main component of 3,4-dihydroxy-L-phenylalanine (DOPA) from mussel adhesive proteins. DOPA and other catechol compounds are known to form strong covalent and noncovalent interactions with metal or metal oxide substrates including Ti and Ti oxide [3]. The adhesive nanoparticles could be uniformly immobilized as a monolayer on Ti surfaces through a simple dipping process in water. The density of the immobilized nanoparticles on the Ti surface was readily modulated by adjusting the concentration of the nanoparticle solution. The nanoparticles are formed by assembly of several hundred chains of amphiphilic Cat-PAsp-PPhe, and thus, a large number of catechol groups are present on its surface. The cooperative adhesion of the surface catechol groups significantly enhances the binding strength of the nanoparticles onto Ti surfaces. Bone morphogenetic protein-2 (BMP-2) was incorporated onto nanoparticle-immobilized Ti surfaces and released in a controlled manner. The BMP-2-releasing Ti surface provided an environment for promoting bone cell activity and enhancing osteogenic potential.

Catechols adhere to a variety of materials (metals, polymers, ceramics), and this property enables the catechol-functionalized nanoparticle to be used as a universal platform for drug delivery from the surface of various biomedical devices, such as orthopedic, dental, and cardiac implants. The adhesive nanoparticles present an advantage over other surface-coating materials in that it can incorporate and release a broad range of bioactive agents. The shell of adhesive nanoparticles can be tailored to be anionic or cationic for loading genetic (DNA, RNA) molecules and proteins (growth factors) irrespective of their charges through electrostatic complexation. In addition, the core domain formed by the self-assembly of the amphiphilic copolymers can hold hydrophobic drug molecules. The study by Professor Lee and his team, while further testing is necessary for eventual clinical applications, presents a simple platform for delivering different types of drugs from the surface of various biomedical devices with any shape and dimension.

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