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PVP-Coated Silver Nanoparticles: Synthesis and their Biological Activity Towards Human Mesenchymal Stem Cells

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Abstract – Silver has well-known antibacterial properties which are also used for biomedical implants and instruments. It is assumed that the biologically active agent of silver is the silver ion. Here we studied the biological activity of silver in the nanoparticulate form. Mechanisms, rates and effects of the interactions between silver nanoparticles and biological systems depend on a number of nanoparticle properties including size, shape, morphology, charge and surface functionalities. The silver nanoparticles were prepared by the reduction of silver salts with different reducing agents. One typical method is the polyol process. The resulting nanoparticles were stabilized by different polymers. The synthesis of different shapes and sizes was possible by changing the reaction conditions such as reagent ratio and temperature. The variation of different anionic and cationic polymers led to charged nanoparticles. The silver nanoparticles were analyzed by dynamic light scattering (DLS), zeta-potential measurements, UV-spectroscopy, scanning electron microscopy (SEM), and transmission electron microscopy (TEM). The biological activity of the silver nanoparticles was tested by human mesenchymal stem cells (hMSC).

The biological effects of nanoparticles and their uses as molecular probes are research areas of growing interest [1]. It is estimated that the silver nanoparticles currently have the highest degree of commercialization among the nanomaterials [2]. The bactericidal character of silver ions is well known [3,4]. However, there is a strong difference in toxicity towards microorganisms and towards higher organisms. This suggests a delicate and hitherto unresolved interplay of silver with the biological system. Moreover, in the case of nanoparticles, the uptake of the whole particle into a living cell is possible and the constituting ions will be released inside the cell [5]. As a model system, silver nanoparticles are especially well suited for fundamental studies because silver has a well-known but yet to be resolved biological action, both as ion and as nanoparticle. Silver nanoparticles can be prepared with different size, shape, charge and surface functionalization.

Silver nanoparticles were prepared by the polyol process [6], i.e. by the reduction of silver nitrate with ethylene glycol in the presence of polyvinylpyrrolidone, PVP. Thereby, the silver nanoparticles were colloidally stabilized by the polymer. The synthesis of nanoparticles of different size and shape (cubes, rods and spheres) was possible by changing the reaction conditions such as reagent ratio and temperature. The silver nanoparticles were characterized by dynamic light scattering (DLS), zeta-potential measurements, UV-spectroscopy, and scanning electron microscopy (SEM) [7]. The biological activity of spherical PVP-coated silver nanoparticles (about 100 nm diameter) was tested on human mesenchymal stem cells (hMSC) in comparison with equivalent amounts of silver ions (silver acetate) [8]. hMSC were treated with silver concentrations in the range of 50 ng mL^{-1} to 50 µg mL^{-1} for 7 days under cell culture conditions. Cytotoxic cell reactions occurred at ≥2.5 µg Ag mL^{-1} for nanoparticles and ≥1 µg Ag mL^{-1} for silver acetate, indicating a critical role of the silver ions for toxic reactions.

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