Two faces of biodegradable molybdenum nanoparticles regarding oxidative stress and biomedical applications

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INTRODUCTION: Recently, biodegradable metal materials have drawn a significant scientific interest owing to their attractiveness for biomedical purposes. In fact, if it were not for the presence of non-degradable metals in a human body, the risk of inflammation, infection and implant malfunction would be reduced. Molybdenum (Mo) is one of the promising materials with high potential for use in load-bearing orthopaedic and cardiovascular implants [1]. However, upon contact with tissues and body fluids, a cascade of reactions leading to the formation of MoO_3 (nano)particles (MoO_3NPs) is triggered. As structures foreign to the body, they are immediately recognized by phagocytic immune cells, especially macrophages [2]. In this work, we focused on the effects of MoO_3NPs on primary human macrophages with regard to oxidative stress.

EXPERIMENTAL: MoO_3NPs were purchased from Sigma-Aldrich Co., USA. To get closer to the real conditions during the immune response to the implant, blood samples from patients undergoing endoprosthesis surgery were used to isolate macrophages. A comprehensive cytotoxicity study of MoO_3NPs was conducted herein, by utilizing the MTT assay, and the analysis of cell morphology and behaviour through confocal microscopy. Macrophage polarization state was analysed using flow cytometry, where CD86+ and CD206+ were used to distinguish M1 and M2 macrophages, respectively. Furthermore, the ability of MoO_3NPs to induce reactive oxygen species (ROS) in macrophages was tested by the nitro blue tetrazolium (NBT) assay and live cell imaging. In addition, the anti- or pro-oxidative properties of MoO_3NPs were evaluated using the DPPH test. All the experiments were performed at least in triplicates, and the results were evaluated using non-parametric statistical tests.

RESULTS AND DISCUSSION: We found that MoO_3NPs at low concentrations (below 0.1 mM) are well-tolerable by macrophages as they do not pose a threat to cell survival, and do not have an impact on morphology changes and natural ROS production. With an increasing concentration (to 0.3 mM), a more harmful effect of oxidative stress was observed. However, the concentration of 0.5 mM tends to trigger the intracellular ROS overproduction in macrophages, potentially leading to their death. Recently, the effect of a higher concentrations of Mo was described, with the greatest emphasis on cytotoxicity [3]. This study shows the crucial role of concentration-dependent effects of MoO_3NPs that alter macrophage polarization and ROS production.

CONCLUSION: Overall, molybdenum should be regarded as a potential material for biomedical applications, providing its cytotoxicity is mitigated.

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