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Editorial

Advances in Stability of Metallic Implants

Changjiang Pan [1,*] and Jingan Li [2]

[1] Faculty of Mechanical and Material Engineering, Jiangsu Provincial Engineering Research Center for Biomaterials and Advanced Medical Devices, Huaiyin Institute of Technology, Huai'an 223003, China
[2] School of Materials Science and Engineering, Henan Key Laboratory of Advanced Magnesium Alloys, Zhengzhou University, Zhengzhou 450001, China; lijingan@zzu.edu.cn
* Correspondence: panchangjiang@hyit.edu.cn

1. Introduction and Scope

Metallic implants have attracted extensive attention because of their importance in enhancing the quality of human lives and treating human diseases. There is a tremendous demand for metallic implants when organ defects or functional damage caused by trauma and disease occur. However, their instability in vivo caused by corrosion, limited mechanical properties, and poor biocompatibility remains a great challenge to be solved, because the stability of metallic implants has a close association with the clinical outcome of medical implants. Therefore, this topic has attracted increasing attention from researchers in the last several decades and great advances have been achieved.

The purpose of this Special Issue is to provide a platform to exhibit the researchers' latest findings, understandings, and insights into Advances in Stability of Metallic Implants. It is anticipated that this Special Issue can enhance the development of metallic implants that can fulfill the clinical requirements. Consequently, full-length articles, short communications and reviews regarding metallic implants and their biomaterials are covered in this special topic.

2. Contributions

In this Special Issue, we collected ten articles, including eight research papers and two review papers, which covered several aspects concerning Advances in Stability of Metallic Implants.

The paper by Alferi [1] investigated the influences of different metal alloys and their manufacturing technologies on anti-corrosion in SGF (standardized simulated gastric fluid). It was discovered that both raw material and the production parameters can influence the anti-corrosion properties, and the released nickel in SGF was positively related to the corrosion degree. On the other hand, the author found that not only the corrosion susceptibility characterized by gastric acid is inadequate and the low pH valve of the environment around the implant should be considered, but also the manufacturing process can abate the influence of the base material on corrosion susceptibility.

It is well known that the mechanical properties of medical implants have a significant impact on the in vivo performances after implantation, and biomimetic simulation and finite element analysis are effective methods for investigating the mechanical properties and in vivo stability of implants. Considering the structural features of natural human cervical, Cheng et al. [2] designed a new fixture for measuring the fatigue properties of artificial cervical disc (ACD) prostheses under different mechanical conditions, including flexion, extension, and lateral bending. The numerical simulations and mechanical experiments were carried out to characterize the equivalence between the designed fixture and the natural cervical sections, and the results indicated that this novel biomimetic fixture could reflect the biomechanical characters of the natural human cervical vertebrae with acceptable accuracy. In another work by Cheng et al. [3], a C2–C7 3D finite element model of the

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cervical spine was constructed based on the data from cervical CT images. Different pure moment loads were used to simulate flexion/extension and the relative motion range between vertebral bodies. The stress of some segments under axial load was also investigated. The results were in accordance with the in vitro experimental data, indicating the validity of the new model.

In the work by Adelmann et al. [4], the authors applied laser powder bed fusion to prepare titanium alloys with different lattice structures, and the hot isostatic pressing was used as post-treatment. The properties of the as-prepared materials with different lattice structures were comparatively studied. It was discovered that hot isostatic pressing had no obvious impact on the strength when high loads and low cycle numbers were applied; however, all samples survived 10^6 cycles at low loads. As a result, after hot isostatic pressing, dode-thick and rhombic dodecahedrons with 2 mm and 1.5 mm lattice sizes were suitable for medical implants due to the high elasticity, high fracture stress, and high resistance against dynamic loads, which can meet requirements of the implants.

Magnesium (Mg) and its alloys have been extensively explored for implants such as cardiovascular stents owing to its biodegradability, but the in vivo fast degradation and poor biocompatibility hindered the applications in the clinic. Surface modification and further biofunctionalization are the popular ways to simultaneously enhance corrosion resistance and biocompatibility. The review by Wu et al. [5] first summarized various surface design strategies to control the corrosion rate of magnesium alloys. This work widely discussed the bioinspired surface designs to enhance anti-corrosion and realize biofunctionalization. The author thought that future work on the anti-corrosion of magnesium-based materials could benefit greatly from the bioinspired surfaces. Subsequently, to investigate the ways to improve the anti-corrosion properties and biocompatibility of magnesium alloys for cardiovascular stents, Meng et al. [6] applied four chemical treatments, including NaOH, HF, phosphoric acid (H_3PO_4) and phytic acid ($C_6H_{18}O_{24}P_6$) treatment, to produce the different chemical conversion coatings on AZ31 surface, and the influences of different layers on the corrosion properties and biocompatibility were investigated. It was discovered that all chemical treatments can improve the anti-corrosion properties to different degrees and significantly affect the surface wettability, which can cause different plasma protein adsorption behaviors. Furthermore, they found that all chemical treatments can enhance the hemocompatibility to varying degrees and the NaOH-treated surface had the best cytocompatibility to endothelial cells. Consequently, the NaOH treatment can be chosen as the pretreatment method for the biofunctionalization of the magnesium-based alloys to further improve the biocompatibility when applied as cardiovascular implants. In another paper regarding surface modification of magnesium alloy by Han et al. [7], ferulic acid (FA) was immobilized on the polydopamine (PDA) modified Mg-Zn-Y-Nd alloy to construct a PDA/FA coating to simultaneously enhance the corrosion resistance and biocompatibility. The outcomes suggested that the PDA/FA coating can be used to modify the medical Mg alloy to improve its performance. In the work by Sheng et al. [8], three Schiff bases were synthesized to construct the Schiff base coatings on the Mg-Zn-Y-Nd (ZE21B) surface by electrostatic spraying. The results indicated that both the single coating and the compound coating can reduce the corrosion rate of ZE21B alloy, and the compound coating had a synergistic effect in inhibiting corrosion, thus displaying the best anti-corrosion character.

Hu et al. [9] prepared Cu/Ti coatings containing different copper concentrations on titanium surface by the physical vapor deposition (PVD), and the effect of deposition bias on the properties of these coatings was further investigated. It was discovered that the deposition dispersion and copper concentration can be controlled by the number of copper sheets, but the bias voltage had no impact on the copper concentration of the Cu/Ti coating. As compared to control samples, Cu/Ti coating-modified samples showed better hemocompatibility. The best adsorption of bovine serum albumin (BSA) can be found on the coating when the bias voltage of −40 V is applied. The increase in copper flakes can reduce the adsorption of fibrinogen on the Cu/Ti-coated surface. Therefore, Cu/Ti coatings have the potential to enhance hemocompatibility and surface performances of cardiovascular biomaterials or implants.

As an important organic synthetic reagent in organic chemistry, the Schiff base has many excellent bioactivities, such as anti-tumor, anti-virus, antifungal, and antibacterial activities. Therefore, the coatings made of the Schiff base can improve the bioactivities of metal biomaterials. In the review paper by Zhang et al. [10], preparation, properties of the Schiff base, and advantages of Schiff base coatings were summarized. Through reviewing the advanced works concerning the functional coatings prepared by Schiff base and Schiff base reaction, and the extensive applications of Schiff base coatings in many aspects such as inhibition of corrosion, antibacterial, flame retardant, etc., the authors obtained four conclusions: (1) Schiff bases are extensively studied because of the synthetic flexibility, selectivity, structural similarity with natural bio-compounds, and their (−N-CH-) groups. (2) Schiff bases can be used to modify biomedical metals to create functional coatings to enhance biocompatibility, mechanical properties, and anti-corrosion properties. (3) An amino acid–paeonol Schiff base can offer the Mg alloy surface a self-healing property and enhance cytocompatibility to endothelial cells. (4) The application mechanisms of many Schiff bases and their compound coatings still need to be explored.

3. Conclusions and Outlook

Although many advances have been achieved in the stability of metallic implants in the past several decades, it is a problem far from being solved satisfactorily in clinical applications. This Special Issue makes some contributions to enhancing the comprehension of the stability of metallic implants and providing some methods to improve the mechanical properties and biocompatibility of the metallic implants. The guest editors hope that the data, the observations, and the methodology presented in these papers can greatly promote the development of metallic implants.

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