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MAGNESIUM FUND PLAYS A ROLE IN MEDICAL IMPLANT MATERIALS

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Abstract: Magnesium-based metal materials have good mechanical properties, mechanical properties and biocompatibility. They are an attractive degradable biomaterial and show good application prospects in the field of hard tissue implant materials. However, its degradation rate is too fast during the degradation process, accompanied by a decrease in strength, which inhibits its application in many biomedical fields. This article analyzes and summarizes relevant reports this year, and summarizes the properties and new research progress of magnesium-based bone implant materials.
Keywords: Magnesium-based metal; Implant material; Degradation performance; Medical application

1 PROPERTIES OF MAGNESIUM AND MAGNESIUM ALLOYS

In the 1960s and 1970s, the first generation of biomedical materials officially entered clinical practice and began to be used in the human body, including metal materials mainly titanium alloys and stainless steel, ceramic materials mainly such as alumina and zirconia, and silicone rubber. and other organic polymer materials. The use of these biomedical materials is to obtain physical properties that are roughly equivalent to those of the tissues they replace, so as to minimize their toxic and side effects on the body [1]. This type of biomedical materials all have a common characteristic, which is biological inertness. The elastic modulus and strength of medical metal materials commonly used in clinical practice are much higher than those of human bones. The most prominent shortcoming is the significant stress shielding effect, which affects the regeneration and shaping of bones and makes bones less dense. And the strength is reduced, which leads to slower healing of bone and surrounding tissues [2]. At the same time, it has many shortcomings such as poor biocompatibility, mismatch with the biomechanical properties of bone tissue, and the need for a second surgical removal [3]. In view of the shortcomings of the first-generation materials and their resulting limited application, second-generation biomedical materials, including bioactive materials and biodegradable materials, have gradually become the focus of biomedical materials research. In the mid-1980s, bioactive materials, including dense hydroxyapatite ceramic materials, bioactive glass materials, and bioactive glass-ceramic materials, first began to be widely used in dental and orthopedic restorations [4]. Biodegradable materials are gradually degraded and absorbed after being implanted into the body, and are eventually replaced by new tissue. Magnesium and magnesium alloys are significant representatives of biodegradable materials. Because they are closer to the biomechanical properties and in vivo degradation characteristics of natural bone tissue, magnesium and magnesium alloys have obvious advantages as medical materials. However, they degrade after implantation in the human body. The speed is too fast, which affects its further clinical application. In recent years, with the rapid development of magnesium-based metal manufacturing technology, new progress has been made in the research and development of new magnesium-based bone grafting materials.

1.1 Advantages of Magnesium and Magnesium Alloys

1.1.1 Magnesium and magnesium alloys have good mechanical properties
The density of magnesium-based metal is 1.74-2.0g/cm3, and its elastic modulus is 41-45GPa. Compared with medical metals such as stainless steel and titanium alloys, the density and Young's elastic modulus of magnesium and magnesium alloys are closest to human bone tissue. [5], and magnesium and magnesium alloys have similar mechanical properties to bone. These advantages enable them to reduce the stress shielding effect to a certain extent after implantation.

1.1.2 Magnesium and magnesium alloys have good biocompatibility
As an important element necessary to participate in the synthesis and metabolism of human body substances, magnesium has good biocompatibility and plays an important role in maintaining the body's physiological functions and normal metabolism [6]. The new American RDN standard stipulates that the daily intake of magnesium for adult men is 350 mg, and that for women is generally 180 mg[7]. During the degradation process of magnesium and magnesium alloys, non-toxic MgO is released and can eventually be completely excreted through urine [8].

1.1.3 Magnesium and magnesium alloys are biodegradable
The standard electrode potential of magnesium and magnesium alloys is low and easy to degrade in the body [9]. Although magnesium and magnesium alloys, as bone implant materials, increase the absorption of magnesium in the body after degradation in the body, in actual daily life, insufficient magnesium intake is still relatively common, thus leading to the risk of excessive magnesium intake. Very low[10].

1.1.4 Magnesium and magnesium alloys have bone-promoting effects
Studies have shown that magnesium and magnesium alloys have good osteoinductive effects, especially in the adhesion, growth proliferation and osteogenic differentiation of osteoblasts derived from bone marrow stem cells in vitro [11-12]. Janning et al. [13] implanted round pins with a diameter of 3 mm made of magnesium hydroxide, the main product of

magnesium alloy degradation, in animals. Through observation, they found that the degradation products of magnesium alloy can stimulate bone formation.

1.2 Disadvantages of Magnesium and Magnesium Alloys

The extremely high degradation rate of magnesium and magnesium alloys results in the inability to form good fixation and protection of tissues in chlorine-containing environments. Magnesium and magnesium alloys are used as internal fixation materials for fractures. When the fracture is not completely healed and the material has not yet played its role, the magnesium-based material is absorbed by the human body and cannot play a supporting role, which limits the medical application of magnesium and its alloys. have been seriously affected [14]. The current obstacle to the clinical implementation of magnesium-based materials is the excessive degradation rate, accompanied by the release of hydrogen and limited biological activity. Since cells at the tissue-implant interface and interactions between tissues and biomaterials are surface phenomena, the ability to change surface properties while maintaining bulk properties is important, and the formation is biocompatible and corrosion-resistant The surface modification layer has always been a topic of interest in the field of biomaterials.

2 RESEARCH DIRECTIONS FOR MEDICAL APPLICATIONS OF MAGNESIUM-BASED MATERIALS

2.1 Bone Implant Material

Magnesium and magnesium-based alloys have broad application prospects in orthopedic and craniofacial repair applications because these alloys not only have physical properties significantly similar to natural bone, but also have unique in vivo degradation capabilities [15, 16]. Therefore, these alloys may be candidates for orthopedic fixation plates and screw devices. Such implants, which degrade as needed in the body after completing their primary function of providing support to the underlying fractured bone or healing of a nonunion, are indeed preferable because this type of implant reduces the risk associated with a permanent implant. The chance of drug-related long-term complications, including foreign body reaction, delayed-type hypersensitivity reaction, and painful secondary resection surgery [17].

Nowadays, with the emergence of a large number of severe fracture cases that cannot be treated by simple external application, in order to meet clinical needs, there have been higher requirements for the development of biodegradable magnesium implant materials in recent years. In response to the above situation, Lili Tan et al. [18] used AZ31B magnesium alloy coating to make intraosseous implants. The results showed that the intraosseous implants treated with AZ31B magnesium alloy coating showed excellent biodegradation effects. , which has research prospects in clinical application.

2.2 Porous Magnesium Material

Relevant studies have now shown that more active osteoblast proliferation can be found around porous magnesium alloy implants. Geng et al. [19] believe that the porous magnesium matrix treated with β-tricalcium phosphate coating has significantly improved corrosion resistance, bone cell adhesion and value-added ability. In research on magnesium alloys with different porosity and pore diameters, it was found that the mechanical properties of magnesium alloys with a porosity of 35% are closest to human bones. It can be seen that the application of porous magnesium-based materials in bone repair shows good prospects [20].

2.3 Stent

The incidence of obstructive vascular disease is increasing year by year, seriously threatening human health. Intravascular stent implantation surgery has become the main treatment method for coronary and peripheral vascular obstructive diseases [21]. Before the introduction of drug-eluting stents, in-stent restenosis remained a problem with bare-metal stents. Inhibition of the healing process by antimitotic drug coatings and permanent metallic residues can promote subacute and delayed stent thrombosis. Therefore, the development of biodegradable scaffolds has become the subject of research. Magnesium-based bioabsorbable devices can provide sufficient radial force during the acute phase of vascular treatment and completely degrade in an aqueous environment, making them potential new candidates for vascular stent applications. Magnesium and magnesium alloys tend to degrade very quickly due to their high electrochemical corrosion potential. Plasma electrolytic oxidative modification of magnesium and magnesium alloys improves the interface and degradation properties and therefore may improve the performance and suitability of these materials for vascular stent applications.

3 CONCLUSION AND OUTLOOK

Compared with traditional metal medical materials, degradable magnesium-based materials show significant advantages in biocompatibility and mechanical properties. If used clinically as an intraosseous implant material, degradable magnesium-based materials can significantly reduce the stress shielding effect and promote good bone tissue healing, thereby effectively reducing the pain caused by secondary surgery after healing; if used as a vascular stent material When applied clinically, degradable magnesium-based materials can become potential new candidates for vascular stent applications, greatly improving the effectiveness of intravascular stent implantation surgeries. However, medical materials based on degradable magnesium-based materials face some challenges in clinical practice, such as whether they can improve the extremely high degradation rate of magnesium and magnesium alloys. It is believed that with the continuous deepening of research on degradable biomedical magnesium-based materials, people will have a deeper understanding of degradable biomedical magnesium-based materials, find treatment methods that can improve the performance of materials for clinical application, and become a new metal that benefits human health biomaterials.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Hench L.L. Biomaterials. Science, 1980, 208(4446): 826-831.
[2] Nagels J, StokdijkM, Rozing P M. Stress shielding and bone resorption in shoulder arthroplasty.Journal of Shoulder & Elbow Surgery, 2003, 12(1): 35-39.
[3] Yang J, Xu Y, He X. RESEARCH PROGRESS OF MAGNESIUM AND MAGNESIUM ALLOYS IMPLANTS IN ORTHOPEDICS.
[4] Plum Xin, Zhou Jinru, Li Ziyan. Application of third-generation biomedical materials in the dental field. International Journal of Stomatology, 2016, 43(3): 309-313.
[5] Seedling Bo, Lu Yan, Liu Miao. Degradation behavior of pure magnesium ultrasonic micro-arc oxidation biological coating implanted in the body for 4 weeks. Chinese Surface Engineering, 2013, 26(3): 45-50.
[6] Wang Shuqin, Yin Shujuan, Xu Jianxia. Study on the degradation behavior of pure magnesium in different corrosion systems. Journal of Pharmaceutical Analysis, 2013, 27(4): 701-705.
[7] Li Longchuan, Gao Jiacheng, Wang Yong. Corrosion behavior and surface modification of medical magnesium alloys. Materials Herald, 2003(10): 29-32.
[8] Saris NE, Mervaala E, Karppanen H.Magnesium.An update on physiological, clinical and analytical aspects. Clinica Chimica Acta, 2000, 294(1): 1-26.
[9] Liu Minghe. Research progress on degradable biomedical magnesium alloy materials. Contemporary Chemical Engineering Research, 2018, (8).
[10] Wang Chang, Wang Lan, Yu Sen, Huangfuqiang, Liu Hanyuan, Yu Zhentao. Research progress on degradable magnesium and magnesium alloys as bone implant materials. Guangdong Chemical Industry, 2016, 43(15): 124-126.
[11] Zhang Tao, Wu Xiaona, Yin Qingshui, Xia Hong, Zhang Yu, Li Mei, Yang Xiaoming, Lan Guobo. Surface properties of magnesium alloy AZ31B material and osteoblast adhesion. Chinese Tissue Engineering Research, 2013, 17(12): 2123-2130.
[12] Li RW, Kirkland NT, Truong J. The influence of biodegradable magnesium alloys on the osteogenic differentiation of human mesenchymal stem cells. Journal of Biomedical Materials Research Part A, 2015, 102(12): 4346-4357.
[13] Janning C, Willbold E, Vogt C. Magnesium hydroxide temporarily enhance osteoblast activity and decreasing the osteoclast number in peri-implant bone remodelling ☆.Acta Biomaterialia, 2010, 6(5): 1861-1868.
[14] Zhou Wanqiu, Shan Dayong, Zeng Rongchang. Corrosion behavior and surface protection methods of magnesium alloys. Materials Protection, 2002, 35(7): 1-3.
[15] Witte F, Hort N, Vogt C.Degradable biomaterials based on magnesium corrosion.Current Opinion in Solid State & Materials Science, 2008, 12(5): 63-72.
[16] Xin Y, Hu T, Chu P K. In vitro studies of biomedical magnesium alloys in a simulated physiological environment: a review.Acta Biomaterialia, 2011, 7(4): 1452-1459.
[17] FW, JF, J N. In vitro and in vivo corrosion measurements of magnesium alloys.Biomateria ls, 2006, 27(7): 1013-1018.
[18] Tan L, Wang Q, Lin X. Loss of mechanical properties in vivo and bone-implant interface strength of AZ31B magnesium alloy screws with Si-containing coating.Acta Biomaterialia, 2014, 10(5): 2333-2340.
[19] Geng F. Tan L L.Jin X X. The preparation, cytocompatibility, and in vitro degradation study of pure β-TCP on magnesium. Journal of Materials Science Materials in Medicine, 2009, 20(5): 1149-1157.
[20] Zhang Jie, Chi Yanxia, Guo Xiaoling. Research status of magnesium-based bone implant materials. Biotechnology World, 2015(06): 136.
[21] Yang Ke. Column Research and Development Progress of Biodegradable Magnesium Alloy Implant Materials. China Medical Equipment, 2015, (9): 1-1.