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Mini review

Biodegradable Magnesium Metal for Bone Regeneration: Mini Review

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Abstract

Bone is the hardest tissue of the human body providing support to the skeleton. However, sometimes the bone undergoes some injuries and fractures. Although bone can renew and rebuilt itself, however, bone renewal is one of the challenging fields of today's world. Various kinds/ varieties of materials such as polymers (both artificial and natural), ceramics, and metals, etc. are used for bone renewal purposes. Some of them are natural while others are synthetic. Any material used for bone healing purposes must be biocompatible with its degradation rate almost equal to the rate of new bone formation. Among various metals used for bone rejuvenation and healing purposes, magnesium metal (Mg) is one of the most extensively used metals for the reason of its non-toxic nature and easy elimination/ exclusion from the body. Some other advantages of Mg metal include its biocompatibility and biodegradability. In addition, there is no need for extra surgery for its removal from the body. Surface modification procedures aids in enlightening the quality of Mg metal and its alloys for use in bone revival. This paper represents a mini review on the usage of Mg as a biodegradable metal for bone rejuvenation and healing.

Keywords: Bone Regeneration, Biocompatibility, Magnesium Metal, Surface Modification

Introduction

Bone is a hard tissue which provides support to vertebrate the body and is made up of three main kinds of cells namely osteoblasts, osteoclast, and osteocytes. However, due to some reasons such as fractures and trauma, bone damage and defects occurs. Bone renewal is a major challenge for orthopedic surgeons.[1] Various kinds of biomaterials are used for bone renewal in several forms such as whole prostheses, scaffolds, hydrogels, and cells in addition to growth factors etc. Biomaterial used for bone regeneration may be polymers, metals, ceramics etc.[2,3] Among various metals used for bone regeneration, Mg metal is extensively used for bone renewal processes owing to its biodegradability, bio-compatibility and non-toxic nature.[4] This mini review emphasizes on the use of Mg metal for bone rejuvenation purposes.

Biodegradable Magnesium-Based Materials

The bone regeneration technique involves a wide use of Mg and its alloys owing to efficient biocompatibility, mechanical potency, and biodegradability.[5] It is said that Mg takes fourth place in the human body amongst all cations in a human body.[6] Bio-mechanical characteristics of Mg makes it a suitable material for bone renewal and density of Mg-grounded metals and human cortical bone are almost similar i.e. 1.7-1.9 gcm^{-3} and 1.75 gcm^{-3} respectively.[7] Additionally, elastic modulus of Mg-grounded metals is approximately 45 Gpa, almost close to that of natural bone i.e. 3-20 Gpa. On the other hand, elastic modulus of titanium alloy and stainless steel is 110 and 200 Gpa.[8]

Mg metal shows a greater degree of biodegradability as compared to other metals as produces Mg^{+2} as a degradation product which is expelled out from the body via urine.[9] Biocompatibility of Mg metal also aids in its effectiveness for use in bone regeneration and there are no such side or adverse effects of Mg^{+2} metal 10. Bio-degradation degree of a material should meet with the regeneration degree of bone for its efficacy and use in bone healing and renewal. Basically, bone healing process consists of three stages: firstly, inflammatory stage for 3-7 days. Secondly, repair stage which lasts for 3-4 months and the third stage which is the continuous remodeling stage lasting from months to years.[11] However, several findings revealed that owing to the quick degradation degree of Mg and its alloys (affected by various kinds of in-vivo parameters such as Cl^-, Ca^{+2}, PO^{-4}, and proteins etc.), it's mechanical strength cannot be maintained for a longer period of time.[12] Large amounts of hydrogen also released by degradation of Mg [13] which ultimately cause delayed bone regeneration by parting of tissue and tissue layer because of its buildup to form air packs in the vicinity of implantation.[14] In addition, the pH of the environment increases by Mg degradation which also adversely affects bone renewal.[4]

Degradable magnesium alloy ZEK100 and tricalcium phosphate layered Mg alloy AZ31proved to be bio-compatible for bone renewal processes by recent experiments.[15] By means of surface modification procedures, biocompatibility of Mg can be upgraded leading to decresed degradation degree.[16] These surface amendment procedures involve Plasma Electrolytic Oxidation (PEO), HA coating, solgel coating, organic coating, electrodeposition, chemical deposition, besides biomimetic treatment.[17] Wu et al., have applied ion electrolytic oxidation besides the hydrothermal treatment technology for surface adjustment of Mg in order to decline its degradation rate and is used for rat skull repair processes where its degradation rate slows down.[18] Lie et al., worked to upgrade the biocompatibility of Mg by applying sandwiched biocompatible coating strategy for improving its resistance and biocompatibility.[19]

Figure 1. An Illustration of Various Orthopaedic Graft Geometries Made of Magnesium Alloys. **(a)** MgCa0.8 screw **(b)** ZEK100-plate **(c)** intramedullary LAE442-nail.[9]

Conclusion

Bone renewal poses a serious issue for orthopedic surgeons and for this purpose a variety of materials are in use today. Some of them are natural while others are synthetic. These materials include metals, polymers, ceramics etc. Any material used for bone healing purposes must be biocompatible. Mg metal finds extensive applications in bone healing due to many reasons such as biocompatibility, non-toxicity, and degradation degree almost equal to bone formation rate.

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