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A Evaluation of Pure Mg and Mg-Zn ALLOYS as a Biomaterial in Bone Remodelling- A Review

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Abstract—*Due to hectic life schedule and adulthood results in degradation of organic elements at a faster rate. This shows various health problems like knee joint pain, back joint pain, cartilage tearing and degradation of bones, etc. To reduce these effects, there is need replacement and implantation. Currently, some implant, materials are being used such as Ti and its alloys, SS and Cr-Co alloys. But testing shows some issues like constantly enduring remodeling and modification after implantation. Therefore, a new bio-compatible material Mg and its alloys show diagnostic positive results in muscles and bone tissues. During testing, the mechanical properties of Mg are similar to natural bone, which shows beneficial bio-compatibility of the material for the improvement of implant materials. Different Mg alloys are also tested such as Mg-Zn, Mg-Zn-Ti etc... . But all of Mg alloys having problems like: High toxicity, High corrosion rate and repeated surgeries so overall results are still negative.*

Therefore, the aim of this review study is to examine the main factors that affect desirable result during implantation and study of mechanical properties of pure Mg and Mg-Zn alloys which shows high strength and less toxicity for bio-implants application.

Keywords*: pure Mg, Mg alloys, bio-compatibility, implants, high degradation, biomaterials etc.*

1. INTRODUCTION

The structural part of a human body is mainly made up of bones as an organic material. This organic material having both the mechanical and physical properties. But in this review, we examine the mechanical properties of the bone to check the similar properties with the bio-materials and biometal for its biofunctionality. In the definition of bone fragility includes at least three components: strength, brittleness and work to failure [4]. These components determined by the mechanical properties such as yield strength, ultimate strength and toughness. As the reinforcement of the damaged bone in orthopedic implantation are studied from this point of views. The yield point [figure1] is defined as the transition phase of the material from elastic to plastic state [15].

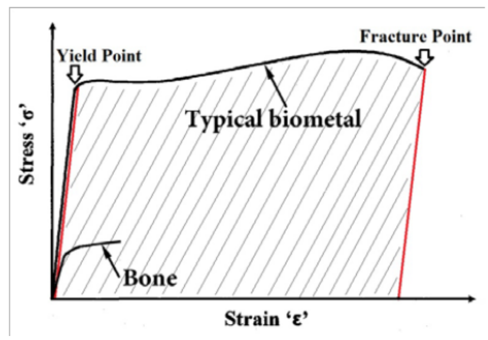

Fig. 1 : Schematic stress strain curve of bone and biometal

The ratio between stress and strain in the elastic state is called as the modulus of elasticity (£).High modulus of elasticity can resist more stress and shows high stiffness of the material. Excessive stiffness of implant results to problems in stress shielding of bone during healing [7].

2. BIOMATERIALS

Biomaterials are the materials which show bioactive and biodegradable properties. These materials are chemically decomposes by natural effectors and ensures a more stable performance for long period of time. Biomaterials depend upon the biocompatibility and biofunctionality that refers to particular functions in mechanical and physical terms. And also related to the combination of properties of a material which safely implemented in a biological body. Some biocompatible materials are Mg, Ca, Zn, Tin, Ag, Earth metals, Al, Zr, Stainless Steel, and Cu etc.

This material shows key connection with the living tissue that implemented partially, totally and externally. Totally implemented example is Knee Joint Replacement where as externally is Skin Grafting.

Selected biomaterials properties are given in the **table 1** for similarities [3]).

BIOMATERIAL	ULTIMATE STRNGTH(MPa)	MODULUS OF ELASTICITY(G Pa)	ELONGAT ION (%)
Stainless Steel	580	195	50
Co-Cr Alloy (Wrought)	793-1000	220	10
Titanium Alloy	900	110	14
Ceramic	300	350	<2
Cortical bone	100-150	10-15	1-3

The above table shows some biomaterials fractured without valid deformation. Brittle materials absorb less energy before fracture such as ceramics have less elongation percentage. The function of bone plates and screws in orthopedic is to provide damaged bone in its position but bone plates also induced compressive stress for recovering the deformities. So the optimal biomechanical properties of bone plates and screw are prefered.These materials are intended to the biological surface to treat and replace any tissue or an organ of a body.

3. MG IN ITS PURE STATE

A magnesium alloy was used by Staiger, to secure a bone fracture in the lower leg in early 1900s [6].Metallic materials have high mechanical strength and fracture toughness that are used in load bearing application and these materials are more dominant than polymer and ceramic composites. Currently used metallic bio-materials are cobalt-chromium alloys, stainless steel and titanium alloys. But today two main problems came across during implantation. Firstly, distinct in mechanical properties of used material and bone tissue environmental conditions. This distinct property results in the degradation of material at faster rate so the need of remodeling also increases. According to R.Murugan study shows that the modulus of elasticity of Co-Cr alloy and Stainless Steel is around 10 times greater than that of bone, while a titanium alloy such as Ti-6Al-4V is around five times greater [8].Stress shielding is a clinical phenomenon which results to a mismatch between different metallic implant materials and bone. This stress shielding creates loading stress around bone tissue surroundings and ultimately results to bone resorption [5].Secondly, releasing of toxic metallic ions such as Ni, Cr-Co into the body affects to a high corrosion rate. This corrosion results to inflammatory effects to the body and reduces the bio-compatibility of implant material [12, 10].

In adults body, about 30g of Mg stored in the bone tissue and muscles which used to form apatite in bone matrix. In terms of engineering application, Mg is a white silvery metal in its pure state. Mg is a light weight and naturally it is present in form of alloy. Three major different alloys forms of Mg are: [1] Mg alloy with some traces of other elements, [2] Mg alloy with aluminum and, [3] Mg alloy without aluminium. These alloys are grouped on the basis of alloy present in it and easy availability of the alloy for research. Such as AZ81, Mg –Ca alloys and AZ91, all of them easily available in the market which contains zinc and Ca as a natural alloy in composite form.

The density of Mg and its alloys are around 1.74 g/cm^3, which are 1.6 and 4.5 times less dense than aluminum and steel, respectively [1]. And the density of Mg is slightly less than natural bone which ranges from 1.8 to 2.1 g/cm^3, while the modulus of elasticity of pure Mg is 45 GPa and human bone varies between 40 and 57 GPa [12, 13, 7].Because of this resemblance in respective elasticity, using Mg greatly reduce the harmful effects of stress shielding and suppress degradation rate. Thus Mg with similar mechanical properties to natural bone, binds with its bio-compatibility, makes it a favorable material for bio-degradable implants [15, 13].

4. MG- ZN ALLOY

Similar to Mg, zinc also plays a key biological role for humans in daily diet. Daily dietary consumption of zinc is 15-40 mg per day which is much lower than magnesium with 300-400 mg per day. For this condition, Zn having lower corrosion rates compare with magnesium. But zinc having low mechanical properties as compare with magnesium so to increase the mechanical strength and low corrosion property, Zn and Mg combined to made an alloy. In 2012, Kubasek and Vojtech research, binary zinc alloys were prepared

That contained from 0.5 to 3 wt. % of magnesium [16].Moreover, corrosion immersion test was studied in physiological NaCl solution and simulated body fluid solution. During test, corrosion rates of Mg-Zn alloys could be calculated lower than pure magnesium [21].The result shows, excellent corrosion resistance and good mechanical properties after cast shape. The result of this alloy to be positive but during implantation limited doses must concerned if not then chances of releasing zinc ions more that results to negative sign[17].

5. MG-ZN-TI ALLOY

Ti alloy mostly used biomaterial in orthopedic implantation applications such as in knee joint replacement, knee cap, ankle joint etc. Titanium shows high mechanical strength and biocompatibity with corrosion resistance property under low load conditions. Thus after implantation Ti alloy fails under high load conditions such as lifting heavy load, high stress to joints etc[2].So need to blend another alloy material with titanium to increase the mechanical property under high load condition.

In this study, forming matrix structures of Mg-Zr-Ti had been evaluated. Diffusion bonding technique was applied. Samples were made to bond pure Mg/AZ31 alloy to pure Zn, pure Ti and Ti6Al4V alloy samples [20]. Mg/AZ31 bonding was also aimed with the idea of coating Ti with magnesium and then dressing Ti parts with magnesium alloys of desired thickness and properties [22]. Before the experiment all of the samples were polished. Under the low melting conditions of magnesium, temperatures were adjusted only by regarding magnesium parts, and hence multi component sample of metals subjected in one operation. SEM micrographic pictures to be taken of the samples under different magnification magnitudes that shows the hardness property and magnitude difference between Mg and Zr/Ti[14]. The examinations shows increase in the strength property under high load conditions. But as compare to pure Ti alloy, Mg-Zn-Ti alloys shows slight other changes such as forming of oxide layers which results to adverse effects after implantation [11].

6. CONCLUSION

The previous studies shows that magnesium based alloys have potential of high biocompatibility and high strength as compare with pure magnesium. Two tests were conducted to study its behavior corrosion immersion test and SEM (scanning electron microscope) test. The research shows that both alloys having high compatibility with low degradation rate. But after implantation some negative results came across that the diffusion of oxide layers and chemical reactions with other tissues in the environment surrounding. Ultimately, results to time to time bone remodeling and repeated surgeries and other adverse effects in the body.

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