A Review on Bio Implant Materials and Their Potential in Medical Field

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***Abstract*—Titanium, stainless steel, and CoCr Mo alloys are the most widely used biomaterials for orthopedic applications. The most common causes of orthopedic implant failure after implantation are infections, inflammatory response, least corrosion resistance, mismatch in elastic modulus, stress shielding, and excessive wear. To address the problems associated with implant materials, different modifications related to design, materials, and surface have been developed with different materials. Among the different methods, coating with different materials is an effective method to improve the performance of implant materials. In this paper, a comprehensive review of recent studies has been carried out to summarize the impact of coating materials on metallic implants. The antibacterial characteristics, biodegradability, bio compatibility, corrosion behavior, and mechanical properties for performance evaluation are briefly summarized. Different effective coating techniques, coating materials, and additives have been summarized. The results are useful to produce the coating with optimized properties. Different types of implant materials are used in different fields of medical science depending on the need of a particular application. Metals, alloys, ceramics, and polymers are the commonly used biomaterials.**

The main focus of this study is to review different types of metals, mechanisms and their properties with applications in various fields of medicine such as orthopedics, teeth implants and skull-based surgeries. Every implant must have certain important characteristics for safe and effective use. These properties like the biocompatibility, relevant mechanical properties, high corrosion and wear resistance and osseointegration are summarized in this review. Various attempts to improve these properties such as different processing routes, surface modifications are also covered in the paper, which provides an insight into the scope of research and effort in developing highly superior implants.

Keywords: **Biodegradability, Bio Compatibility, Corrosion Behavior, Cytocompatibility**

1. INTRODUCTION

Nowadays the use of biomaterials for medical applications is very essential especially for the replacement of hard tissues for artificial implant. With increasing number of elderly people aged over 65 years each year, increases the demand for the replacement of damaged tissue implants made from bio materials. Metallic implant from vanadium steel was first introduced in early 1900s. At this stage, surgeons identified material and design problems that resulted in premature loss of implant function due to mechanical failure, corrosion and bio compatibility. The introduction of stainless steel in 1920s was considered to be stronger and more corrosion resistant than vanadium steel has led to the rapid development in medical devices. In 1960s and 1970s, the first generation of bio materials was developed for routine use as medical implants and devices. Since then, the biomedical industries had evolved significantly and today, metals such as stainless steel, cobalt-based alloys and titanium-based alloys recorded the most widely used metallic implants. This paper aims to review the application of metallic bio materials such as stainless steels, titanium alloys and cobalt chromium molybdenum alloys for orthopedic implants.

Many materials including polymers, metals, alloys, ceramics, and composites are used in orthopedic applications. These materials are required to have excellent physical, mechanical, and tribological properties and must be non-toxic, bio compatible, and corrosion-resistant. The most widely used materials for orthopedic applications are listed in Table. The problems with these conventional materials are their least biodegradability, biological inertness, similarity in properties to the bone, long-term stability, wear, and corrosion resistance. The other issues related to these implant materials are stress shielding, secondary infections, metal ion release, etc. Therefore, in most cases, multiple revisions are required in case of failure of implants. Moreover, the implants made of non-degradable materials often remain in the body up to their need. Hence, the no degradability and long healing time demand revision surgery to replace or remove the implant after healing.

The fabrication of coatings on implant materials has become a topic of major interest to enhance the biological, tribological, antibacterial, and mechanical properties of orthopedics. The most important objective of implant material is to improve bio compatibility. The coating of bio active material improves bio compatibility, prevents ion release from the metallic substrate which results in reduced mechanical failure. A high-quality coating should exhibit sufficient adhesion strength (50 MPa approved by US-FDA), high hardness of the final coat, excellent osseointegration, and osteo conduction properties, reduced cracks among the coating, and free of inclusions. Another important feature is the degree of crystalline which affects the solubility of the bio active coating in the human body. This article aims to review the impacts of coatings on the implant materials for the orthopedic prosthesis. The relative comparison of different coatings on metallic implant materials is reviewed systematically to choose the optimized coating properties.

2. MATERIALS

2.1 Specimen preparation:

2.1.1 Stainless Steel

Rectangular specimens of AISI 316L austenitic SS (Baoshan Iron & Steel Co., Ltd., China, chemical composition in wt.%: C _ 0.08%, 16.0e18.5% Cr, 2.0e3.0% Mo, 10.0e14.0% Ni, Mn _ 2.0%, Si _ 1.0% and balance Fe) were used as substrates with the following. Before laser cladding, SS were sand sprayed and then washed with acetone. The commercial Fe based amorphous powder (Beijing ZJLG Amorphous Technology Co., Ltd., China, chemical composition in wt.%: 4e9% Cr, 7e15% Mo, 2e5% Co, 3e6% Si, 3e6% Al, 2e5% Y and balance Fe) with 45e75 mm particle size was used for the coatings. The amorphous powders were mixed with 4% PVA solution (The Science Company, USA, 89% hydrolysed) and then put on 316L SS. About 0.1 mm was obtained for the thicknesses of each pre-placed amorphous powder layer.

2.1.2 Titanium material

Discs of 5 mm in diameter were punched out from annealedtit anium sheets 99.6+% (Goodfellow Cambridge Limited, Huntingdon, England). Uniform clean surfaces were obtained (Mirror polished surface) on one side of each disc by polishing using grinding and a polishing disc (Struers A/S, Ballerup, Denmark) which considered a polished titanium control surface (PT).

2.1.3 cobalt-chromium

The specimens were fabricated from a representative Co-Cr powder (Star bond CoS Powder 45; S&S Scheftner GmbH) which had spherical grains ranging between 10 mm and 45 mm with some satellites. The chemical composition of this gas atomized powder satisfies International Organization for Standard-ization (ISO) 22674 for dental materials. To facilitate the roughness and hardness measurements, the specimen design took into consideration the build angle of a restoration intaglio surface

2.1.4 Titanium blasted with zirconia (TPZ)

Titanium discs that were polished were subsequently blasted with zirconium oxide powder (ZrO2) with a particle size_44 mm (Zirconium oxide powder; Alfa Aesar, Heysham, UK) using 4.5 bar pressure 3 cm distance. Discs were then ultrasonicated (Ultra wave, Cardiff, UK) in distilled water for 15 min in order to remove any loose remnants of these powders from the surfaces of the discs.

2.1.5. Titanium blasted with zirconia/acid etched (TBZA)

Titanium discs that were blasted with zirconia were subsequently subjected to acid etch with 0.2 wt.% hydro-fluoric acid (Sigma–Aldrich, Steinneim, Germany) for 1.5 min. During the time between preparation and analysis, the samples were stored in an air tight container.

2.1.6 Zirconia material

The pre-sintered yttrium-stabilized tetragonal zirconia (Y-TZP) ceramic blocks (Nissin-Metec, China) were prepared with a diamond saw (Buehler, USA) into zirconia discs (diameter = 14 mm, thickness = 1.5 mm) and strips (1.5 × 5 × 25 mm) for three-point bending tests. Specimens were polished until 1200-grit and cleaned with a lot water. Grouping all samples into C, T1 and T2 group. C was used as a control. T1 and T2 were used as experimental groups, in which a suspension of 1 mol/L $ZrOCl_2$ was mixed with 0.1 mol/L and 0.5 mol/L TiO_2, respectively, before being heated to 95 ◦C and held for 4 h by water bath. Finally, all the samples were sintered to 1450 ◦C in a sintering furnace (Everest, Kavo, Germany), and then they were cleaned by deionized water and kept in a desiccator before use.

3. METHODS

3.1 Laser Cladding

Using GD-ECYW300 type pulse fibre laser, the laser cladding was carried out with the corresponding processing parameters: 2500W peak power, 4 mm s_1 scanning speed and 15 Hz laser frequency. To produce multilayer coatings, the second layer and the third layer of Fe-based amorphous powder were pre-placed on the former laser cladding coating, and then melted again by laser beam. So, 1-layer, 2-layer and 3-layer Fe-based coatings were manufactured, respectively. The samples for tribo corrosion tests were obtained from the laser cladding multi-layered coating with 10 _ 20 _ 10 mm size. The sample surfaces were rubbed with 1000-grit sandpaper and then polished to get a uniform surface roughness Ra _ 0.1 mm before tribo corrosion tests.

3.2 powder metallurgy

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3.3 Atmospheric Plasma spray

The atmospheric plasma spray (APS) process on Ti6Al4V alloy. The HA layer was applied at the metal interface to ensure long term stability, while the calcium silicate (CS) outer layer was applied to achieve fast tissue–implant interactions.

The properties of various degradable and non-degradable materials are studied here and compared with developed samples biomechanical properties. The samples are prepared and fabricated using casting techniques as shown in Fig 1 and examined using tensile, compression, hardness and cellular tests.

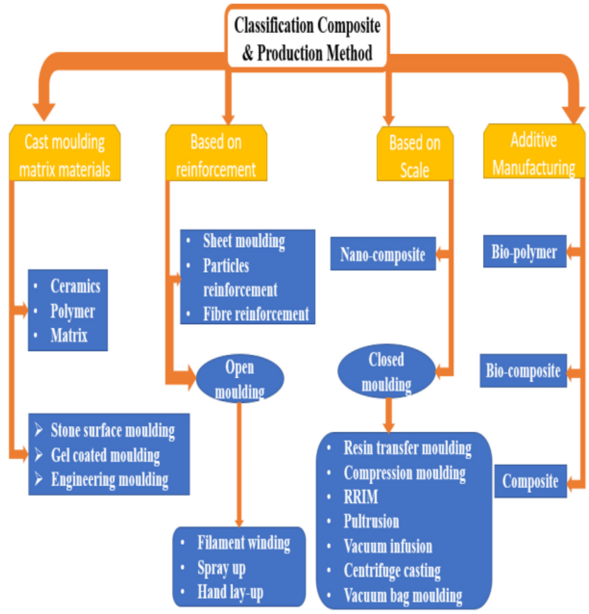

Fig 1 Classification of composite materials and manufacturing methods.

3.4 Hydroxyapatite and coating techniques

The most widely used application of HA p is in coating of metal implants. The metal-ceramic composite combination can not only exert the excellent bioactivity and osteo conductivity of HA p but also use the metal matrix to ensure the overall mechanical strength of the implant. There has been a large amount of research work on HA p coating on metal implant materials such as stainless steels and titanium alloys. Various coating techniques are available, including chemical, hydrothermal, electro-chemical deposition, plasma spray, ion implantation, sputtering and sol-gel methods. Since some of these methods operate at high temperatures, it is extremely challenging to deposit HA p on magnesium-based materials. However, chemical and electrochemical coating methods are attractive for coating HA p since they are done at relatively low temperatures and are also not expensive and is feasible to coat intricate shaped implants. A broad classification of HA p coating methods on magnesium-based materials is illustrated in Fig 2. These methods are described in detail in the following sections.

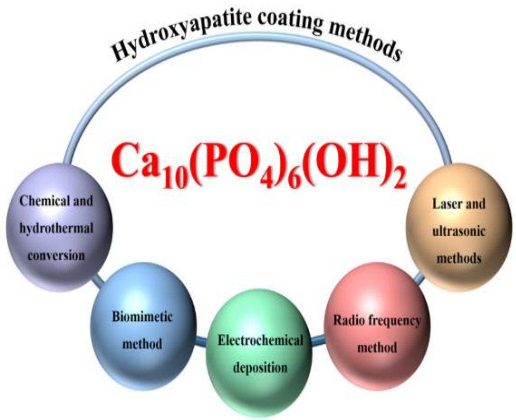

Fig. 2 A broad classification of HAp coating methods on magnesium-based materials.

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4. RESULTS

The result of surface wettability and surface free energy (SFE) of the surfaces. The surface wettability of the TBZA surface had highly significant differences with all of the other surfaces [$P < 0.01$] reflecting a strongly hydrophobic surface. PZ and TBZ surfaces showed relatively similar contact angle values at significant differences with PT surface [$P = 0.03$, 0.011 respectively]. Both PZ & TBZ surfaces has lower SFE than the PT control surface. Chemical composition exploration for the both PZ and TBZ surfaces showed the presence of oxygen, carbon and zirconia as major components, whilst the PT and TBZA surfaces showed oxygen, titanium, carbon as major components.

5. CONCLUSION

Many coating techniques such as physical vapour deposition chemical vapour deposition, electro chemical deposition, sol-gel, plasma spraying, and micro-arc oxidation have been used in recent years to coat metallic implants. Among these techniques physical vapour deposition techniques including cathodic arc deposition, DC reactive magnetron sputtering, close field magnetron sputter ion plating, etc. are effective techniques to produce the coating with improved bio compatibility, corrosion resistance, and mechanical properties. A significant enhancement in performance is reported for several coating materials including Ti, zirconium and HA. However, the stability, adhesion, and degradation performance of these coatings are challenges and limiting the use of these coatings on an industrial scale.

As per the above Journal Publications we concluded that the performance of Ti and zirconium materials are more effective when compared with other bio implant materials.

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