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Current Trends in Bio-Implants' Research

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***Abstract* - Biomaterials are used for making devices that can interact with biological systems of peoples who not only suffers from congenital heart, bone or dental diseases but even sometime young and dynamic people such as sportspersons need replacements due to fracture and excessive strain. The biomaterials are commonly used in dentistry, orthopedics, plastic and reconstructive surgery, ophthalmology, cardiovascular surgery, neurosurgery, immunology, histopathology, experimental surgery, and veterinary medicine etc. Biomaterials when placed inside the human body are called bio-implants. In spite of the technological advancements in the field of medical sciences, the infection and osteomyelitis are still noteworthy after implantation. Therefore, it is need of the hour to improve the performance of traditional biomaterials. This paper summarizes some recent trends and studies, in the research field of bio-implants, which are aimed at the enhancement of current generation biomaterials.**
***Keywords:* Additive Manufacturing, Bioglass, Bio-Implants, Coating, Surface Texturing**

I. INTRODUCTION

Bioimplants are immensely important in improving the longevity and quality of human life. About four millennia ago, the Egyptians and Romans utilised wooden toe replacements and gold for dental applications [1]. However, the practice was systematized in the science of implantology in the late 18th century [2]. In modern society, it was estimated that about 90% of the people over 40 years old suffered from degenerative and inflammatory diseases, which led to immobility and unbearable pain. Moreover, due to busy lifestyle, irregular and poor eating habits most of the people are suffering from life threatening conditions like osteoporosis and atherosclerosis. Osteoporosis is characterized by low bone mass with micro architectural deterioration of bone tissue leading to enhanced bone fragility that increases the susceptibility to fracture of bone joints, hip and knee etc. According to an international report by the International Osteoporosis Foundation, osteoporosis causes more than 8.9 million fractures annually, resulting in an osteoporotic fracture every 3 seconds worldwide [3]. In the developing countries, like India, it was estimated in 2013 that that 50 million people were osteoporotic [4]. By 2020, India is estimated to record 0.6 million hip fractures annually and this number is expected to increase to a million by 2050 [5]. The worldwide incidence of hip fracture in men is projected to increase by 310% and 240% in women, compared to rates in 1990 [6]. Atherosclerosis is the condition in which blood vessels in the heart are narrowed by accumulation of plaque. Atherosclerosis is the root cause of cardiovascular diseases (CVDs) that take the lives of 17.7 million people every year, 31% of all global deaths [8]. The National Interventional Council (NIC) report discloses that India is one of the few countries where PCI are growing at 14.5 percent annually. Total number of stents implanted in 2014 was 3.10 lakh [9]. The number of PCI and stents implantation would be extremely higher for the developed nations.

Researchers are aggressively working in the area of biomedical field to improve performance of current generation biomaterials. In the last few years, some new approaches have been explored to enhance the performance of bio-implants which are summarized in the subsequent sections along with some recent relevant studies

II. SOME RECENT TRENDS AND DEVELOPMENTS IN THE AREA OF BIO-IMPLANTS

A. Bioactve Glass/Bioglass Coatings

Bioactive glasses/Bioglasses are amorphous and biologically active silicate based synthetic materials that are able to form tenacious bonds with bone by forming apatite on reacting with physiological fluids. Clavijo *et al.* [10] investigated the effect of bioglass coating on the mechanical properties of SS316L deposited via EPD process. The hardness, elastic modulus and compressive strength were observed to improve by virtue of coating. The addition of chitosan and titania further enhanced these properties. Flame spray method was utilized by Monsalve *et al.* [11] to obtain bioglass coating on SS316L. Bioactive testing i.e. immersion SBF for 15 days revealed that an apatite layer was generated on the surface of SS, which was not observed on uncoated SS. Their result revealed that the bioglass coating can result in bettter osseointegration than the uncoated SS. Pourhashem *et al.* [12] produced a double layer bioglass-silica coating on SS316L via sol gel method. The results of electrochemical investigation revealed that the coating significantly improved the corrosion resistance of SS. Moreover, immersion tests in SBF demonstrated that a uniform layer of amorphous HA was observed on the bioglass coated surface. Composite polyetheretherketone (PEEK)/Bioglass coating was deposited on Ti-alloy (Ti-6Al-7Nb) via EPD method by Moskalewicz *et al.* [13]. Coating was found to be crack-free and no large void was observed on its surface. The results revealed that EPD method can be used to deposit uniform and reproducible microporous composite PEEK/bioglass coatings on titanium alloy substrate for biomedical applications. Corrosion behaviour of Ti-6Al-4V was invesitgated with and without bioglass coatings obtained via EPD [14]. The results of electrochemical investigation revealed that the Icorr was consideraby lower and Ecorr changed towards more for noble value for coated alloy, which demonstrated better corrosion resistance of the bioglass coated alloy. Shen *et al.* [15] coated Mg alloy with bioglass coating via uniaxial pressing and microwave hybrid heating technique to obtain a combination of suitable mechanical strength and adjustable corrosion resistance that are desired for biodegradable implants. It was shown that uniaxial pressing conducted at the glass transition temperature significantly densified the bioglass coating, which was free of pores and micro-cracks. The compact coating structure combined with mild interfacial stress not only improved the cohesion/adhesion strength but also enhanced corrosion resistance by retarding the penetration of corrosive solution. To improve the corrosion resistance and bioactivity, mesoporous bioactive glass (58S MBG) coatings were prepared on AZ31 magnesium alloy via the sol gel method by Huang *et al.* [16]. Immersion tests in SBF demonstrated that the coating effectively enhanced the corrosion resistance of Mg alloy on account of the stable barrier properties. Meanwhile, apatite was observed on coating surface after 3 days immersion in SBF, demonstrating that the mesoporous coatings could accelerate the apatite precipitation and thus improved the bioactivity of Mg alloy substrate.

B. Surface Texturing

After implantation, firstly, the surface of a bioimplant comes in the contact with the body tissue. So the performance of different kind of surfaces was investigated for bioimplant applications. The antibacterial nature of SS316 was observed after surfec texturing with magneto rheological abrasive flow finishing (MRAFF) [17]. The bacterial adhesion was observed to increase with the increase in surface roughness value. Jagtap *et al.* [18] utilized precision computerized numerical control turning process to obtain surfaces with different surface toughness values ranging from 1.05 to 0.45 µm. The results of corrosion analysis revealed that the surface with lowest surface roughness (0.45 µm) had minimum corrosion rate. The better surface integrity was reported to be the reason for the same. Lancaster *et al.* [19] investigated microrough surfaces of Cocr alloy for the drug delivery in stent application. The microrough surfaces were obtained by grit blasting with glass beads and alumina particles. A medicational drug, Paclitaxel (PAT) was then applied on the microrough surfaces to test its releasing behaviour. The molecules of the PAT were orderly formed on the glass grit lasted surface; while the molecules were disordered on alumina grit blasted surface. The release of PAT was observed for up to two weeks by using high performance liquid chromatography. Alumina grit blasted microrough surface showed continuous release profiles, while the glass bead grit blasted surface showed burst release profiles. Their study concluded that the microroughness of surface can be selected on the basis of required drug release profile. Biologic studies were conducted on Ti-6Al-4V for dental and orthopedic applications after ultrafast laser surface texturing [20]. The laser textured surface shown a noticeable effect on cell shape. When the cells were cultured (after 4 weeks of seeding) in osteogenic medium, better matrix mineralization and bone-like nodule formation was observed on textured surface. Klocke *et al.* [21] combined electodischarge machining with plasma electrolytic conversion process for the surface modification of Mg alloy. The results of corrosion behaviour and biocompatibility analysis revealed that the degradation rate was significantly lower and better tissue response was observed for processed Mg alloy.

C. Additive Manufacturing

Additive manufacturing (AM) consists of different automated fabrication technologies that produce parts by the successive joining of material layer by layer rather than removing material. To make bioimplants that are of complex geometry and custom fitted for individual patients by using traditional cutting, forming and casting methods is neither economically nor technologically viable. Additionally, AM can be used to implement the traditional strategies for the protection of bioimplants. For the enhanced biocompatibility, biologic material can be directly printed/deposited by using AM. The ability of AM technology to produce actual functioning parts is also a contributing factor to its newly acquired popularity. Various AM technologies had been investigated for making bioimplants such three dimensional (3d) printing, selective laser melting (SLM), selective laser sintering (SLS) and electron beam melting etc. Scaffolds of HA and tricalcium phosphate (TCP) were 3d-printed by Warnke *et al.* [22]. In vitro biocompatibility testing was performed by using human osteoblasts. Both versions were colonised by human osteoblasts, however more cells were seen on HA scaffolds than TCP scaffolds. Kolan *et al.* [23] utilized SLS to produce bioglass scaffolds. The results of cell culture studies provided evidence that the rough surface of SLS scaffolds provides a cell-friendly surface capable of supporting robust cell growth. Cui *et al.* [24] developed a bioprinting system with simultaneous photopolymerization capable of 3d-printing of cartilage. To repair the defects in osteochondral plugs, poly(ethylene glycol) dimethacrylate (PEGDMA) with human chondrocytes were printed in this study. Compressive modulus of printed PEGDMA was found to be nearer to the range of the properties of native human articular cartilage. Firm adherence of printed cartilage implant with surrounding tissue was observed and greater proteoglycan deposition was observed at the interface of implant and native cartilage. A patient specific implant of SS was designed and fabricated to reconstruct a facial bone defect via direct metal laser sintering (DMLS) technology by Salmi *et al.* [25]. The implant was revealed to have very accurate fitting with the surrounding tissues after the surgery. Yang *et al.* [26] fabricated a self-stabilizing artificial vertebral body (SSAVB) of Ti-6Al-4V by electron beam melting for cervical vertebral body replacement and investigated it through in vivo study. The open porous structure of Ti-6Al-4V fabricated by EBM facilitated bone ingrowth and the SSAVB maintained cervical spine stability. Sing *et al.* [27] fabricated biphasic scaffolds of titanium and collagen for regeneration and repair of osteochondral defects by using SLM. The results of their study demonstrated continuous interface between the two phases and feasibility of the newly developed scaffolds for tissue engineering in osteochondral defects. At present, the AM technology for bioimplants is at developing stage and certain limitations are still associated with it. Even though there are many materials available, not all are biocompatible and not all biomaterials are available to be used with AM technologies. Although there are many different software available, most software require users to design 3D structures in a 2D plane which is not very convenient. From commercialization point of view, automation in packaging, handling, transportation and accurate tracking, and deploying of biomanufactured parts and their building blocks is still a challenge.

III. CONCLUSION

Along with the ever increasing demand for better biological performance of bio-implants, the researchers are trying hard to explore new ways. Bioactive glass/bioglass coating of bioimplants can also be an option for the betterment of biological performance. Surface texturing of the bioimplants can be used to further enhance the osseointegration with the surrounding tissue. Last but not the least, AM technologies have a tremendous potential in the biomedical field and which deserves serious attention for further development of these technologies.

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