Nanotechnology in corrosion control of biomaterials

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Abstract

Biomaterials plays an important role for mankind as they help in increasing the longevity of the life span of living beings who more or less require biomedical implants to sustain the life. Medical devices comprise of metallic materials, which includes various types of stainless steels, alloys of titanium or cobalt- chromium, and biodegradable materials. Since metallic materials are the most used family of materials used in biomedical devices due to their biocompatibility and high mechanical strength. Human body possesses aggressive environment for the metal implants due to which corrosion occurs and leads to the failure of implant surgery. Nanotechnology gives advancement in the field of biomaterials as various nanotechnological methods are in process to modify the implant surface to combat corrosion problem.

Keywords: biomaterials, implants, nano- coatings, nanomaterials

1. Introduction

Biomaterials include substances designed for various biological applications. Humans from ancient times are using biomaterials. Some of the early examples of use of biomaterials include iron, gold and linen. More specific example is wood as a replacement for missing toe. After Second World War, more biomaterials namely stainless steel, teflon, silicon, and titanium were used for various human applications.

Early use of biomaterials for corrosion application is well defined. Currently biomaterials are increasingly being used for disease diagnosis, tissue engineering and other therapeutic applications. It include biomaterials based implants for dental, bone, eye, heart, nervous system, immune system. Biomaterials are used not only for human applications but also for other domestic animal applications. It also includes material used for plastic and reconstructive surgery **[1]**. This is feasible if we have robust material because in younger patients the replacement period should be more than twenty years. However, the failure of an implant due to corrosion has always been the biggest hurdle in tissue engineering **[2]**.

Table 1. Types of materials used in bio implants or biomedical devices

Metallic material	Location of implant	Type of implant	Type of surface oxide	Reference
Stainless steel	Orthopedic/ Dental alloy, Oral Implants Skrews and nuts	Orthopaedic, dentistry, cardiovascular, otorhinology	Iron oxide, chromium oxide, nickel oxide, molybdenum oxide and manganese oxide; (thickness about 3.6 nm	[3]
Co-Cr-Mo alloy	Oral Implants Skrews and nuts,	Orthopaedic, dentistry,	Cobalt oxide; chromium oxide without	[4]

	ball joints	cardiovascular, craniofacial	molybdenum (thickness 2.5 nm)	
Titanium (Ti)	Ball joints	Orthopaedic, dentistry, cardiovascular	TiO^{+}, Ti^{2+}, Ti^{3+}, Ti^{4+}	[5]
Magnesium alloys	Cardiovascular implants	Orthopaedic, dentistry, cardiovascular	Magnesium oxide	[6]
Nickel- titanium	Dental, orthopedic and cardio vascular applications	Orthopaedic, dentistry, cardiovascular	TiO_2 oxide	[7]

2.1 Corrosion of metallic biomaterials

Corrosion is defined as the continuous process of deterioration of materials as a result of electro-chemical reactions. It is of very much concern especially when a metal is put in the harsh in vivo human condition also having presence of electrolyte. The inserts leads to extreme corrosion condition that incorporates blood and different constituents of the body fluids, which include a few constituents namely water as solvent and, proteins, chlorine, sodium, plasma, amino acids and mucin on account of salivation [8]. The aqueous medium in the human body comprises of different negatively charged ions namely phosphate, bicarbonate, and chloride; positively charged ions like Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} to name a few natural substances of low-atomic weight species just as moderately high sub-atomic weight polymeric segments, and broke down oxygen [9, 10]. The organic particles upset the balance of the corrosion responses of the implants by deteriorating the items because of reaction over anode or cathode. Proteins can attach themselves to metal particles and transport them away from the implant surface. This upset the electron balance over the surface double layer of implant because of abundance of positively charged ions in the solution. The proteins also reduce the dissemination of oxygen at specific places. This further induces localized corrosion in these particular areas. In contrast hydrogen produced by reaction at cathode acts as corrosion inhibitor. This inhibition is suppressed by presence of microorganisms that set reaction in reverse direction. Microorganism pushes reaction towards corrosion by retaining the hydrogen present in the region of the biomaterial. There are some more factors like pH and body temperature that affect corrosion rate. Body temperature is constant 37ºC but the pH depends upon area of application [11]. Changes in the pH of the implant environments also influence the occurrence as well as rate of corrosion. However, the pH of the human body is regularly kept up at 7.0, this however changes from 3 to 9 because of a few causes, for example, surgeries, imbalance in the organic framework of the body because of infections, diseases and different in vivo conditions, and after medical procedure this pH could be altered in the range from 5.3 to 5.6 [12]. The greater part of the materials utilized are shielded by the surface oxide layers. But still there are clinical proofs that prove corrosion can occur from the implants [13].

2.2 Types of corrosion of biomaterials

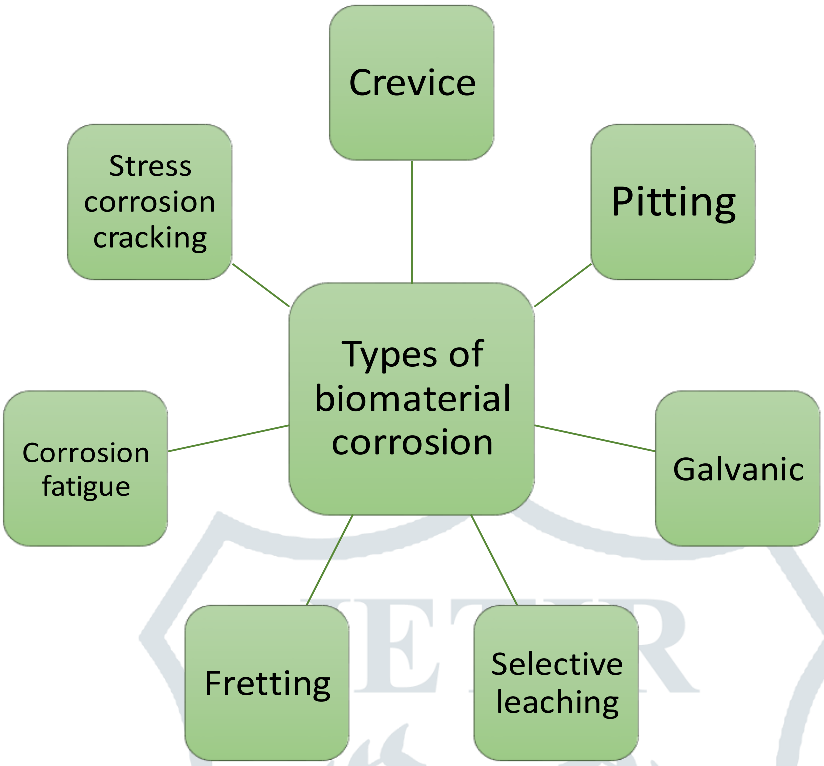

Fig. 1 type of corrosion occurring in biomedical device

2.3 Effects of corrosion of biomaterials on human body

The response of the metallic particles that drains from the metallic bio-material because of corrosion in the human body influences a few organic parameters. At the beginning of corrosion the leaching of metal will start disintegration that thus will in the long run make implant fragile and prone to breakage. When the material cracks, erosion gets quickened because of increment in the measure of uncovered surface zone and loss of defensive oxide layer. On the off chance that the metal sections are not precisely separated, further disintegration and discontinuity can happen, which may bring about irritation of the surrounding tissues. The arrival of erosion items will clearly enhance unfriendly natural responses in the patient body. Few studies have shown appearance of corroded products in the tissue close to the inserts and in different parts of the human body like liver and kidney [14, 15]. Regardless of the way that there is no histological proof to show the moderate arrival of metallic particles because of erosion, the staining of the encompassing tissue and the outside body responses unmistakably demonstrate this is because of corrosion of bio- inserts [16]. Corrosion exhaustion along with fretting corrosion in bone plates and screws at the bone-stem, and stem-concrete interfaces of secluded hip inserts has already been reported. The disappointment of stent gadget is because of stress corrosion on the surface of the implant [17]. This pressure erosion breaking in biomedical inserts can prompt loss of basic honesty of the embedded gadget capacities. In this manner these confusions lead to disintegration of the material [18]. It has been discovered that this disintegration of metal particles can be decreased by appropriate biologically compatible inorganic coatings covering with certain covers. Hydroxy-apatite (HAP) is a good example of such materials. It can postpone the corrosion of inserts from bone [19]. Therefore, the main answer for obstruct corrosion is by picking better quality materials with appropriate covering.

2.4 Nanotechnology in corrosion control of biomaterials

The utilization of nanotechnology to bone substitutes marks the beginning of new era. Nanomaterials generally are alternate to unpredictable and various leveled structure of the local bone tissue [20] Since regular tissues have component that are nano meter in measurements. So cells straightforwardly collaborate with nanostructured extracellular lattices, the bio-mimetic highlights and amazing physio-chemical properties of nano materials assume an essential job in stimulating cell development just as tissue recovery [21] Some of the key qualities that make nano materials alluring for orthopedic applications incorporate high solidarity to-weight proportion, wear/erosion obstruction, antimicrobial/sedate discharge possibilities, and tissue reconciliation/recovery abilities [22]. It is normal that progress in metals development advancements assumes a significant job in the improvement of the up and coming age of clinical inserts. Current development in the field of nanotechnology enable precise plan and balance, at nanoscales, surface and mass properties of materials utilized for various applications in medication, which offers more up to date dreams to patients [23]. The mix of nanotechnology and biomedical designing guarantees a more up to date age of inserts. Implant industry can be taken into far higher places by planning and balancing their properties through the capacity of nanotechnology. It should to be noted that how nano-organizing can make agonistic the nano-structures in the body conceivable. Therefore, nano structured implants have the interesting ability to positively impact the cellular functions [24, 25]. These might be advantageously named as bio implants with nano-structured mass or surface topology.

Biocompatibility is a significant factor for biomaterials, for example they should be non-dangerous, non-cancer-causing materials that don't show unfortunate synthetic responses with body liquid [26]. They ought to likewise be precisely safe with long exhaustion life and legitimate thickness. Then again, a perfect orthopedic embed requires having high erosion opposition as well as a versatile modulus pleasant with that of the bones [27]. Due to fitting mechanical properties including moderately high consumption opposition, simple produce, and relatively minimal effort in contrast with numerous different compounds, the austenitic treated steels have various uses as a biomaterial like human body inserts and orthopedic gadgets among the current metal inserts [28]. Regardless of its significant focal points, a 316L tempered steel is inclined to corrode in chloride condition, especially localized consumption (pitting erosion). 316L hardened steel consumption brought about discharging metal particles, for example, nickel and chromium in the body and prompts sensitivities. Poor mechanical conduct of embed is the result of limited erosion. Because of the way that numerous mechanical, physical and compound properties of metals support essential changes during their nano organizing, scientists proposed development of nanostructured materials during the two past decades [29]. Diminishing the grain miniaturized scale size escalates the response of surface with destructive condition; hence decreasing the nano-sized crystalline material reduces the potency of surface towards reactivity. The mass and surface nano-crystallization can enhance the strength of the materials [30]. Various reports have suggested the potential of nanostructures to harden steel. Nanostructured steel possesses smaller grain size and high volume of grains, responsible for their significant physical properties, mechanical strength and biocompatibility [31, 32]. Further, uniformity in the size of nano-hardened steel has been reported. The grain size in the nano hardened steel generally ranged from 20 to 200 nm [29].

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3. Conclusion

Since nanotechnology is an emerging field which finds it significant application in the field of biomaterials. The studies on nanomaterials for various biomedical applications have shown the potential of various nanomaterials for their utilization as biomaterials. Methods like surface modification and surface topography plays an important role in increasing the biocompatibility of implant materials and further nano-coatings can help in reducing the corrosion of metallic biomaterials. Hence, new advancement and technological methods should be developed to harness the potential benefits of nanotechnology in the field of biomaterials.

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