Chapter 9
Corrosion Behaviour of Metallic Biomaterials in Physiological Environments

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ABSTRACT

Metals are often used in a wide range of biomedical applications since they have good mechanical characteristics, like higher strength, ductility, and toughness. However, the primary disadvantage of metallic biomaterials is their rapid reactivity, which causes corrosion when exposed to physiological conditions like body fluids. When exposed to body fluids, the metallic biomaterial is subjected to wear and corrosion; hence, the mechanical properties are reduced. Corrosion resistance, which also has a significant impact on biocompatibility, affects the efficacy and longevity of an implant material. In this chapter, the body environment will be carefully examined and the potential impacts of corrosion on the biocompatibility of various biomaterials will be highlighted. The fundamentals of implant failure, recovery, and failure mechanisms will be mentioned, and the most common in-vitro and in-vivo corrosion processes will be discussed. Finally, the different methods for preventing biomaterial corrosion will be emphasised.

DOI: 10.4018/978-1-6684-7689-5.ch009

1. INTRODUCTION

According to Williams, biomaterials are described as "the materials which is used to interact with biological systems to analyse, improve, or substitute any tissue, organ, or part of the body" (Callister & Rethwisch, 2007). In order to minimise the negative consequences of various illnesses, infections, or damages that can impact a patient's health, biomaterials are used to develop biomedical devices. The skeletal and muscular systems, which are made up of bones, cartilage, ligaments, muscles, and tendons, give the body stability and motion. Devices intended to aid in healing or replace functionality include joint replacements, bone fixation plates, and muscle structures. Because the musculoskeletal system bears the weight of the body, the mechanical characteristics of implanted biomaterials have a big impact on how long medical devices last. Metals are therefore employed as implant materials. Generally, bio metals and alloys have elements joined together through metallic bonding, with the positively charged ions oriented in a crystal structure and encircled by an electron cloud (Revie, 2011). This atomic structure gives metals characteristics including outstanding thermal and electrical conductivity, high strength, stiffness, and toughness, as well as moderately good malleability and ductility (Revie, 2011). Additionally, the metal's characteristics can be changed by mechanical or thermal processing. Contrarily, most of the bio metals have a built-in propensity to corrode and transform into more stable states, particularly in aqueous solutions with dissolved oxygen and ions, as is the case with physiological fluids. Metals with strong corrosion resistance are typically employed for numerous biomedical fields. High resistance to corrosion is a property of passive metals, which can react with their surroundings to generate a very durable and protective oxide coating that covers them from further corrosive action. The main categories of passive metals that are most frequently used in the biomedical field are titanium alloys, stainless steel, and cobalt-chromium-molybdenum alloys. Corrosion is the degradation of a material as a result of its environment's reaction with it. Chemical, electrochemical, physical, or a mixture of these reactions may result in the material degrading (Sin, 2015). In low and stable energy such as oxides, sulphides, silicates, etc., metals can be found in ores. The stable chemicals in the ore are broken down into a low stable metallic form during processing. Thermodynamics dictates that metals in a high-energy state are more likely to interact with nearby species and return to much more stable states. Biological fluids, which are aqueous fluids including various nutrients, electrolytes, organic entities, etc., are exposed to metals implanted into the body (Eliaz, 2019a). Electrochemical mechanisms dominate the corrosion of metallic biomaterials due to the watery nature of bodily fluids. The many species that are carried by biological environments can alter the ion mobility inside the fluid, which can alter how quickly metallic implants corrode. Additionally, even while human fluids typically have a pH of 7.4 since they are buffered solutions, their pH might alter due to illnesses or during surgery (Eliaz, 2019a), which will impact the corrosion of materials in contact. Different types of corrosion can occur when metals are exposed to corrosive conditions. The material's entire surface is equally affected by general or uniform corrosion. Pitting corrosion is a sort of localised corrosion that causes tiny cavities to grow on the metal's surface. Lower pH is caused by the oxidation reaction in the pit, and chloride ions move there to balance the charging of the metallic ions. This intensifies the corrosion locally and makes the environment more hostile, penetrating quickly. When different materials come into contact and are exposed to a conducting fluid, galvanic corrosion can occur. The far more active material tends to experience more corrosion due to its various potentials. When a metal implant surface is usually hidden from the environment, such as through small gaps, joints, or deep fissures, crevice corrosion a localised kind of corrosion occurs. Because of the difference in aeration with the bulk environment, the anodic processes preferentially

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