Chapter 7
A Review on Metallic Biomaterials Corrosion

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ABSTRACT

Metallic biomaterials are predominantly used in human medical devices compared to other material types. The corrosion resistance of implant materials significantly impacts their utility and longevity, serving as a crucial factor in determining biocompatibility. Except for biodegradable metals, the foundational principle for metallic biomaterials is that increased corrosion resistance correlates with enhanced biocompatibility. The human body presents a challenging environment that complicates corrosion control. This book chapter provides an in-depth examination of the body's environment and explores how the corrosion of various biomaterials can affect biocompatibility. It covers the dynamics of corrosion, including breakdown, passivity, and regeneration within the body. The book chapter also discusses the corrosion performance of commonly used metallic biomaterials such as cobalt-chromium alloys, stainless steels, gold, titanium and its alloys, dental amalgams,

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Nitinol, biodegradable metals, and metallic glasses.

1. INTRODUCTION

Decades after their initial adoption, metallic biomaterials remain a leading choice for surgical implants due to their enduring advantages. Metals have high strength and fracture resistance, especially with proper processing, making them dependable for long-term use in load-bearing applications like orthopedic and dental implants. Their favourable electrical conductivity also makes them suitable for nerve stimulation devices like pacemakers. Additionally, the ease of manufacturing using traditional methods (casting, forging, machining) and more recent advancements like additive manufacturing solidify the continued preference for metals in cardiovascular and dentistry beyond orthopedics surgery. Metal's promising properties, like electrical conductivity, formability, and fracture resistance, directly result from metals' unique interatomic bonding and atomic arrangements. Furthermore, due to their unique metallic bonding, metals can be incredibly ductile when processed correctly. This property arises because metallic bonds allow for the relatively easy movement of crystal imperfections called dislocations (both edge and screw dislocations) along specific crystal planes known as slip planes [Brettle, J. et al., 1974]. Dislocations are a type of linear defect that can exist within the crystalline structure of solids. This mobility of dislocations within the metallic lattice enables the large-scale rearrangement of atoms, allowing the metal to be deformed into new shapes without breaking apart. It's important to note that some properties, like elastic constants, depend solely on the type of interatomic bonds and atomic packing and are not influenced by the microstructure created through processing [Pilliar, R. M. et al., 2009]. To engineer successful implants, a deep understanding of material properties and manufacturing processes is paramount. Unlike many engineered structures where mechanical failure might be inconvenient, it's utterly unacceptable for surgical implants. Here, a broken component can translate to immense patient suffering, the need for risky revision surgery, and even death, as seen in heart valve component fractures (e.g., heart valve component fracture).

Weinstein et al. [A. Weinstein et al., 1973] examined cases of 133 explanted orthopedic implants and found that corrosion was almost all seen at the screw-plate interface and at interfaces in multi-component systems. [Hughes & Jordanet al., 1973] noted that 316 stainless steel was already known as being subject to crevice corrosion. [Colangelo & Greene, 1967] also found crevice corrosion to be the dominant mechanism, studying 155 components from 53 prostheses from patients (43 nos.). They found that 37% of components had corroded in 56% of patients. For the 30 single–component devices, corrosion was present in only 3 (10%), but for 23

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