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Review Article

To The Point Review of Implant Materials Corrosion

Qari T[1], Almadani A[2]* and Bukhary E[3]

[1]Resident Prosthodontics, King Fahad general Hospital, KSA

[2]Saudi resident, students in German board

[3]Dental intern, Al-Farabi Dental College, KSA

***Corresponding Author**: Qari T, Resident Prosthodontics, King Fahad general Hospital, KSA.

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Introduction

Increasing knowledge about interaction of dental materials with oral environment has resulted in a gradual development of high performance dental materials to meet the various requirements.

For selecting an alloy or material to be used for implant procedure, it is necessary to remember that this depends on a number of factors like corrosion behavior, mechanical properties, biocompatibility and cytotoxicity, the availability and cost, and the aesthetic measures need. The corrosion behavior is the most important property as it is responsible for the continuity of the mechanical properties beside the biocompatibility and cytotoxicity caused by the corrosion products.

Metal and alloys in the mouth are exposed constantly to changes in physical and chemical environment, which includes the rapidly fluctuating temperature and the widely changed pH from the components like saliva, salts, foods, liquids and drugs. So, corrosion of metals and alloys in the mouth is expected and does occur.

Many heavy metals like Nickel, Chromium and Brellium are classified as carcino-genic, hazardous, and priority toxic pollutants [1]. On the other view Anusavice (1996) said that adequate passivity film for alloys containing Chromium could be achieved if the alloy contains a minimum of 12% Cr [2]. The corrosion products of Copper-Aluminum alloy are easily removed by brushing [3,4]. It had had reported that the formation of oxide film on Titanium provides corrosion-resistance only under static conditions and not under loading conditions [5]. Corrosion-fatigue life for dry specimens of pure Ti and Ti-6Al-4V alloy have no significant difference compared to that stored in different environments, but it got significantly reduced when aqueous solutions were present, probably due to the production of corrosion pits caused by superficial reactions [6].

Corrosion

Why corrosion behavior is the most important factor for selecting any material to be implanted in oral cavity? It is the most important factor as corrosion behavior will lead to poor biocompatibility and may be the toxicity of the products liberated, and by time also it will affect the mechanical properties of the material; so it makes the material worst to be used for implantation purpose.

Corrosion is defined as the destruction or deterioration of a material because its reaction with the surrounding environment [7]. Furthermore, it is important to know that there are other factors rather than surrounding environment will affect the corrosion behavior of the alloys, as the purity of the materials and the casting and melting techniques used during fabrication [8].

Fontana [7] and Jones [9] have classified corrosion into eleven distinct forms as follows: Uniform corrosion, Galvanic corrosion, Crevice corrosion, Intergranular corrosion, Pitting corrosion, Dealloying corrosion, Erosion corrosion, Hydrogen damage corrosion, Stress corrosion, Corrosion fatigue, and Hydrogen-induced cracking corrosion. While Upadhyay [10] classified corrosion into eight forms as follows: Uniform or General corrosion, Galvanic or Two-Metal corrosion, Crevice corrosion, Pitting corrosion, Intergranular corrosion, Selective leaching corrosion, Erosion corrosion, and Stress corrosion. These forms will be mentioned in our review then we are going to mention briefly the most important form of corrosion from our opinion, which is Fretting corrosion.

Forms of Corrosion

Uniform or General Corrosion: This type of corrosion is defined as a chemical or electrochemical reaction which uniformly proceeds over large area or the entire exposed surface of the material [10].

Galvanic or Two-Metal Corrosion: This type of corrosion occurs due to galvanic coupling of dissimilar metal involved. It could cause galvanic current which have harmful effect on surrounding soft tissues [10].

Crevice Corrosion: This type of corrosion is unavoidable due to the shape of implant or plate which forms crevices at its contact with the bone. These crevices cause regions of stagnant solutions which attack the material. The local flux of ions are drastically enhanced at the crevice sites and tissue impregnation follows [10].

Pitting Corrosion: This is a form of extremely localized attack at the localized breakdown sites of the protecting passive layer resulting in holes on the surface [10].

Intergranular Corrosion: This type of corrosion occurs due to the in homogeneity and technological errors which lead to more reactive nature of grain boundaries, so the intergranular corrosion occurs adjacent to grain boundaries with relatively little corrosion of grains. This tendency was attributed to the precipitation of chromium carbide at the grain boundaries at elevated temperature [10].

Selective Leaching Corrosion: This is the removal of one element from a solid alloy by corrosion process, and it is not that important in dentistry [10].

Erosion Corrosion: This is the acceleration or the increase in rate of deterioration of a material due to the relative movement between the material surface and the corrosive fluid.

It includes cavitations' damage which is not important in dentistry, and also Fretting Corrosion (the most important form), which is described as the corrosion occurring at contact areas between materials under load subjected to vibration and slip, as during insertion of an implant, there is some degree of abrasion occurred between fixing screw and implant material or between tools used and the implant. Also, functional loading is an another source of abrasion [10].

Abrasion is the mechanical component of the fretting corrosion which disrupts the protective surface film and removes metal particles, so stimulates the chemical activities at the surface leading to oxidation or active corrosion or repassivation as a result of the electrochemical aspect of the process [11].

Stress Corrosion Cracking: It refers to cracking caused by the simultaneous presence of tensile stress (as during teeth movements for mastication) and a specific corrosion medium [10].

Fretting Corrosion

This is a form from Erosion Corrosion and considered as the most important form of corrosion for implantology.

Fretting corrosion is a degradation process resulting from the combined action of small movements between contacting parts and the corrosivity of the environment [12]. This will lead to tissues inflammation caused by degradation of metallic materials used in prosthetic implants which can lead to failure of orthopedic surgical operations [13].

The nature of the passive film and the electrochemical conditions play a relevant role in fretting corrosion [12]. Indeed, fretting corrosion results in metal degradation due to simultaneous action of mechanical wear and of (electro)chemical oxidation in a complex way depending on each other [12,13].

Materials for Implant

The discovery of relatively inert metallic and alloy biomaterials has led to their use in the field of biomedical applications specially in dentistry.

They are being increasingly used due to physical-chemical properties and compatibility with biological surroundings.

Pure Ti or Ti alloys e.g. Ti-6Al-4V, and to a lesser extent Zr, are the metals that are most often used in direct contact with human tissues. These metallic biomaterials are highly reactive and when exposed to fluid media or air, quickly develop a layer of TiO_2 or ZrO_2. This layer of dioxide forms a boundary at the interface between the biological medium and the metal structure. It produces passivation of metal, determining the degree of biocompatibility and the biological response of the implant [14-17].

No metal or alloy is entirely inert in Vivo, so corrosion is one of the possible causes of implant failure after initial success, that is why management and control of corrosion is a crucial problem from biological, metallurgical and economic standpoints.

Titanium and its alloys have been use as dental materials specially for implants for long time, because they are covered with passive film (surface oxide) consisting of low-crystallite, thin, or amorphous structures, these films are correlated to corrosion resistance. However, researchers found that there are problems with these films such as corrosion and fracture of implants; which caused either by the presence of fluoride in tooth paste, mouth-rinses, and the prophylactic agents used as prevention of dental caries, or by the presence of peroxides in denture base cleaning agents [18-27].

It was found that corrosion resistance depends on fluoride concentration, pH, and amount of dissolved oxygen in media [25,27-32].

A little platinum or palladium added to titanium alloys, good corrosion resistance was obtained in a fluoride-containing solution, and this was caused by anodic polarization of titanium due to surface enrichment of palladium or platinum [28].

Experimental alloy Ti-20 mass %Cr was reported to have the least tarnish among several Ti alloys examined by immersion in an acidic saline solution containing fluoride or hydrogen peroxide [33,34]. However, Ti-Cr 20% has similar corrosion resistance of Ti in a saline solution, it has higher corrosion resistance in a saline solution containing fluoride up to +0.7V and this was attributed to the formation of a Cr-rich oxide film [35].

In 2009, different Cr concentrations in Ti-Cr alloys were examined in terms of corrosion resistance in fluoride-containing saline solution, and surface texture. They found that, the amount of Cr oxide in the oxide films, which improves the corrosion resistance, was correlated with the amount of Cr content in the alloy. Ti-20%Cr alloy was the best for all experimental study, and they found that the increase in Cr oxide would decrease the potential for contact between Ti oxide and fluoride solution [36].

Conclusion

After many years' researchers improves that Ti and its alloys in market are not the best as implant material and this is the reason for implant failure. New Ti alloys come to the field and improve better results specially in corrosion resistance, but more investigations are need.

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