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Influence of C-glucose on Corrosion Resistance of Orthodontic Wires in Presence of Artificial Saliva

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ABSTRACT

In the oral environment, orthodontic appliances are exposed to potentially damaging physical and chemical agents which may cause metallic corrosion. The study reveals that there is a strong dependence of the corrosion resistance of different alloy on the concentration of C-glucose in the electrolyte medium. The corrosion behavior of experimental 22 carat gold alloy, stainless steel 316L alloy has been carried under Artificial Saliva (AS) condition in presence of C-glucose. Corrosion resistance and ability to form protective oxide scales are evaluated and compared by polarization study. The SS316L orthodontic alloy so better corrosion resistance in all experimental condition than other alloys. This agrees with the results obtained potentiodynamic polarization curves.

Keywords: Corrosion of metals, Artificial Saliva (AS), 22 Carat gold, SS316L, C-glucose

INTRODUTION

Biomedical materials play a vital role in manufacturing of Prosthetic devices in modern world. Prosthetic devices are artificial replacements which are used in biological system [1]. These devices are generally made up of polymeric, metallic and ceramic material. The important requirement for any material to place in human body is biocompatible and not to cause any adverse reaction in the body. Corrosion resistance is an important property for dental materials. Oral environment is one of the factors responsible for the formation of corrosion products. The mouth is moist and continually subjected to fluctuations in temperature. Foods and drinks cause transitory, but important and wide, variations in the chemistry of the environment. The most important fluid in the oral environment is represented as natural saliva. It is obvious about tests involving dental material should be done in that media [2,3]. However, the unstable nature of natural saliva makes it inadequate for standardized *in vitro* studies and artificial saliva is frequently used. The artificial saliva generally used in corrosion studies of dental alloys.

In dentistry metallic materials there are implants in reconstructive of oral surgery to replace a single teeth or an array of teeth or in the fabrication of dental prostheses such as metal plates for complete and partial dentures, crowns and bridges, essentially in patients requiring hypoallergenic materials [4]. Corrosion of metallic implants will play vital importance because it can be adversely affect the biocompatibility and mechanical integrity of implants. Many metals and alloys have been used in dentistry field that alloy has been considered the problem for long durability of implants into the human bodies verse and release of metal ions will cause adverse physiological effects, toxicity on exposure to air to form an oxide layer spontaneously on the surface of biomedical alloys [5,6]. The corrosion resistance of these alloys is owed to the presence of this thin passive oxide film on its surface. The physico-chemical properties of the passive film control the corrosion behavior of materials and the interaction with tissues, surrounding of the body [7-10]. Over the past two decades, with the accelerated development of tissue engineering, the demand for a variety of synthetic and natural biomaterials has been dramatically increased. Biomaterial sales have already exceeded $240 million per year and due to the rapid development of biomaterials. The market will increase their product for tissue engineering and artificial organ materials. Specifically cost related point of view an organ replacement accounts for 8% of global healthcare. Such demands require unique, better performing biomaterials for regenerative medicine. For example, it is necessary to develop better material for mechanical properties and biocompatibility. Conventional biomaterials (or those materials with constituent dimensions greater than 1 μm) have not satisfactorily met clinical demands. Hence Researchers, clinicians and other investigators are seeking for better novel materials to serve for the next generation of tissue engineering and artificial organ materials.

MATERIALS AND METHODS

Artificial saliva

The intention of being as close as possible to clinical conditions, artificial saliva was chosen as the electrolyte, Open to the atmosphere at 37°C. The test solution used was the artificial saliva from Fusayama and Meyer B. Its Composition is shown in Table 1. The test solution had to be used shortly after preparation because of urea's instability.

Table 1: Composition of artificial saliva [11-13]

Composition	Quantity gL^{-1}
KCl	0.4
NaCl	0.4
$CaCl_2.2H_2O$	0.906
$NaH_2PO_4.2H_2O$	0.69
$Na_2S.9H_2O$	0.005
Urea	1

Orthodontic wires

The two types of orthodontic wires such as 22 carat gold alloy, 316 L stainless steel were chosen for the present study. Compositions of wires are given in Tables 2 and 3.

Table 2: Composition of 22 carat gold alloy [14]

Composition	Percentage [%]
Gold	91.67
Silver	5
Copper	2
Zinc	1.33

Table 3: Composition of SS316L [15,16]

Composition	Percentage [%]
Chromium	18
Nickel	12
Molybdenum	2.5
Carbon	<0.03
Iron	Balance

Oral fluid

Glucose is the human body's key source of energy. It supplies almost all the energy for the brain. So its availability influences psychological process when glucose is low, psychological process requiring mental effort. C-glucose was taken as oral fluids for this study (Table 4).

Table 4: Composition of the C-glucose

	Composition
C-glucose	Dextrose monohydrate
	Sucrose
	Citric acid
	Calcium phosphate
	Sodium chloride
	Vitamin-C

MATERIALS AND METHODS

Polarization study

Polarization methods are often used for laboratory corrosion testing. These techniques can provide useful information regarding the corrosion mechanisms and susceptibility of specific materials. Polarization studies were investigated in a CHI Electrochemical workstation/analyzer, model 660A. It was provided with automatic IR compensation facility. The three electrode cell was consisting of metal specimen's 22 ct gold, SS316L alloy as working electrodes. The other two electrodes were Saturated Calomel Electrode (SCE) as reference electrode and platinum foil as counter electrode. A time interval of 5-10 min was given for the system to attain a steady state of open circuit potential. The working electrode and platinum electrode were immersed in artificial saliva in the absence and presence of C-glucose. From the polarization study corrosion parameters such as Corrosion potential (E_{corr}), Corrosion current (I_{corr}), Tafel slopes (b_a and b_c) and Linear Polarization Resistance (LPR) were calculated. During the polarization study, the scan rate (V/s) was 0.01 Hold time at E_f (s) was zero and quiet time (S) was two (Figure 1).

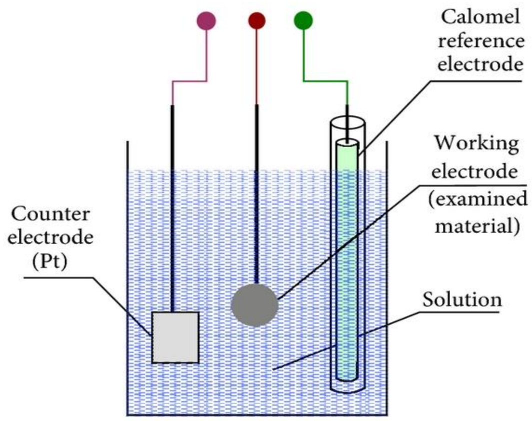

Figure 1: Schematic diagram of three-electrode cell assembly

RESULT AND DISCUSSION

Polarization study has been used to investigate the formation of protective film which formed on the metal surface during corrosion process. If corrosion resistance increases, the LPR value increases and corrosion current decreases [17-25]. The present experiment has proved that while increases the LPR value the lower corrosion current. From the tables there is also electrochemical parameters, mentioned for the three metals dissolution in artificial saliva. These parameters are such as Corrosion potential (E_{corr}), Corrosion current (I_{corr}), Tafel slopes (b_a and b_c) and LPR.

Corrosion behavior of metals in AS containing C-glucose

22 ct gold

When 22 ct gold is immersed in AS containing C-glucose the corrosion potential is 249 mV vs. SCE. The addition of 150 ppm C-glucose the corrosion potential is shifted from 249-236 mV vs. SCE. This reveals that anodic reaction is predominant. When 300 ppm of C-glucose is added, the corrosion potential is shifted from 236-251 mV vs. SCE. In the blank system the LPR value is 108750 ohm.cm^2, the corrosion current is1.765 × 10^{-7} A/cm^2. The addition of 150 ppm of C-glucose increases the LPR value increases from 108750-157268 ohm.cm^2 and the corrosion current is spontaneously decreased from 1.765 × 10^{-7}-1.172 × 10^{-7} A/cm^2. Obviously at 300 ppm of C-glucose LPR value increases from 157268-168278, the corrosion current decreases from 1.172 × 10^{-7}-1.045 × 10^{-7} (Figures 2 and 3; Table 5).

Table 5: Corrosion parameters of metals immersed in AS in the presence of C-glucose

Metal	System	E_{corr} (mV vs. SCE)	I_{corr} (A cm^{-2})	b_a (mVdecade^{-1})	b_c (mVdecade^{-1})	LPR (Ohm.cm^2)
22 ct gold	AS	249	1.765 × 10^{-7}	341	436	108750
	AS+150C-Glucose	236	1.172 × 10^{-7}	280	427	157268
	AS+300C-Glucose	251	1.045 × 10^{-7}	235	403	168278
SS316L	AS	272	8.994 × 10^{-7}	308	270	301102
	AS+150C-Glucose	263	3.118 × 10^{-7}	190	200	614565
	AS+300C-Glucose	246	2.952 × 10^{-7}	247	160	694132

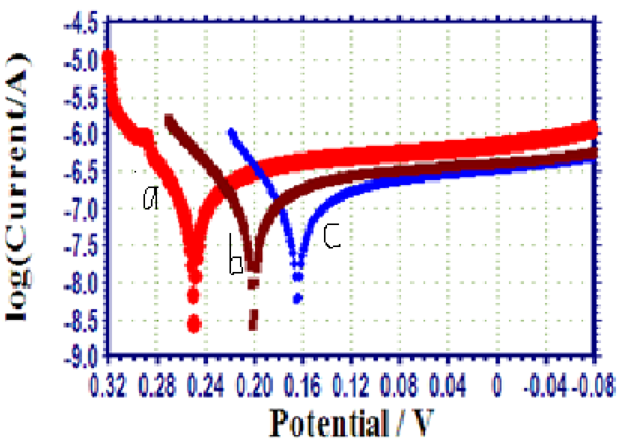

Figure 2: Polarization curves of 22 ct gold alloy immersed in artificial saliva in the absence and presence of C-glucose: (a) Artificial saliva; (b) As+150 ppm C-glucose; (c) As+300 ppm C-glucose

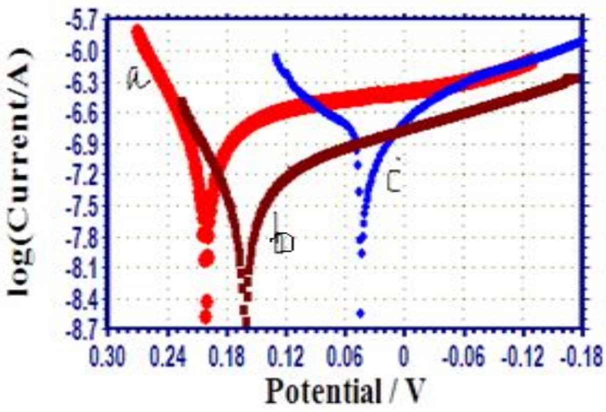

Figure 3: Polarization curves of SS316L alloy immersed in artificial saliva in the absence and presence of C-glucose: (a) Artificial saliva; (b) As+150 ppm C-glucose; (c) As+300 ppm C-glucose

SS316L

When SS316L is immersed in AS containing C-glucose the corrosion potential is 272 mV vs. SCE. The increasing concentration (150 ppm) the potential is shifted to anodic side (272-263 mV vs. SCE). The LPR value increases from 301102-614565 ohm.cm^2, corrosion current decreases from 8.994 × 10^{-8}-3.118 × 10^{-8} A/cm^2. The addition of 300 ppm of C-glucose LPR value is increases from 614565-694132 ohm.cm^2 and corrosion current is decreases from 3.118 × 10^{-8}-2.952 × 10^{-8} A/cm^2. It is well known that LPR value is better increase due to the formation of protective film on the metal surface. From the results in the experiment performed on the various orthodontic alloys, it appears clear that the differences of compositions create difference in electrochemical behavior. This was shown by in the polarization curves.

The difference in corrosion behavior of metals and alloys is due to the spontaneous formation of a thin, compact layer of oxides called the passive layer. The corrosion resistance and stability of their passive oxide films are quite different. Corrosion of dental alloy is complex process dependent not only on alloy’s composition and structure, but also on many other factors as, among others, surface conditions and treatment and certain environmental conditions around the alloy example acidity and composition of the surrounding electrolyte. Results from potentiodynamic tests revealed that stainless steel had the best resistance to corrosion.

CONCLUSION

Corrosion resistance of fixed orthodontic wires made up of 22 carat gold and SS316L immersed in artificial saliva was evaluated with the help of polarization study. The influence of various concentrations of C-glucose on corrosion resistance of the above orthodontic wires has been investigated. It is observed that for 22 carat gold, SS316L system, the corrosion resistance increases with increase of C-glucose concentration. The orthodontic wire immersed in artificial saliva C-glucose (150, 300 ppm), the shifts depends on the concentration C-glucose in the medium. The presence of citrate and phosphate ions in C-glucose forms as citrate complex and phosphate complex on the metal surface. The corrosion resistance of SS316L is better than 22 Carat gold. The present study concludes that the people having implanted with orthodontic wires made of SS316L need not bother about corrosion and hesitate to take C-glucose orally.

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