CORROSION RESISTANCE OF SS 316L ALLOY IN ARTIFICIAL SALIVA IN PRESENCE OF ALMOX 250 DT TABLET


Keywords: corrosion resistance of metals, SS 316L alloy, synthetic saliva, orthodontic wires.

Corrosion resistance of SS316L alloy in artificial saliva, in the absence and presence of a disinfectant tablet, namely, Almox 250 DT has been evaluated by AC Impedance Spectra. It is observed that when 50 ppm of Almox is added to artificial saliva, charge transfer resistance of SS 316 L increases. Similar observation is made in presence of 200 ppm of Almox also. Hence it is concluded that people having orthodontic wires made of SS 316L, can take the Tablet Almox 250 DT without any hesitation, because in its presence corrosion resistance of SS 316L increases.

Introduction

Over the past two decades, with the accelerated development of tissue engineering, the demand for a variety of synthetic and natural biomaterials has dramatically increased. Biomaterial sales have already exceeded $240 million per year and due to the rapid development of biomaterials, the market will only increase in the years ahead for tissue engineering and artificial organ materials. Specifically, costs related to organ replacement account for 8% of all global healthcare spending and by 2040 as much as 25% of the US gross domestic product (GDP) is expected to be related to healthcare. Such demands require unique, better performing biomaterials for regenerative medicine.

Corrosion resistance of metals and alloys in various body fluids has attracted the attention of many researchers. Corrosion resistance of biomaterials in synthetic body fluids such as blood plasma, urine, Hank solution, Ringer solution and artificial saliva has extensively been studied. The corrosion resistance of metals and alloys in artificial saliva has been reviewed recently. Corrosion resistance of various metals have been investigated in various synthetic (simulated) body fluids such as Ringer’s solution, simulated body fluids,5-6,7,8,9-11 urine,12-14 bovine serum,15 and artificial saliva.16-20

Various metals and alloys have been used as biomaterials whose corrosion resistance has been investigated in artificial body fluids; various metals and alloys such as Ni-Al-Fe intermetallic alloys,21 titanium alloy,22 NiTi alloy,23 CoCrMo alloys,24-25 magnesium alloy,26,27 Cr-Ni stainless steel, Cr-Ni-Mo stainless steel,28 316L stainless steel,29,30 Five non-precious Ni-Co based alloys have been analyzed with respect to their corrosion behavior in artificial saliva.31 The effect of different concentrations of eugenol in artificial saliva on titanium corrosion has been investigated by Kinani and Chtaini.32 The corrosion resistance of the commercial metallic orthodontic wires in a simulated intra-oral environment has been evaluated by Ziebowicz et al.33 The results of corrosion resistance tests of the CrNi, TiNi, and CuNiTi wires showed comparable data of parameters obtained in artificial saliva. The effects of multilayered Ti/TiN or single-layered TiN films deposited by pulse-biased arc ion plating (PBAIP) on the corrosion behavior of NiTi orthodontic brackets in artificial saliva have been investigated by Liu et al.34 The corrosion behavior of various metals and alloys in artificial saliva has been investigated. Rajendran et al., have studied the corrosion resistance of artificial saliva in presence spirulina powder.35 Corrosion behavior of metals in artificial saliva in presence of D-glucose has been investigated.36

Liu,et al have investigated corrosion behavior of nickel-titanium orthodontic wires in presence of Artificial saliva using the methods of continue bending stress thought the 14 days experimental process, they have been findings that bending stress, loading condition with respect to corrosion behavior.37 Koike, et al studied corrosion resistance of Titanium alloy in presence of Artificial Saliva at 37°C using the method of potentiostatic polarization. They have found that all the mechanical properties and corrosion characters were tested.38 Anwar et al investigated corrosion behavior of Ti and Ti 6Al4V in presence of artificial saliva using electrochemical methods. They found that as fluoride concentration increases, corrosion resistance is decreased.39 Rajendran et al have studied the corrosion resistance of SS 316 L in Artificial Saliva in presence of electroal.40

Ni-Ti alloys have been used by Rondelli and Vincentini41 and Bahije et al42. Krishnaveni et al43 have investigated the corrosion resistance of 18 carat gold in synthetic saliva in presence of Almox 250 DT Tablet.
Dentists recommend the use of orthodontic wires to regulate the arrangement of teeth. After the regulation, people having these orthodontic wires, regulating the arrangement of teeth, have to take orally many tablets. These tablets may corrode the wires in the oral environment, especially saliva. Hence there is a need to investigate the influence of various tablets on the corrosion resistance of orthodontic wires made of many metals and alloys. Can people implanted with orthodontic wires made of SS316L Almox 250 DT Tablets orally? To give an answer this question, the following investigation was undertaken. Corrosion resistance of SS 316L gold in artificial saliva (AS) in the absence and presence of Almox 250 DT has been investigated by AC Impedance Spectra.

### Experimental

**SS 316L**: The composition of SS 316L (in wt. %) is the following: Cr-18 %; Ni 12 %, Mo -2.5 %, C-0.03 %, balance – iron. Wire of 1 mm diameter was used in the present study.

**Artificial Saliva**: The composition of artificial saliva is given as: KCl – 0.4 g L⁻¹, NaCl – 0.4 g L⁻¹, CaCl₂.2H₂O - 0.906 g L⁻¹, NaH₂PO₄.2H₂O 0.690 g L⁻¹, Na₂S.9H₂O – 0.005 g L⁻¹, urea – 1 g L⁻¹.

**Almox 250DT**: The Almox 250DT contains 250 mg of Amoxicillin Tri hydrate.

**AC impedance spectra**: AC impedance spectral studies were carried out in a CHI 660A. A three-electrode cell assembly was used. The working electrode was SS316L. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode. The real part (Z') and imaginary part (Z") of the cell impedance were measured in ohms at various frequencies. Values of the charge transfer resistance (Rᵦ) and the double layer capacitance (Cₜ) were calculated.

### Results and Discussion

**Analysis of AC impedance spectra**

AC impedance spectra have been used to detect the formation of film on the metal surface. If a protective film is formed, the Charge transfer resistance (Rᵦ) increases and double layer capacitance (Cₜ) value decreases. The impedance value increases.

The AC impedance spectra of SS 316L immersed in various test solutions are shown in (Figs. 1 to 9). The Nyquist plots are given in Figures 1 to 6. The Bode plots shown in [Figs. 7 to 9]. The Corrosion parameters derived from AC impedance spectra are given in Table 4. The charge transfer resistance and double layer capacitance are derived from Nyquist plot. The impedance value and phase angle value are derived from Bode plots.

### Table 1. Impedance parameters of SS 316L in artificial saliva in presence of Almox (250DT) obtained by AC impedance spectra.

<table>
<thead>
<tr>
<th>System</th>
<th>Rᵦ ohm cm⁻²</th>
<th>Cₜ F cm⁻²</th>
<th>Impedance logZ/ohm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Saliva</td>
<td>5.7458x10⁴</td>
<td>8.876048x10⁻⁷</td>
<td>5.260</td>
</tr>
<tr>
<td>Saliva</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS + Almox (250DT)</td>
<td>7.0198x10⁴</td>
<td>7.265164x10⁻⁷</td>
<td>5.265</td>
</tr>
<tr>
<td>50 ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS + Almox (250DT)</td>
<td>1.59680x10⁵</td>
<td>3.19388x10⁻⁷</td>
<td>5.603</td>
</tr>
<tr>
<td>200 ppm</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**SS 316L immersed in Artificial Saliva only**

When SS 316L is immersed in artificial saliva the Rᵦ value is 5.7458x10⁴ ohm cm⁻² and Cₜ value is 8.876048x10⁻⁷ F/cm². (Figs. 1 and 2).

**Figure 1. AC impedance spectrum of SS 316L immersed in Artificial Saliva solution (Nyquist Plot)**

**Figure 2. AC impedance spectrum of SS 316L immersed in Artificial Saliva solution (Nyquist Plot Zoomed)**

**Corrosion behavior of SS 316L in Artificial Saliva in the presence of 50ppm Almox 250DT**

When 50 ppm Almox 250DT is added Rᵦ value increases from 5.7458x10⁴ to 7.0198x10⁴ ohm cm⁻² Cₜ value decreases from 8.876048x10⁻⁷ to 7.265164x10⁻⁷ F/cm². This indicates that the corrosion resistance of SS 316L increases in presence of 50 ppm Almox (250DT) (Figs. 3 and 4).
Corrosion resistance of SS316L alloy in artificial saliva in the presence of ALMOX 250 DT

Figure 3. AC impedance spectrum of SS 316L immersed in Artificial Saliva +50 ppm Almox 250DT (Nyquist Plot)

Figure 4. AC impedance spectrum of SS 316L immersed in artificial saliva + 50ppm Almox 250DT (Nyquist Plot Zoomed).

Corrosion behavior of SS 316L in Artificial Saliva in the presence of 200ppm Almox 250DT

When 200 ppm Almox 250DT is added $R_t$ value increases from $70198 \times 10^4$ to $159680 \times 10^5$ ohm cm$^2$ $C_{dl}$ value decreases from $7.265164 \times 10^{-7}$ to $3.19388 \times 10^{-7}$ Fcm$^{-2}$. This is also supported by the increase in impedance value. (Figs 5 and 6).

Figure 5. AC impedance spectrum of SS 316L immersed in Artificial Saliva + 200ppm Almox 250DT (Nyquist Plot)

Figure 6. AC impedance spectrum of SS 316L immersed in Artificial Saliva +200 ppm Almox 250DT (Nyquist Plot Zoomed)

When 50 ppm of Almox 250DT is added the log (Freq/Hz) vs impedance plot [Figure7,8,9] reveals that the impedance value sharply decreases as frequency increases. The slope of the straight line in the low frequency region is nearly 0.5. This is characteristic of a system having very high protective efficiency.

Similar observation is made in presence of 200 ppm of Almox 250DT also. There is also increase in the phase angle values ($65^\circ$ and $67^\circ$) respectively. [Figs.7, 8 and 9]. Thus AC impedance spectra reveal that in presence of Almox 250DT the corrosion resistance of SS 316L increases.

Figure 7. AC impedance spectrum of SS 316L immersed in Artificial Saliva solution. (Bode Plot)

Figure 8. AC impedance spectrum of SS 316L immersed in Artificial Saliva + 50 ppm Almox 250DT. (Bode Plot)
It is concluded that people having orthodontic wires made of SS316L can take orally Almox 250DT without any hesitation.

**Conclusion**

Corrosion Resistance of SS316L in artificial saliva, in the absence and presence of a Tablet, namely, Almox 250 DT has been evaluated by AC Impedance Spectra. It is observed that when 50 ppm of Almox is added to artificial saliva, Charge transfer resistance of SS 316 L increases, in presence of 50 ppm Almox 250 DT. Similar observation is made in presence of 200 ppm of Almox also. Hence it is concluded that people having orthodontic wires made of SS 316L can take the Tablet Almox 250 DT without any hesitation, because in its presence corrosion resistance of SS 316L increases.

**References**

41. Rondelli, G.; Vicentini, B.; *Biomater. 1999,* 20, 785.
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Section B-Research Paper


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