Corrosion Resistance of SS316L in Synthetic Saliva in Presence of D-Glucose

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Abstract
One of the primary requisites of any metal (or) alloy that is to be used in the mouth is that it must not produce corrosion products that could be harmful to the body. Some metallic elements that are completely safe in the elemental state can form hazardous or even toxic ions (or) compounds. Besides, the degradation of the Alloy should be limited in order to guarantee its service life. Several metals and alloys have been in dentistry as bracket, band, orthodontic wires it is essential to know the corrosion resistance of this materials in the presence of saliva. corrosion resistance of three metallic materials, namely 18ct gold, 22ct gold, SS316L has been evaluated in artificial saliva in the presence of (100)ppm D-glucose. AC impedance spectra have been used to investigate the corrosion behavior of these metals.

Keywords: Corrosion resistance of metals, artificial saliva (AS), D-glucose, dentistry, oral hygiene.

The corrosion resistance these materials in artificial saliva in presence of D-glucose, decreased in the following order SS316L>22ctgold>18ctgold.

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Introduction
Corrosion resistance of metals and alloys in various body fluids has attracted the attention of many researchers. Corrosion resistance of various metals have been investigated in various body fluids such as bloodplasma[1,2];urine[3,4];Hanksolution[5,6];Ringersolution[7,8];bovineserum[9];artificialsweat[10,11] And artificial saliva[12,14].

In the oral environment, orthodontic appliances are exposed to potentially damaging physical and chemical agents which may cause metallic corrosion [15]. Factors such as quantity and quality of saliva, salivary pH, the amount of protein in the saliva, physical and chemical properties of foods and liquids general and oral health conditions may influence corrosion in the oral cavity. corrosion will occur continuously in the mouth due to the release of ions with abrasion by foods and liquids. salivary fluid is an exocrine secret in consisting of approximately 99% of water, containing a variety of electrolytes(sodium,potassium,calcium,chloride,magnesium,bicarbonate,phosphate) and proteins represented by enzymes, immunoglobulin and other antimicrobial factors, mucosal glycoproteins, traces of albumin and some polypeptides and oligopeptides of importance to oral health[16].

Generally oral environment, dental implants are exposed to several adverse factors such as change of temperature and oxygen level (due to the food and changes in the saliva), masticatory force and chemical components which contribute to the degradation process of implants (Nakagawa et al.2002). In addition, the electrolytes from saliva can induce crevice corrosion in the peri-prosthetic space of the implant(Nikolopoulou 2006). The P⁰ of saliva varies in
area around dental implants. Food such as milk, calcium-fortified foods and nuts can alkalify the oral pH (Murell et al. 2010). Several situations can acidify the pH of saliva such as infections, certain foods (sugary food, pickled food, sour candies, fruits, soft drinks and juices-PH around 2.5-3.5), mouthwash products (Dong et al. 1999; Gregory-Head et al. 2000; Murrell et al. 2010), smoking chronic, systemic diseases, and medication, which may also contribute to the corrosion of dental implants also contribute to the corrosion of dental implants (Nikolopoulou 2006; Vieria et al. 2006; Correa et al. 2009). As a consequence of those corrosion products, inflammatory mediators produced by macrophages are released, contributing to bone loss (Nikolopoulou 2006; Denaro et al. 2008). This issue has been investigated in depth in orthopedics. In density, literature that describes the clinical implications of the corrosive nature of dental implants is limited [17].

The present work was undertaken to study the corrosion behavior of 18ct gold, 22ct gold, and SS316L in the artificial saliva in the presence of 100 ppm D-glucose has been evaluated by AC impedance spectra. An aqueous solution of D-glucose is orally administered to get energy at once. It will be interesting to investigate if this glucose will corrode the orthodontic wires metal plates used for complete and dentures, crowns and bridges. Corrosion behavior metals and alloys have been studied in artificial saliva in many researchers the composition is given table-1

Table 1 Composition of artificial saliva[12-14]

<table>
<thead>
<tr>
<th>Content</th>
<th>Quantity gL⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>0.4</td>
</tr>
<tr>
<td>NaCl</td>
<td>0.4</td>
</tr>
<tr>
<td>CaCl₂.2H₂O</td>
<td>0.906</td>
</tr>
<tr>
<td>NaH₂PO₄.2H₂O</td>
<td>0.690</td>
</tr>
<tr>
<td>Na₂S.9H₂O</td>
<td>0.005</td>
</tr>
<tr>
<td>Urea</td>
<td>1</td>
</tr>
</tbody>
</table>

In electrochemical studies, the metal specimens were used as working electrodes. Artificial saliva was used as the electrolyte. The temperature was maintained at 37±1°C Commercially available D-glucose [Indian pharmacopeias grade] was used in this study. 100 ppm of D-glucose was used in AS.

Experimental:
Materials and Methods:

Table 2 Composition of 18 ct gold [18, 19]

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>75%</td>
</tr>
<tr>
<td>Copper</td>
<td>5-15%</td>
</tr>
<tr>
<td>Silver</td>
<td>10-20%</td>
</tr>
</tbody>
</table>

Table 3 Composition of 22ct gold [20]

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>91.67%</td>
</tr>
<tr>
<td>Silver</td>
<td>5%</td>
</tr>
<tr>
<td>Copper</td>
<td>2%</td>
</tr>
<tr>
<td>Zinc</td>
<td>1.33%</td>
</tr>
</tbody>
</table>
The 18ct gold, 22ct gold and SS316L where used in the present study. Their composition is given in table 2, 3 and 4.

### AC impedance spectra:

AC impedance spectra were recorded on the same instrument used for polarization study using the same type of three electrode cell assembly. The real part and the imaginary part of the cell impedance were measured in ohms for various frequencies. The charge transfer resistance \((R_t)\) and double layer capacitance values are derived from Nyquist plots. Impedance values, \(\log(Z/\text{ohm})\) are derived from Bode plot. The result are summarized in table-5.

\[
R_t = (R_s + R_t) - R_s
\]

Where,
\(R_s\) = solution resistance
\(R_t\) = charge transfer resistance
\(C = \text{Double layer capacitance}\)
\(C = \frac{1}{2\pi R_t f_{\text{max}}}\)

Where, \(f_{\text{max}}\) = frequency at maximum imaginary impedance

### Table 4 Composition of SS316L [21, 22]

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr</td>
<td>18</td>
</tr>
<tr>
<td>Ni</td>
<td>12</td>
</tr>
<tr>
<td>Mo</td>
<td>2.5</td>
</tr>
<tr>
<td>C</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Iron</td>
<td>Balance</td>
</tr>
</tbody>
</table>

### Table 5 Corrosion parameters of metals immersed in Artificial saliva (AS) in the presence of D-Glucose obtained from AC impedance spectra

<table>
<thead>
<tr>
<th>METAL</th>
<th>SYSTEM</th>
<th>(R_t) ohm cm(^2)</th>
<th>(C_{dl}) (\mu)F/0.00785cm(^2)</th>
<th>IMPEDANCE log(Z/ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 ctgold</td>
<td>AS+100ppmD-glucose</td>
<td>235928</td>
<td>3.38164\times10^{-11}</td>
<td>5.6</td>
</tr>
<tr>
<td>22 ctgold</td>
<td>AS+100ppmD-glucose</td>
<td>471540</td>
<td>4.06809\times10^{-11}</td>
<td>5.79</td>
</tr>
<tr>
<td>SS316L</td>
<td>AS+100ppmD-glucose</td>
<td>510413</td>
<td>3.75827\times10^{-11}</td>
<td>5.88</td>
</tr>
</tbody>
</table>
Figure 2 AC impedance spectra (Nyquist plots) of 18ct gold immersed in AS

Figure 2a AC impedance spectra (Nyquist plots) of 22ct gold immersed in AS+100ppmD-glucose

Figure 2b AC impedance spectra (Nyquist plots) of SS316L immersed in AS+100ppmD-glucose
Result and Discussion

Corrosion resistance of three metals namely 18ct gold, 22ct gold, SS316L in AS in the presence of D-glucose has been investigated by AC impedance spectra. When corrosion rate decreases due to formation of protective film, the charge transfer resistance (R_t) value increases and double layer capacitance (C_{dl}) value decreases, the impedance log (Z/ohm) value increases [23-39].

**Corrosion behavior of metals in AS containing D-glucose**

**18ct gold**
When 18ct gold was immersed in AS containing D-glucose (100ppm) the charge transfer resistance was 235928 ohm cm^2. The double layer capacitance was 3.38164 x 10^{-11} F/0.00785 cm^2. The impedance value log(Z/ohm) was 5.6. It is observed that the charge transfer resistance value increased, double layer capacitance decreased. There was an increase in the value of impedance log (Z/ohm). These observations indicated AS containing D-glucose, the corrosion rate of 18 ct gold was reduced, due to the formation of a protective film formed on the metal surface.

**22ct gold**
When 22 ct gold was immersed in AS containing D-glucose (100ppm) the charge transfer resistance was 471540 ohm cm^2. The double layer capacitance was 4.06809 x 10^{-11} F/0.00785 cm^2. The impedance value log(Z/ohm) was 5.79 compared with 18ct gold the R_t value increased and C_{dl} value is decreased. There was an increase in the value of impedance log (Z/ohm). It is inferred that a protective film is formed on the metal surface in the presence of D-glucose. It prevents the corrosion of metal in AS.

**SS316L**
When SS316L immersed in AS containing D-glucose (100ppm) the charge transfer resistance was very high 510413 ohm cm^2; the C_{dl} value was very low 3.75827 x 10^{-11} F/0.00785 cm^2; The impedance value was high 5.88. These observations indicate that the corrosion resistance of SS316L in AS increased in the presence of D-glucose. The film formed on the metal surface suggests SS316L was more stable and also prevented the loss of electron from the metal. Because of the presence of the film, the charge transfer resistance increased and the double layer capacitance value decreased because they are inversely related to each other. SS316L was able to withstand the attack of aggressive ions present in AS. So SS316L was more corrosion resistant, when compared with 18ct gold and 22ct gold. Thus AC impedance spectra study leads to the conclusions that in the presence of D-glucose, the corrosion resistance of all three metals in AS increased.

![Figure 3 AC impedance spectra (Bode plots) of 18 ct gold immersed in AS](image-url)
Conclusion

In the presence of D-glucose all three metals showed better corrosion resistance. The decreasing order of corrosion resistance is SS316L > 22ctgold > 18ctgold. People who make use of SS316L orthodontic wires need not hesitate to take D-glucose solution orally, since the corrosion resistance of the metal increases in the presence of D-glucose.
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References


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