Effects of Tablet on Orthodontic Wire made of SS316L Alloy in Artificial Saliva

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ABSTRACT: *In order to regulate the growth of teeth, people are implanted or clipped with orthodontic wires made of different materials. When these orthodontic wires are exposed to the oral environment, by the influence of food intake, toothpastes, mouthwash, some tablets like vitamin, used as pain killer and antibiotics. During this process, the orthodontic wires may undergo corrosion. Hence, the main objective of this study was to evaluate the Effects of Tablet on Orthodontic Wire made of SS316L Alloy in Artificial Saliva. An electrochemical study has been used to investigate the corrosion behaviour of this alloy. By using Scanning Electron Microscopy and Energy Dispersive Analysis of X-rays the elemental composition was determined. Further, the analysis of the protective film formed on the metal surface was done using AC impedance spectra. The corrosion resistance of SS316L alloy is increases in presence of Azithromycin tablet. This is evidenced by increases of Charge transfer resistance (Rct) and decreases of double layer capacitance (Cdl) in AC impedance spectra. The high corrosion resistance offered by the tablet is due to the formation of a protective film on the metal surface. Hence these electro chemical studies conclude that people clipped with orthodontic wire made of SS316L alloy can take Azithromycin (500mg) tablet orally without any hesitation.*

Key Words: : *Corrosion resistance, Scanning electron microscopy, Energy Dispersive Analysis of X-rays, AC impedance spectra, orthodontic wire, SS316L alloy and Azithromycin.*

1. INTRODUCTION

In the past decades, a variety of wire alloys was introduced into orthodontics, leading to improvement of treatments. The major process of degradation of alloy is corrosion. Until the 1930s, the available orthodontic wires were made of gold. Austenitic SS was introduced as an orthodontic wire in 1929, and because of its superior strength, higher modulus of elasticity, good resistance to corrosion, and moderate costs, SS promptly gained acceptance and preference over gold.[1] The alloy of SS most frequently used for orthodontic materials is the American Iron and Steel institute type304,containing 18-20% of chromium and 8-10% of nickel.[2,3] SS wires have good biocompatibility, good corrosion resistance, excellent formability, high yield strength, and high modulus of elasticity.[1,4] So SS is more preferable orthodontic wire than any other materials in terms of its affordability and good biocompatibility. Stainless steels contain sufficient chromium to undergo passivation, forming an inert film of chromium oxide on the surface. This layer prevents further corrosion by blocking oxygen diffusion to the steel surface and stops corrosion from spreading into the bulk of the metal.[5] In recent years, there has been a significant increase in the number of studies examining the corrosion properties of 316L stainless steel used in medical/dental applications. In some recent studies the corrosion mechanisms of 316L stainless steel in various solutions, including different artificial saliva have been examined.[6 -8] Influence of some tablets on corrosion resistance of orthodontic wire made of SS316L alloy in artificial saliva have been investigated by Aanandan et al. [9] Corrosion resistance of SS316L Alloy in artificial saliva in presence of a Sparkle Toothpaste, have been investigated by Renita Souza et al. [10] Electrochemical Corrosion Behaviour of Dental/ Implant Alloys in Artificial Saliva have been investigated by Mohit Sharma et.al. [11] Corrosion Behavior of Metals in Artificial Saliva in Presence of Spirulina Powder and electrol have been investigated by S.Rajendran et.al. [12,13] The best candidate for implantation of orthodontic wire for people desirous of drilling maaza have been evaluated by Adhithya et,al.[14] Corrosion resistnce of SS316L in synthetic saliva in presence of D-Glucose has been evaluated by Saranya et. Al. [15] Orthodontic wires and its corrosion –The specific case of stainless steel and beta-titanium have been investigated by Saul M. castro et.al.[16] Influence of Ciprofloxacin Hydrochloride on corrosion resistance of SS316l immersed in artificial saliva have been evaluated by

Mohamed Kasim Sheit et.al.[17] Inhibition evaluation of mango juice extracts, cashew juice extract, fruit peel aqueous extracts, Carica papaya extracts, Garlic and Ginger extract on the corrosion of mild steel in HCl have been evaluated by Loto,Rocha, Okaufor, Priya, Bouyanzen and Singh et al.[17-23] The present work is undertaken to study the Effects of Tablet on Orthodontic Wire made of SS316L Alloy in Artificial Saliva has been evaluated by electrochemical studies such as AC impedance Spectra, SEM and EDAX

2. EXPERIMENTAL

2.1. Materials

The metal specimens, namely, SS316L alloys is chosen for the present study. The study was carried out in the presence of Artificial Saliva (AS) using Azithromycin tablet (500mg). The composition of SS316L alloy is Cr (18%), Ni (12%), Mo (2.5%), C (<0.03%) and balance is Fe [15].The composition of Artificial Saliva in g/L-1 is KCl (0.4), NaCl (0.4), $CaCl_2.2H_2O$ (0.906), $NaH_2PO_4.2H_2O$ (0.690), $Na_2S.9H_2O$ (0.005) and urea (1.0) [16-18].The ingredients of Azithromycin tablet is Azithromycin (500mg).

2.2. Methods

2.3. Electrochemical studies

2.3. i . AC impedance Spectroscopy measurements

The measure of the ability of a circuit to resist the flow of electrical current is known as impedance. By applying an AC potential to an electrochemical cell and then measuring the current through the cell, the electrochemical impedance is usually measured using a small excitation signal. The instrument used for the polarization study was also used to record AC impedance spectra. The cell setup was also the same. 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 (R_{ct}) and double layer capacitance (C_{dl}) were calculated from the Nyquist plot and the impedance; log (z/Ohm) value was calculated from Bode plots. During AC, impedance spectra were recorded: the scan rate (V/s) was 0.005; hold time at Ef(s) was zero and quite time (s) was 2. The value of charge transfer resistance (Rt) and double layer capacitance (Cdl) were calculated from Nyquist plot.

$$Rt = (Rs + Rt) - Rs$$

(where Rs = solution resistance, Rt =charge transfer resistance)

$$Cdl = \frac{1}{2 \times 3.14 \times Rt \times fmax}$$

where f_{max}= frequency at maximum imaginary impedance.

2.3. ii. Scanning Electron Microscopic studies (SEM)

The surface morphology measurements of the thin wire metal (SS316L) specimen were examined using scanning electron microscope. The surface morphology was examined for the thin wire of (SS316L) metal specimen in the absence and in the presence of Azithromycin tablet system. The specimen immersed in the best system for a period of one day was removed, rinsed with double distilled water, dried and observed in a scanning electron microscope to examine the surface morphology.

2.3. iii. Energy Dispersive Analysis of X-rays (EDAX)

SEM imaging gives the morphological data for a sample;The elements present in a material are determined by an EDAX spectrum. An energy dispersive X-ray analyzer (EDAX) [Brucker, Nano,GMBH, Germany] unit attached to the SEM machine was used to carry out the elemental analysis of the metal surface.

3. RESULTS AND DISCUSSION

3.1. Analysis of AC Impedance spectroscopy

AC impedance spectroscopy has been used for detection of the formation of protective film on the metal surface during corrosion resistance process.AC impedance parameters such as charge transfer resistance (R_{ct}), double layer capacitance (C_{dl}) (derived from Nyquist plots), and impedance value log (z/ohm) (derived from Bode plots) of various alloys immersed in Artificial Saliva and Artificial Saliva containing Azithromycin tablet are given in Table1. Nyquist plots are shown in Figures 1 and 2, Bode plots in Figures 3 and 4. When corrosion resistance increases, the charge transfer resistance (R_t) value increases, impedance value increases and double layer capacitance value decreases.

Table 1: Corrosion parameters of alloys immersed in Artificial Saliva (AS) in the absence and presence of Azithromycin tablet 500 mg obtained by AC impedance Spectroscopy.

Metal	System	Nyquist plot		Bode plot
		R_{ct} ohm cm^2	C_{dl} F/cm^2	Impedance log(z/ohm)
SS316L alloy	Artificial Saliva (AS)	8775	5.81×10^{-10}	4.146
	Artificial Saliva + Azithromycin tablet	123990	4.11×10^{-11}	5.225

The AC impedance spectra of SS316L alloy immersed in various test solutions are shown in Figure 1 and 2.The corrosion parameters are given in table 1. It is observed from the table 1 that in presence of Azithromycin tablet in artificial saliva the corrosion resistance of SS316L alloy increases. This is evident by increases of the charge transfer resistance (R_t) from 8775 to 123990 ohmcm^2 and decreases of the double layer capacitance (C_{dl}) from 5.81×10^{-10} to 4.11×10^{-11}F/cm^{2}and increases of impedance value from 4.146 to 5.225 log (z/ohm).These observations indicate that a protective film is formed on the metal surface when SS316L alloy is immersed in artificial Saliva in presence of Azithromycin tablet.[24] The protective film prevents the transfer of electrons from the metal surface to the bulk of the solutions.[1] The protective film probably consists of SS316L ions, and the active principle of the Azithromycin tablet ingredients.[9] Hence people clipped with orthodontic wire made of SS316L alloy need not any hesitation to take Azithromycin tablet orally.

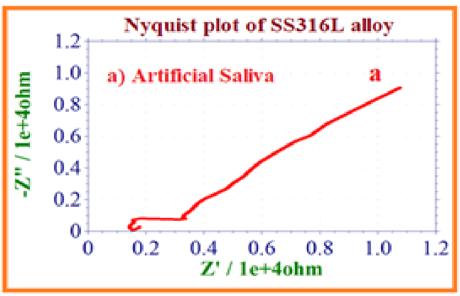

Figure 1

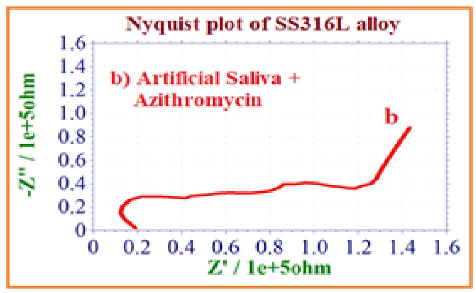

Figure 2

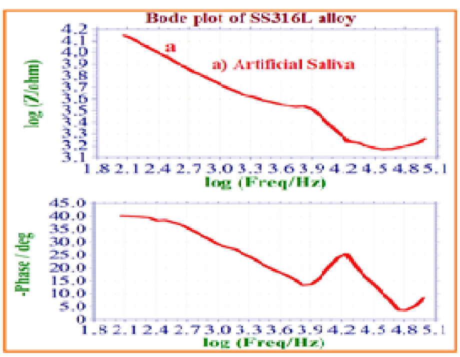

Figure 3

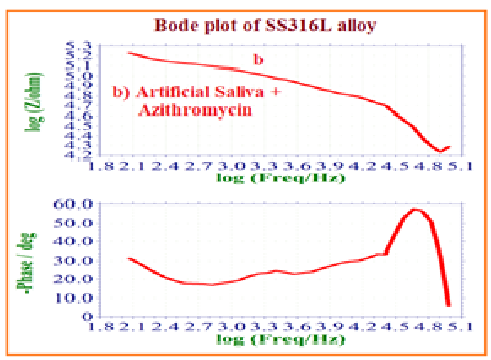

Figure 4

Figure 1: AC impedance spectra (Nyquistplot) of SS316L alloy immersed in various test solutions
a) Artificial Saliva (AS)

Figure 2: AC impedance spectra (Nyquistplot) of SS316L alloy immersed in various test solutions
b) Artificial Saliva (AS) + Azithromycin

Figure 3: AC impedance spectra (Bode plot) of SS316L alloy immersed in various test solutions.
a) Artificial Saliva (AS)

Figure 4: AC impedance spectra (Bode plot) of SS316L alloy immersedin various test solution
b) Artificial Saliva (AS) + Azithromycin

3.2. Analysis of Scanning Electron Microscopy (SEM)

SEM images for SS316L alloy in absence and presence of Azithromycin tablets are shown in Figure 5 (a) and (b). The surface is found to be smooth only for pure polished metal. When this surface is exposed to oral cavity (Artificial saliva) they quickly developed a passive film (Cr_2O_3/Fe_2O_3),[26-29]. This passive film act as protective interface between the metal structure and biological medium that is saliva [30,31]. Due to the complex degradation process, this passive film undergo surface corrosion. [32] Therefore the surface is looking more rough (Figure 5(b)) than polished metal. In presence of Azithromycin tablet the roughness of the metal surface is less (Figure 5 (c)) than the artificial saliva alone. This is because of the presence of a protective film on the metal surface. This protective film is due to the deposition of the active principles of the ingredients present in the tablet. [10]

Figure 5(a) Figure 5(b) Figure 5(c)

Figure 5. SEM images for SS316L alloy in absence and presence of Azithromycin tablet in Artificial Saliva.(a) Polished SS316L alloy. (b)Polished SS316L alloy immersed in Artificial Saliva.(c)Polished SS316L alloy immersed in artificial saliva containing Azithromycin tablet.

3.3. Energy Dispersive Analysis of X-rays (EDAX)

The EDAX spectra are shown in Fig. 6 (a) and (b). It is seen from the EDAX spectra that, Fe, Cr, Ni and C are present in both absence and presence of the tablet Azithromycin (Table 2 and 3). But the weight percentage of these elements has changed after immersion in the Artificial Saliva containing Azithromycin tablet. The weight percentage of Fe and Cr has increased and the weight percentage of C decreases. The intensity of the peak of Fe is reduced because a protective film is formed on the metal surface.[33] This is due to the deposition of the active principle of the tablet ingredients.[10] This preventing the SS316L alloy from further corrosion.

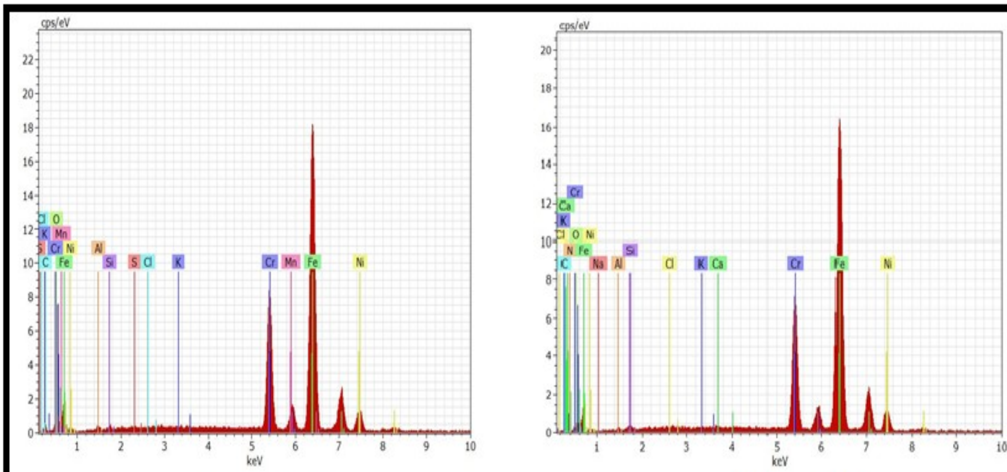

Figure 6(a) Figure 6(b)

Figure 6: EDAX Spectra of SS316L alloy in absence and presence of the system (Artificial Saliva + Azithromycin tablet). (a) Polished SS316L alloy immersed in Artificial Saliva. (b) Polished SS316L alloy immersed in artificial saliva containing Azithromycin.

Table 2: Spectrum of SS316L alloy immersed in artificial saliva

E1	AN Series unn. [wt.%]	C norm. [wt.%]	C Atom. [at.%]	C Error (1 Sigma) [wt.%]
Fe 26 K-series	60.74	65.53	50.01	1.63
Cr 24 K-series 16.15 17.43 14.29 0.49	16.15	17.43 14.29 0.49	14.29 0.49 14.29 0.49	0.49
Ni 28 K-series	6.49	7.00	5.08	0.27
C 6 K-series	6.36	6.87	24.36	2.63

Table 3: Spectrum of SS316L alloy immersed in artificial saliva containing Azithromycin tablet

E1	AN Series unn. [wt.%]	C norm. [wt.%]	C Atom. [at.%]	C Error (1 Sigma) [wt.%]
Fe 26 K-series	65.21	67.73	54.04	1.75
Cr 24 K-series	16.60	17.24	14.78	14.78
Ni 28 K-series	6.75	7.01	5.33	0.28
C 6 K-series	4.74	4.92	18.25	2.23

4. CONCLUSIONS

From the electro chemical study of AC impedance spectra, SEM and EDAX concluded that, in presence of Azithromycin tablet in Artificial Saliva, the corrosion resistance of SS316L alloy increases. Hence, it is recommended that people clipped with orthodontic wire made of SS316L alloy can take Azithromycin tablet orally without any hesitation. So, dentists can prescribed this tablet (Azithromycin500 mg) to their patients while they are clipping with orthodontic wire made of SS316L alloy on their teeth.

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