Corrosion resistance of orthodontic wire made of SS 18/8 alloy in artificial saliva in presence of Halls menthol candy investigated by electrochemical studies

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Abstract

Doctors make use of orthodontic wires such as SS 18/8, Ni–Cr, Ni–Ti, SS 316, Gold 22 K *etc*., to regulate the growth of teeth. These wires undergo corrosion in the saliva environment. Apart from this, they undergo corrosion by the juices, food items and Tablets orally taken in. Corrosion resistance of SS 18/8 alloy in artificial saliva (AS), in the absence and presence of Halls menthol candy juice has been investigated by polarization study and AC impedance spectra. It is found that corrosion resistance of SS 18/8 alloy in artificial saliva decreases in the presence of Halls menthol candy. This is proved by decrease in linear polarization resistance (*LPR*) value, decrease in charge transfer resistance (R_t) value, decrease in impedance value, increase in corrosion current and increase in double layer capacitance value (C_{dl}). In the presence of Halls menthol candy juice, the *LPR* value decreases from $5.299 \cdot 10^5$ Ohm·cm^2 to $2.519 \cdot 10^5$ Ohm·cm^2. The corrosion current value increases from $7.323 \cdot 10^{-8}$ A/cm^2 to $7.724 \cdot 10^{-8}$ A/cm^2. The charge transfer resistance (R_t) value decreases from $1.231 \cdot 10^4$ Ohm·cm^2 to $1.187 \cdot 10^4$ Ohm·cm^2. The double layer capacitance value increases from $4.142 \cdot 10^{-10}$ F/cm^2 to $4.296 \cdot 10^{-10}$ F/cm^2. The impedance value decreases from 4.387 to 4.281 log (*Z*/Ohm). The phase angle decreases from 43.21° to 42.59°. Therefore, the chances of orthodontic wire made of SS 18/8 alloy undergoing corrosion are greater in those who consume Halls menthol candy juice excessively.

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Introduction

Beautiful objects are symmetrical in nature. Symmetry leads to beauty. Symmetry is a result of regular arrangement. Regular arrangement of teeth leads to attractive and beautiful smiles which attract everyone. Unfortunately by God's grace, some people do not have regularly

arranged teeth. To regularize the growth of teeth, people need the help of Dentists. They make use of orthodontic wires made of various alloys such as SS 316 L, SS 18/9, NiTi, NiCr *etc*., after clipping these wires, people take many tablets, food items and juices orally. Because of these activities the orthodontic wires undergo corrosion. In addition, in the oral environment, in the presence of saliva, which contains 98% water, plus electrolytes, mucus, white blood cells, epithelial cells (from which DNA can be extracted), glycoproteins, enzymes (such as amylase and lipase), antimicrobial agents such as secretory IgA and lysozyme, the orthodontic wires undergo corrosion further. Many research activities have been undertaken in this regard [1–11].

The corrosion resistance orthodontic arch-wires made of AISI304 steel in artificial saliva has been investigated by Kamiński *et al*. by electrochemical studies [1]. An increase in corrosion resistance of AISI304 steel after conventional glow-discharge nitriding has been observed. Affi *et al*. have studied the corrosion resistance of Titanium alloys in artificial saliva at various temperatures [2]. It was observed that under these conditions the corrosion rate of orthodontic wires increased and the hardness of the material decreased. The influence of snake fruit extract in inhibiting the release of chromium and nickel ion from stainless steel orthodontic wire in saliva has been studied by Erwansyah and Susilowati [3]. It has been established that Snakefruit seeds extract controlled the release of chromium and nickel ion from stainless steel orthodontic wire in saliva. Corrosion resistance of stainless steel orthodontic wire in saliva in the presence of watermelon rind extract has been investigated by Nahusona and Koriston [4] by means of electrochemical studies. It is noted that the corrosion resistance of stainless steel orthodontic wire in saliva in the presence of watermelon rind extract increases [4]. Corrosion behavior of stainless steel and three types of NiTi orthodontic wires in simulated saliva in the presence of *Lactobacillus reuteri* has been studied by Musa Trolic *et al*. It was noted that the added substances from probiotic supplement are accountable for the localized corrosion of studied wires [5].

Influence of some tablets on corrosion resistance of orthodontic wires made of SS 316L alloy in artificial saliva has been studied by Anandan *et al.* by means of electrochemical studies such as polarization study and AC impedance spectra [6]. Renita D'souza *et al*. have measured corrosion resistance of SS 316L alloy in artificial saliva in the presence of Sparkle fresh Toothpaste, by electrochemical studies [7]. Agnes Brigitta *et al*. have studied corrosion resistance of SS18/8, Gold18 carat, Gold 22 carat and SS 316L alloy in artificial saliva in the absence and presence of Vitavion Fort Tablet 500 mg [8]. Influence of *D*-glucose on corrosion resistance of SS 316L in the presence of artificial saliva has been studied by Saranya and Rajendran by means of electrochemical studies [9]. Zhang *et al*. have investigated the effect of the heat treatment on corrosion and mechanical properties of CoCrMo alloys manufactured by selective laser melting [10].

Gowri *et al*. have investigated the influence of Metformin Hydrochloride – 250 mg (MFH) tablet on corrosion resistance of orthodontic wire made of NiCr alloy in artificial saliva [11].The present effort is undertaken to study the corrosion resistance of orthodontic

wire made of SS 18/8 alloy in artificial saliva in the presence of Halls menthol candy juice, by electrochemical studies such as polarisation study and AC impedance spectra.

Materials and Methods

Preparation of the metal specimens

A thin wire of SS 18/8 alloy was used as test material for this work. The chemical composition of the alloy was as follows: 18% Cr, 8% Ni, and balance was Fe. The orthodontic wire was encapsulated in Teflon rod. It was polished to mirror finish and used for electrochemical studies.

Preparation of artificial saliva

The preparation of artificial saliva was done using the composition of Fusayama Meyer artificial saliva. Artificial saliva was prepared in laboratory and the composition of artificial saliva was as follows: KCl – 0.4 g/l, NaCl – 0.4 g/l, $CaCl_2 \cdot 2H_2O$ – 0.906 g/l, $NaH_2PO_4 \cdot 2H_2O$ – 0.690 g/l, $Na_2S \cdot 9H_2O$ – 0.005 g/l, urea – 1 g/l.

Halls menthol candy

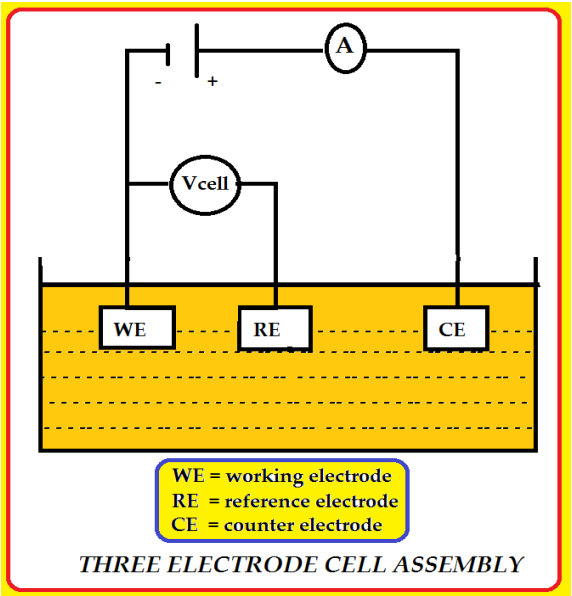
Halls is a mentholated hard candy. Halls produces a sugar-free line of mentholated cough drops. In some parts of the world, including Brazil, Argentina, Peru, Ecuador, Colombia, the Philippines, and Pakistan, Halls is advertised as a mentholated hard candy and is not recognized as a medicine for coughs**.** Their active ingredient is menthol. These candy-like lozenges can feel soothing and help calm a cough, at least temporarily [12].

Potentiodynamic polarization study

A CHI 660 A workstation model was used in the electrochemical studies. Polarization study was carried out using a three electrode cell assembly (Scheme A). SS 18/8 was used as working electrode, platinum as counter electrode and saturated calomel electrode (SCE) as reference electrode. After having done iR compensation, polarization study was carried out at a sweep rate of 0.01 V/Sec. The corrosion parameters such as linear polarization resistance (*LPR*), corrosion potential E_{corr}, corrosion current I_{corr} and Tafel slopes (b_a and b_c) were measured.

Alternating current impedance spectra

AC impedance spectra were recorded in the same instrument used for polarization study, using the same type of three electrode cell assembly. The real part (Z') and imaginary part ($-Z''$) of the cell impedance were measured in Ohms for various frequencies. The charge transfer resistance (R_t) and double layer capacitance (C_{dl}) values were derived.



Scheme A. Three electrode cell assembly.

Results and Discussion

The present investigation is undertaken to study the corrosion resistance of orthodontic wire made of SS 18/8 alloy in artificial saliva in the presence of Halls menthol candy juice, by electrochemical studies such as polarisation study and AC impedance spectra [13–27].

Influence of Halls menthol candy on corrosion resistance of SS 18/8 alloy in artificial saliva

The influence of Halls menthol candy (powder juice) on corrosion resistance of SS 18/8 alloy in artificial saliva (AS), has been investigated by polarization study and AC impedance spectra.

Polarization study

In the present exploration, polarization studies were carried out in a CHI Electrochemical work station/analyzer, model 660A. It was provided with automatic iR compensation facility. A three electrode cell assembly was used (Scheme A).

The electrodes were immersed inartificial saliva (AS), in the absence and presence of Halls menthol candy. From polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes anodic=b_a and cathodic=b_c and *LPR* (linear polarization resistance) value were calculated.

The Polarization curves of SS18/8 alloy in AS in the absence and presence of 1000 ppm of Halls menthol candy are shown in Figure 1. The corrosion parameters are given in Table 1.

In polarization study, when corrosion resistance decreases, *LPR* decreases and corrosion current increases.

Table 1. Corrosion parameters of orthodontic wire made of SS 18/8 alloy immersed in various test solutions obtained by polarisation study.

System	E_{corr} mV *vs.* SCE	b_c mV/decade	b_a mV/decade	*LPR* Ohm·cm^2	I_{corr} A/cm^2
AS	–673	155	210	$5.299 \cdot 10^5$	$7.323 \cdot 10^{-8}$
AS + Halls menthol 1000 ppm	–742	059	186	$2.519 \cdot 10^5$	$7.724 \cdot 10^{-8}$

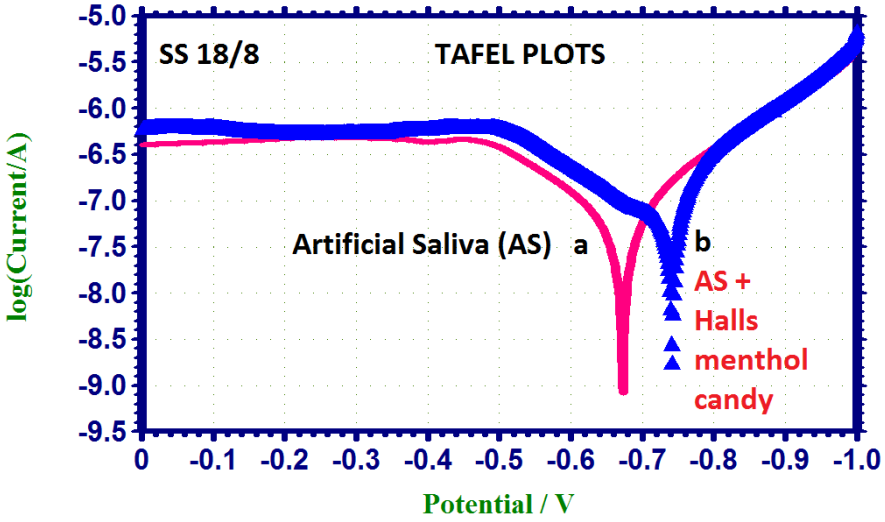


Figure 1. The polarization curves of SS18/8 alloy in AS in the absence (a) and presence of 1000 ppm of Halls menthol candy (b).

It is observed from Table 1, that in the presence of Halls menthol candy, the corrosion resistance of SS 18/8 in AS decreases. This is revealed by the fact that, in the presence of Halls menthol candy, *LPR* value of SS 18/8 decreases and corrosion current increases.

It is also observed that in the presence of Halls menthol candy the corrosion potential shifts from –673 to –742 mV *vs.* SCE. It is inferred that in the presence of Halls menthol candy the cathodic reaction is controlled predominantly.

Implication

Corrosion resistance of SS 18/8 alloy in artificial saliva decreases in the presence of Halls menthol candy. Therefore, the chances of orthodontic wire made of SS 18/8 alloy undergoing corrosion are greater in those who consume Halls menthol candy excessively.

AC Impedance spectra

The same instrument set-up used for polarization study was used to record AC impedance spectra also. A time interval of 5 to 10 min was given for the system to attain a steady state open circuit potential. The real part (Z') and imaginary part ($-Z''$) of the cell impedance were

measured in ohms at various frequencies. From Nyquist plot the values of charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated. From Bode plot, double layer capacitance (C_{dl}), impedance value [log(Z/Ohm)] and phase angle values were calculated.

The AC impedance spectra of SS 18/8 alloy in AS in the absence and presence of 1000 ppm of Halls menthol candy are shown in Figures 2–5. The Nyquist plots are shown in Figure 2. The Bode plots are shown in Figures 3 and 4.

The corrosion parameters such as change transfer resistance (R_t), impedance value and double layer capacitance (C_{dl}) values are given in Table 2.

When corrosion resistance decreases, R_t values decreases, impedance value decreases whereas C_{dl} values increases.

Table 2. Corrosion parameters of orthodontic wire made of SS 18/8 alloy immersed in various test solutions (Artificial saliva, AS, systems) obtained by AC impedance spectra.

System	R_t Ohm·cm^2	C_{dl} F/cm^2	Impedance Log(Z/Ohm)	Phase angle°
AS	$1.231 \cdot 10^4$	$4.142 \cdot 10^{-10}$	4.387	43.21°
AS + Halls menthol 1000 ppm	$1.187 \cdot 10^4$	$4.296 \cdot 10^{-10}$	4.281	42.59°

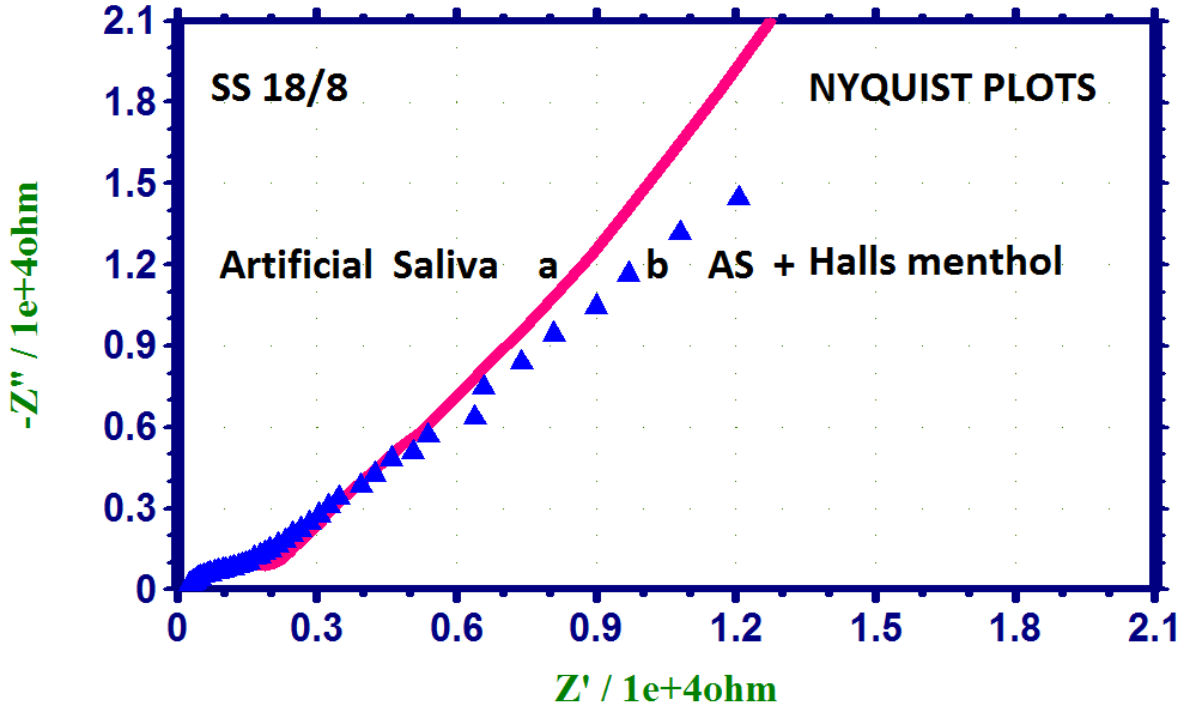


Figure 2. Nyquist plots of SS18/8 alloy in AS in the absence (a) and presence of 1000 ppm of Halls menthol candy (b).

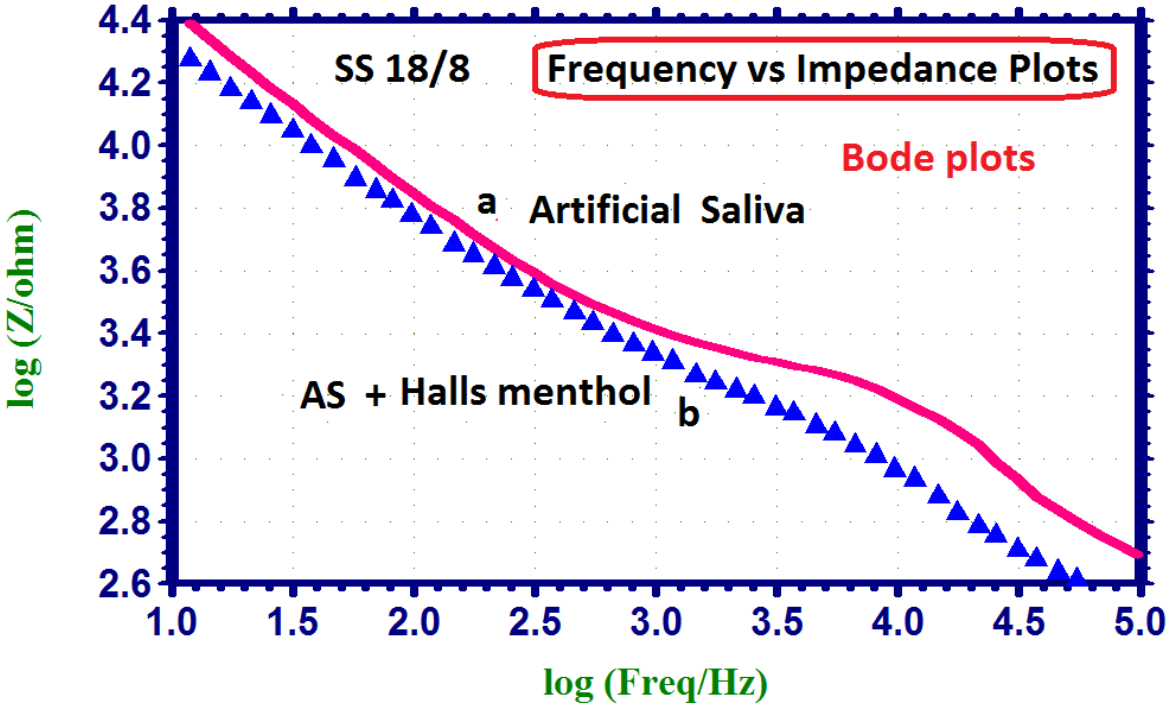


Figure 3. Bode plots of SS18/8 alloy in AS in the absence (a) and presence of 1000 ppm of Halls menthol candy (b). (Frequency *vs*. impedance plots).

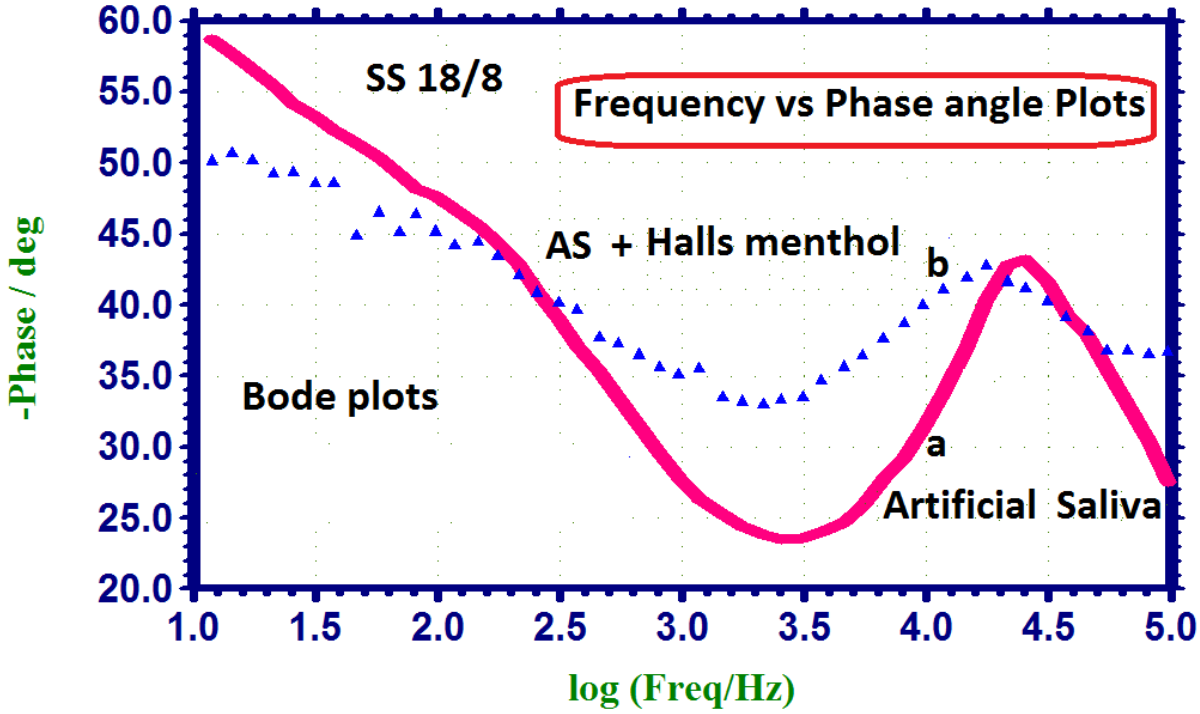


Figure 4. Bode plots of SS18/8 alloy in AS in the absence (a) and presence of 1000 ppm of Halls menthol candy (b). (Frequency *vs*. phase angle plots).

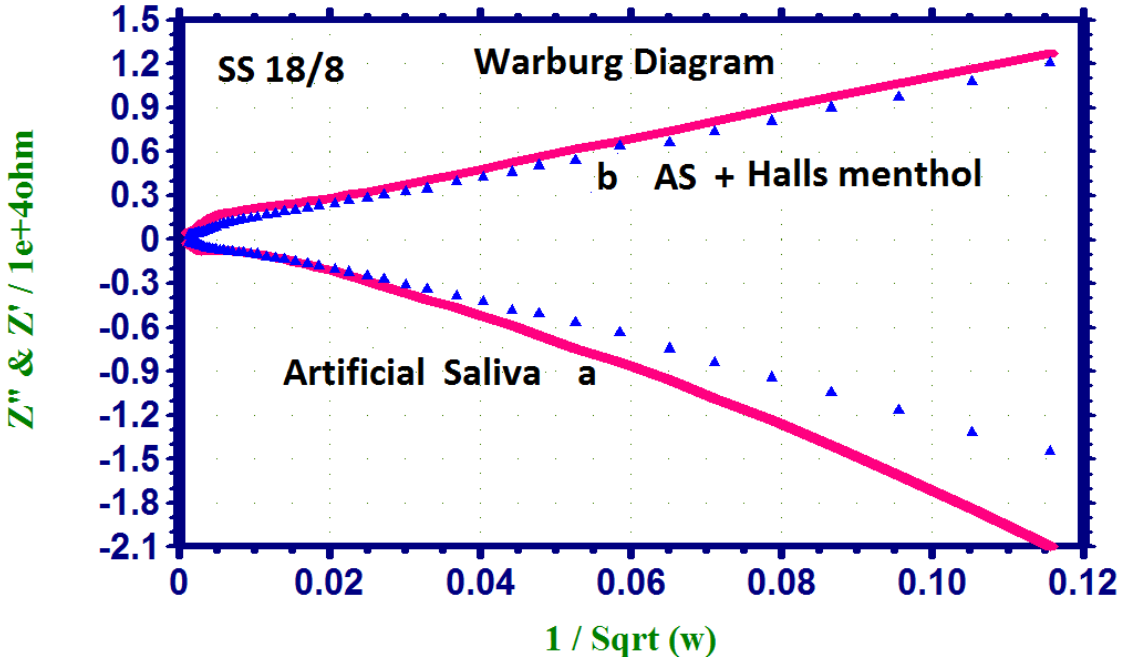


Figure 5. Warburg diagrams of SS18/8 alloy in AS in the absence (a) and presence of 1000 ppm of Halls menthol candy (b).

It is observed from Table 2, that is in the presence of Halls menthol candy, the corrosion resistance of SS 18/8 in AS decreases. This is revealed by the fact that in the presence of Halls menthol candy, R_t value decreases, impedance value decreases, phase angle value decreases and C_{dl} value increases.

The following is inferred from Figure 5. It is well known that when there is more corrosion resistance in the presence of an additive, for the blank system, the two lines parallel to the x axis, passing through origin will be very close to each other. For a system having less corrosion resistance in the presence of an additive, these lines are far apart. Figure 5 indicates that in the presence of an additive the corrosion resistance of the system decreases.

Implication

Corrosion resistance of SS 18/8 alloy in artificial saliva decreases in the presence of Halls menthol candy. Therefore, the chances of orthodontic wire made of SS 18/8 alloy undergoing corrosion are greater in those who consume Halls menthol candy juice excessively.

Summary and Conclusions

Outcome of the study

Corrosion resistance of SS 18/8 alloy in artificial saliva (AS), in the absence and presence of Halls menthol candy has been investigated by polarization study and AC impendency spectra. It is inferred that corrosion resistance of SS 18/8 alloy in artificial saliva decreases in the presence of Halls menthol candy. This is revealed by decrease in *LPR* value, decrease

in R_t value, decrease in impedance value, increase in corrosion current, decrease in phase angle and increase in double layer capacitance value. Therefore, the chances of orthodontic wire made of SS 18/8 alloy undergoing corrosion are greater in those who consume Halls menthol candy juice excessively.

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