

Evaluation of corrosion resistance of 18k gold alloy in artificial saliva in the presence of fennel powder

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Abstract

The present study focuses on the evaluation of the corrosion resistance of 18K gold alloy in artificial saliva with and without fennel powder. Dental alloys such as 18K gold are widely used in orthodontic and prosthodontic applications due to their excellent biocompatibility and corrosion resistance. However, their long-term performance can be influenced by dietary and medicinal substances consumed orally. In this study, electrochemical techniques such as potentiodynamic polarization and AC impedance spectroscopy were employed to assess the corrosion behavior of 18K gold alloy. The alloy was immersed in artificial saliva, both with and without the addition of fennel powder, a commonly consumed herbal product known for its antioxidant and antimicrobial properties. The findings suggest that fennel powder influences the corrosion resistance of 18K gold, potentially through adsorption of organic compounds on the alloy surface or interaction with alloying elements. This study provides insight into the impact of herbal substances on the electrochemical stability of dental materials in the oral environment.

Keywords: Corrosion resistance, 18K gold alloy, Artificial saliva, Fennel Powder, Polarization study, AC impedance spectroscopy.

1. INTRODUCTION

Symmetry is a defining feature of beauty, often found in nature and art. It arises from regular arrangement and in the case of teeth such alignment results in an attractive and appealing smile. However not everyone is naturally endowed with well-aligned teeth. To correct dental misalignments, individuals seek the help of dentists, who use orthodontic wires made from various alloys such as SS 316L, SS 18/9, NiTi, and NiCr. During treatment, these wires are clipped onto the teeth, and patients continue to consume various medications, foods, and beverages. These oral activities expose the wires to different chemical environments, leading to the risk of corrosion over time.

Vincent Agnes Brigitta et al, have investigated the polarization study leads to the conclusion that corrosion resistance of SS18/8 alloy decreases in the order: AS > AS + Erythromycin.[1]

D Brune, et al, have examined the amounts of gold were observed to be retained on the glass filter explained by the presence of gold in particular form or as a component of a dispersed colloidal phase.[2]

Corrosion resistance of stainless steel orthodontic wire in saliva in presence of watermelon rind extract has been investigated by Nahusona and Koriston by means of electrochemical studies. It is noted that the corrosion resistance of stainless steel orthodontic wire in saliva in presence of watermelon rind extract increases [3]

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 [4].

Renita D'souza et al. have measured corrosion resistance of SS 316L alloy in artificial saliva in presence of Sparkle fresh toothpaste, by electrochemical studies [5].

Agnes Brigitta et al. have studied corrosion resistance of SS18/8, Gold 18 carat, Gold 22 carat and SS 316L alloy in artificial saliva in the absence and presence of Vitavion Fort tablet 500 mg [6].

Martina Pencheva et al, have investigate the inhibitory effect of fennel fruit essential oil (*Foeniculum vulgare* Mill.) and its main component anethole. The inhibitory effect of three different concentrations of the fennel essential oil and anethole (1.0 mL/L, 1.5 mL/L, and 2.5 mL/L) in a solution of 1 M HCl at 298 K for 6 h on a sheet of low-carbon steel was investigated [7].

In the present work corrosion resistance of 18 K Gold alloy in artificial saliva in the presence and absence of fennel powder has been investigated by electrochemical studies such as polarization study and AC impedance spectroscopy.

2. EXPERIMENTAL METHODS

Preparation of the metal specimens

A thin wire of 18 K gold alloy was used as the test material in this work. 18K gold consists of 75 parts of pure gold, 5-15 parts of copper and 10-20 parts of silver. The added metals make the texture of 18K gold harder and thereby more durable for making jewellery.

The preparation of artificial Saliva was done using the composition of Fusayama Meyer's artificial saliva [8]. Artificial saliva as prepared in the laboratory, and the composition of artificial saliva was as follows: KCl-0.4g/L, NaCl-0.4g/L, CaCl₂ · 2H₂O-0.906 g/L, NaH₂PO₄·2H₂O-0.78g/L, Na₂S·9H₂O-0.05g/L, Urea-1g/L.

Preparation of fennel powder:

The preparation of Artificial saliva was done using the composition of fusayama Meyer fennel powder. 66. The fennel powder as prepared in laboratory and the weight of fennel powder was 0.5 g.



Fig 1 fennel powder

Composition of fennel powder^[9,10]

+Trans-anethole (48.6%), Estragole (14.87%), Nonacosan-10-one (13.43%), Fenchone (4.38%), 3-Allyl-6-methoxyphenol (2.24%), Dotriacontanal (1.82%) and Oleic acid (1.77%), oxygenated monoterpenes (87.30%), followed by monoterpene hydrocarbons (7.88%) and sesquiterpene hydrocarbons (0.35%)

Electrochemical study

Potentiodynamic polarization study:

Polarization methods such as potentiodynamic polarization are often used for laboratory corrosion testing. These techniques can provide useful information regarding the corrosion mechanisms, CR and susceptibility of specific materials to corrosion in designed environments. Polarization methods involve changing the potential of the working electrode and monitoring the current that is produced as a function of time or potential. In the present study, polarization studies were carried out in a CHI Electrochemical work station/ analyser, model 604E. It was provided with an automatic IR compensation facility. Three electrode cell assembly was used. The working electrode was 18K gold. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode. A time interval of 5 to 10 min was given for the system to attain a steady-state open-circuit potential. The working electrode and platinum electrode were immersed in artificial saliva in the absence and presence of cinnamon powder. From the polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes (β_a and β_c), and linear polarization resistance (LPR) were calculated.

AC impedance measurements:

In the present study, the same instrument and setup used for the polarization measurements were employed to record the AC impedance spectra. A stabilization period of 5-10 min was allowed for the system to reach a steady-state open circuit potential. The real (Z') and imaginary (Z'') components of the cell impedance were measured in ohms over a range of frequencies. Impedance spectra were recorded with the following parameters: initial potential $E(v) = 0$, high frequency = 1×10^5 Hz, low frequency = 1 Hz, amplitude = 0.005 V, and a quiet time of 2s. From the Nyquist plots, the transfer resistance (R_t) and double-layer capacitance (C_{dl}) were determined, while Bode plots were used to obtain the impedance.

$$R_t = (R_s + R_t) - R_s$$

R_s = solution resistance.

C_{dl} = values were calculated using the relationship

$$Cdl = \frac{1}{2 \times 3.14 \times R_t \times f_{max}}$$

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

RESULTS AND DISCUSSION

Polarization study:

The polarization curves of the 18K gold alloy in artificial saliva (AS) with and without fennel powder, are presented in Figure 2. The corresponding corrosion parameters are summarized in Table 1 and compared in Figures 3 and 4.

Table 1: Corrosion parameters of 18K gold immersed in artificial saliva (AS) with and without fennel powder, obtained by polarization study.

Metal	System	E _{corr} mV vs SCE	b _c mV/decade	B _a mV/decade	LPR Ohm cm ²	I _{corr} ² A/0.00785 cm
18 Karat gold	Artificial saliva	-0.188	1.993	3.724	675061	1.127x10 ⁻⁷
18 Karat gold	Artificial saliva + fennel powder	-0.295	4.640	3.205	1172719	4.726x10 ⁻⁸

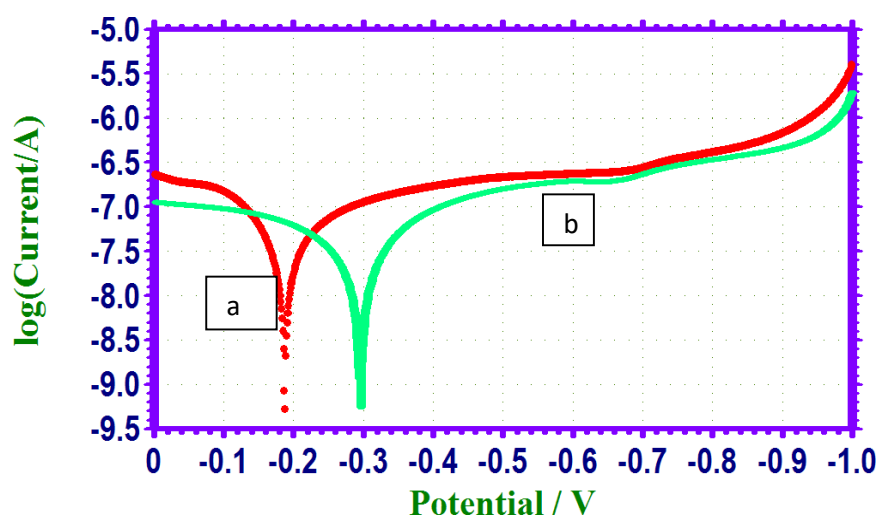


Figure 2. Polarization curves of 18 Karat Gold immersed in various test solution
a) AS b) AS+fennel powder

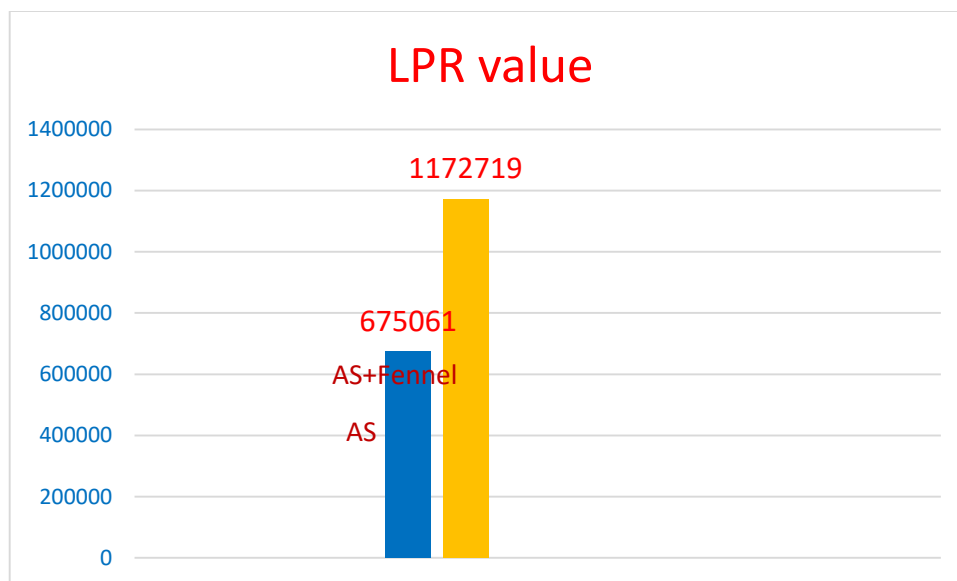


Figure 3. Comparison of LPR values of 18 K gold alloy immersed in artificial saliva (AS) with and without of fennel powder

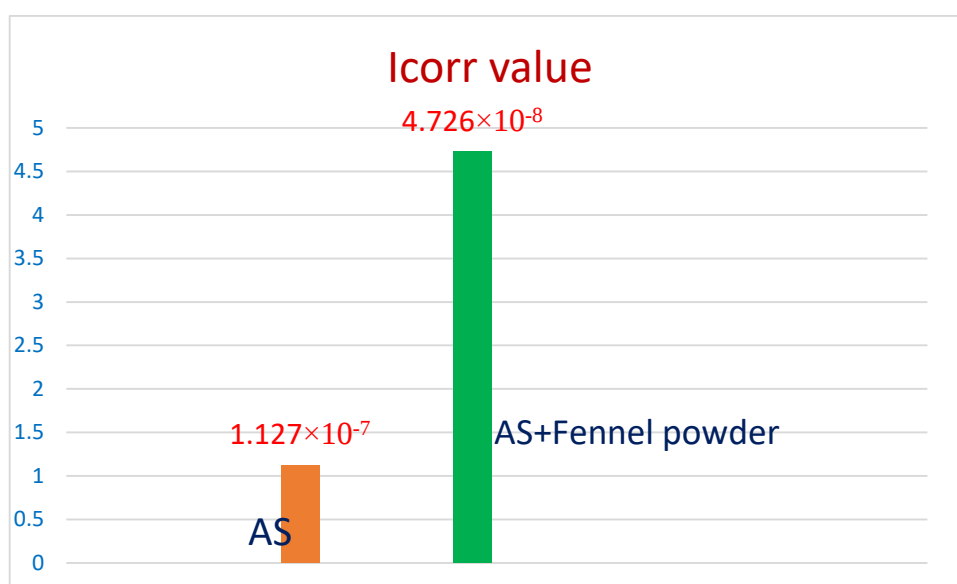


Figure 4. Comparison of Icorr values of 18 K Gold alloy immersed in artificial saliva (AS) with and without of fennel powder.

In the presence of fennel powder, the corrosion resistance of 18 Karat gold in Artificial Saliva increased. This was revealed by the increase in LPR value and decrease in corrosion current. Thus, the polarization study has led to the conclusion that in the presence of fennel powder, the corrosion resistance of 18 Karat gold in artificial saliva increased.

Implication

The corrosion resistance of the 18 K gold alloy in artificial saliva increased in the presence of

fennel powder. Hence, it was concluded that individuals fitted with orthodontic wires made of 18 K gold alloy in artificial saliva need not hesitate to take fennel powder orally.

Ac impedance spectra

The AC impedance spectra (Nyquist plot) of 18 Karat gold immersed in artificial saliva are shown in Figure 5, and the AC impedance spectra (3D Interaction) of 18 Karat gold immersed in artificial saliva (AS) + fennel powder are shown in Figure 6. The AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva are shown in Figure 7, and the AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva (AS) + fennel powder are shown in Figure 8. The corrosion parameters are compared in Figures 9 and 10, respectively.

The corrosion parameters, such as the charge transfer resistance (R_t) and double layer capacitance (C_{dl}) values are listed in Table 2.

Table 2: Corrosion parameters of 18K alloy immersed in artificial saliva (AS) with and without of fennel powder, obtained from AC impedance spectra.

Metal	System	Nyquist plot		Bode plot impedance $\log(Z/\text{ohm})$
		R_t ohm cm^2	C_{dl} 2 F/cm	
18 Karat gold	Artificial saliva	9027	6.4972×10^{-11}	4.329
18 Karat gold	Artificial saliva + fennel powder	620410	0.822×10^{-11}	5.937

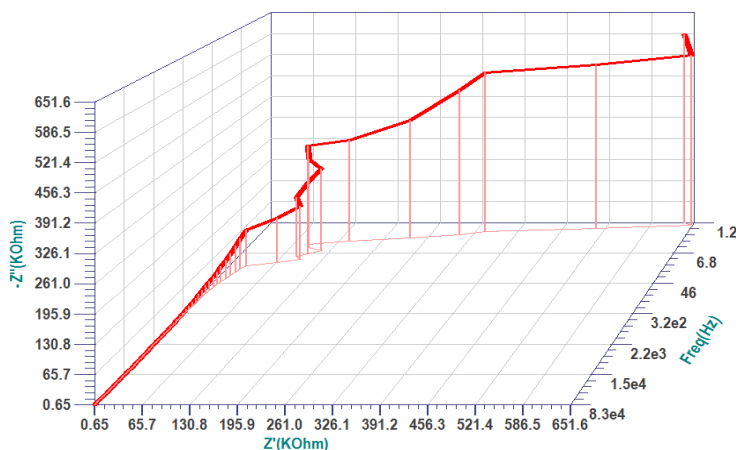


Figure 5: AC impedance spectra of 18 Karat gold immersed in artificial saliva.

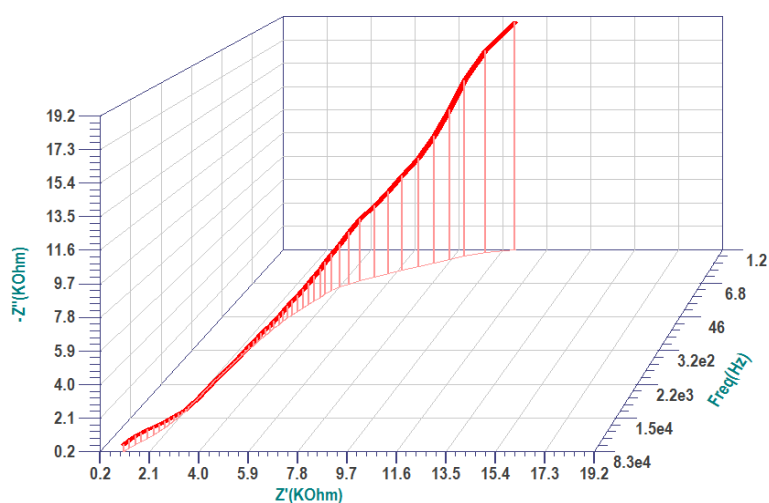


Figure 6: AC impedance spectra (3D Interaction) of 18 Karat gold immersed in artificial saliva (AS)+ fennel powder

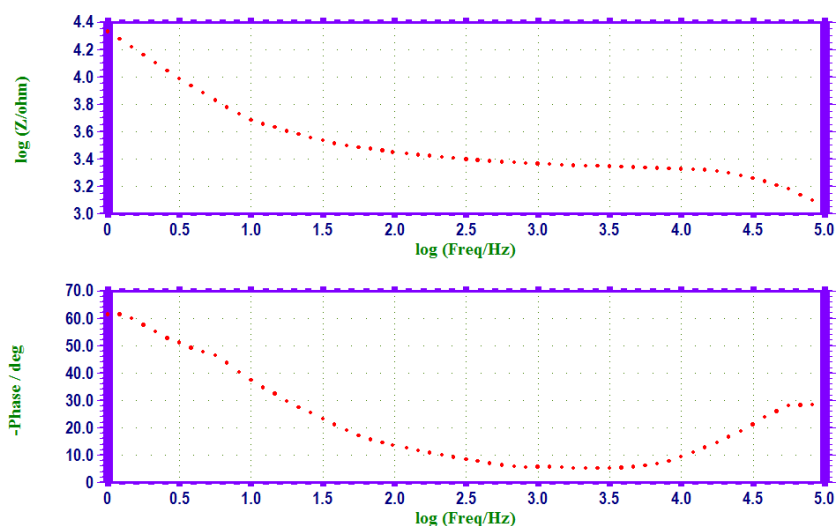


Fig 7. The AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva

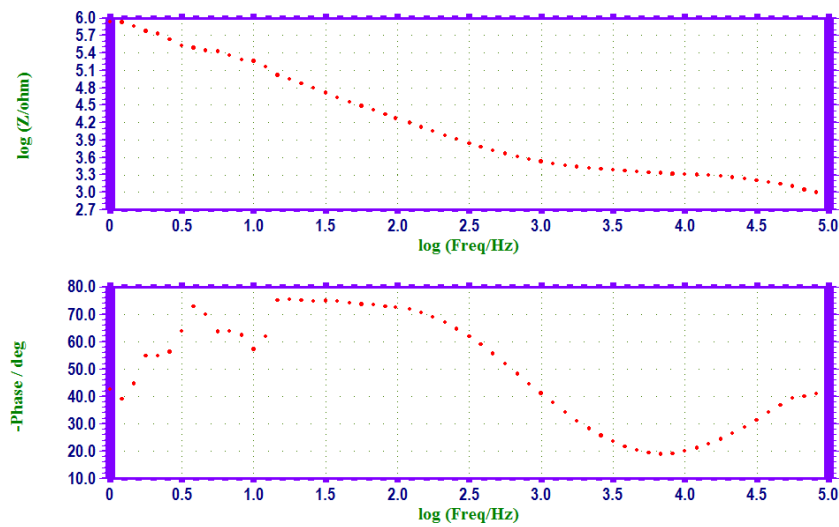


Figure 8. AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva (AS)+ fennel powder

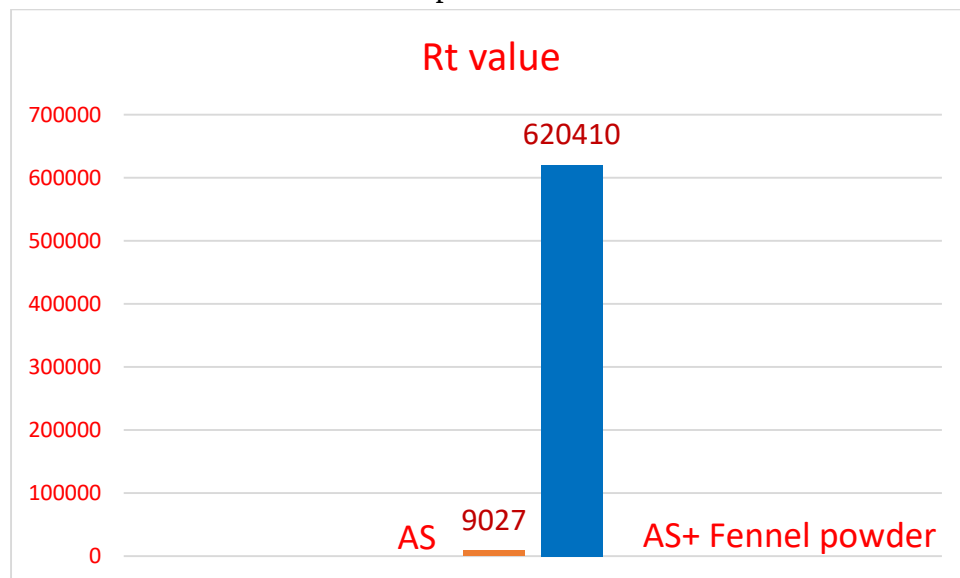


Figure 9. Comparison of R_t values of 18 K gold alloy immersed in artificial saliva (AS) with and without of fennel powder

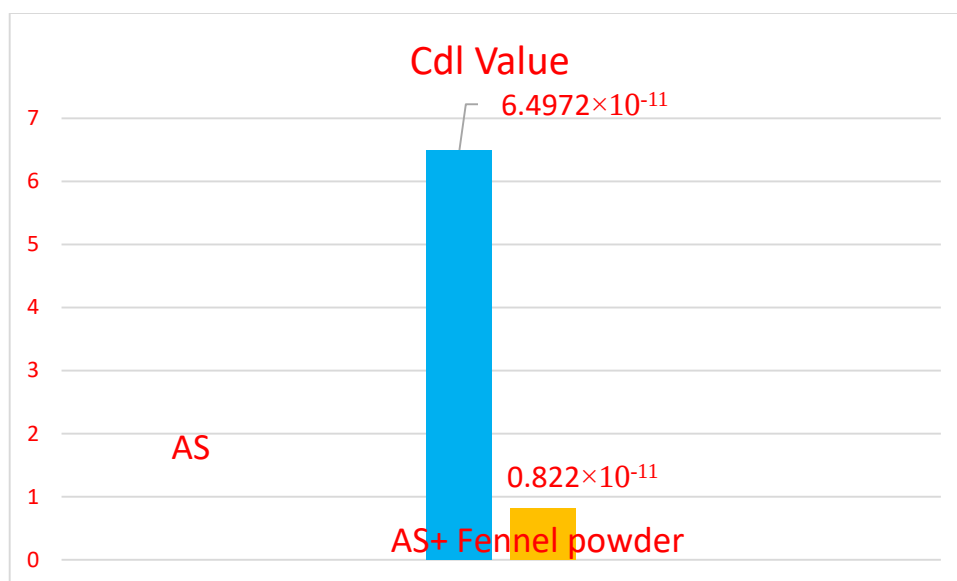


Figure 10. Comparison of C_{dl} values of 18 K gold alloy immersed in various test Solutions

When 18 Karat gold was immersed in AS, the charge transfer resistance(R_t) value was 9027 ohm cm^2 (fig.3). The double layer capacitance (C_{dl}) was 6.4972×10^{-11} . These observations indicate the protective film formed on 18 Karat gold was more stable. It was able to with stand the attack of aggressive ions present in AS. (fig.3). When 18 Karat gold was immersed in AS containing fennel powder, the charge transfer resistance(R_t) value was 620410 ohm cm^2 (fig.4)

The double layer capacitance (C_{dl}) was 0.822×10^{-11} , and the impedance value $\log(Z/\text{ohm})$ was 5.937 (fig.4). These observations indicate that the corrosion resistance of 18 Karat gold in AS increased in the presence of fennel powder. The film formed on the metal surface prevented the loss of electrons 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.

Implication

People who make use of orthodontic wire made of 18 k gold can take orally fennel powder without any hesitation because in the presence of Artificial Saliva the corrosion resistance of 18K gold increases.

SUMMARY AND CONCLUSIONS

The corrosion resistance of 18K gold alloy in artificial saliva (AS) with and without of fennel powder was investigated using polarization studies and AC impedance spectra. The corrosion resistance of the 18 K gold alloy in artificial saliva increased in the presence of fennel powder. This was revealed by an increase in the LPR value, an increase in the R_t value, a decrease in the corrosion current, and a decrease in the double-layer capacitance value. Hence, it was concluded that people fitted with orthodontic wires made of 18 K gold alloy in artificial saliva need not hesitate to take orally fennel powder. (Table 3).

Table 3. Summary of the study

Corrosion parameters	Artificial Saliva (AS)	AS+ fennel powder (increases/decreases)
LPR	675061	1172719 (increases)
Rt	9027	620410 (increases)
Corrosion Current	1.127×10^{-7}	4.726×10^{-8} (decreases)
Double-layer Capacitance	6.4972×10^{-11}	0.822×10^{-11} (decreases)

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