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AN INVESTIGATION ON ELECTROCHEMICAL CORROSION RESISTANCE OF 18 K GOLD ALLOY IN ARTIFICIAL SALIVA IN THE PRESENCE OF CINNAMON POWDER

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Abstract: This study examines the electrochemical corrosion resistance of 18K gold alloy in artificial saliva with and without the addition of cinnamon powder, to assess its potential as a natural corrosion inhibitor in oral environments. Electrochemical techniques, including potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) were employed to study the corrosion behaviour. Corrosion parameters, including LPR, corrosion current (Icorr), Tafel slopes (βa and βc), were determined from polarization curves. Additionally, EIS measurements provided insights into the charge transfer resistance (Rt) and double-layer capacitance (Cdl) offering a comprehensive understanding of the corrosion process at the alloy–electrolyte interface. The results indicated that in the presence of cinnamon powder led to a significant decrease in Icorr and increase in LPR suggesting improved corrosion resistance. Moreover, the increased values of Rt, along with reduced Cdl, confirm the formation of a protective layer on the alloy surface, likely due to the adsorption of bioactive compounds in cinnamon. These findings suggest that cinnamon powder can act as an effective, eco-friendly corrosion inhibitor for dental alloys in simulated oral conditions.

Keywords: 18K gold alloy, electrochemical corrosion, artificial saliva, cinnamon powder, potentiodynamic polarization, electrochemical impedance spectroscopy (EIS).

I. INTRODUCTION

Many metals and alloys used to prepare orthodontic wires, these wires undergo corrosion in the oral environment especially saliva.

Tipanan Yanisarapan et al. have investigated the APF gel, which caused corrosion of metal orthodontic appliances, particularly affecting TMA archwires, leading to increased metal ion release, greater surface roughness, and reduced cell viability.[1].

H.S. Hafez *et al* and M. Karadas *et al.* have studied that corrosion compromises the mechanical properties of metal alloys by increasing surface roughness and decreasing mechanical strength [2], [3].

Chang, Y.-H., Pan, Y.-T., Chao, C.-Y., Lee, H.-E, Ju-Hui Wu has studied The results of this study indicate that a high gold content (75 mass%) in the bulk alloy does not provide superior corrosion resistance compared to certain noble or base metals when exposed to acidic artificial saliva with a pH of 3–6. [4].

Łosiewicz, B et al, have reported that TiO_2-ZrO_2 coatings on the surface of the Co-Cr-Mo dental alloy are effective in reducing pitting corrosion susceptibility, critical for the longevity and safety of dental devices. The findings underscore the potential of TiO_2-ZrO_2 sol–gel coatings in improving the performance of Co-Cr-Mo dental alloys in various oral environments [5].

Rebeka Rudolf et al have declared that the microalloying of Au by La initiates the formation of Au_6La at a small alloying concentration. Such microalloying increases the strength and hardness significantly, caused by the distribution of the primary phase between dendrites [6].

Anitha et al. have observed the corrosion resistance of 18K gold alloy in artificial saliva (AS), both with and without the presence of Éclairs milky candy, was investigated using polarization studies and AC impedance spectroscopy. The results indicate that the presence of Éclairs' milky candy enhances the corrosion resistance of the 18K gold alloy in artificial saliva [7].

The purpose of this study is to evaluate the electrochemical corrosion resistance of 18K gold alloy in artificial saliva, specifically assessing the influence of cinnamon powder on the alloy's corrosion behavior. This investigation aims to determine whether the presence of cinnamon, commonly found in dietary or oral care products, affects the durability and stability of dental materials made from 18K gold alloy under simulated oral conditions.

This study examines the influence of cinnamon powder on the corrosion resistance of 18K gold in artificial saliva, utilizing electrochemical techniques such as polarization and AC impedance spectroscopy.

II. EXPERIMENTAL METHODS

2.1 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, $CaCl_2 \cdot 2H_2O$-0.906 g/L, $NaH_2PO_4.2H_2O$-0.78g/L, $Na_2S.9H_2O$-0.05g/L, Urea-1g/L.

2.2 Preparation of Cinnamon powder:

About 0.5 g of cinnamon powder was accurately weighed and powdered.

2.3 Composition of cinnamon powder[9]

Cinnamon contains a range of resinous compounds, including cinnamaldehyde, cinnamate, cinnamic acid, and other essential oils.

2.4 Electrochemical study

2.4.1 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 ($Ecorr$), corrosion current ($Icorr$), Tafel slopes (βa and βc), and linear polarization resistance (LPR) were calculated.

2.4.2 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 (Cdl) were determined, while Bode plots were used to obtain the impedance.

$Rt = (Rs+Rt) - Rs$

Rs=solution resistance.

Cdl= values were calculated using the relationship

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

Where $fmax$= frequency at maximum imaginary impedance.

III. RESULTS AND DISCUSSION

3.1 Polarization study:

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

Table 1: Corrosion parameters of metals immersed in artificial saliva (AS) with and without Cinnamon 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} A/0.00785 cm^2
18 Karat gold	Artificial saliva	-0.373	4.684	6.510	1217534	3.190×10^{-8}
18 Karat gold	Artificial saliva + Cinnamon powder	-0.233	5.336	4.432	2522971	$1.764\ X10^{-8}$

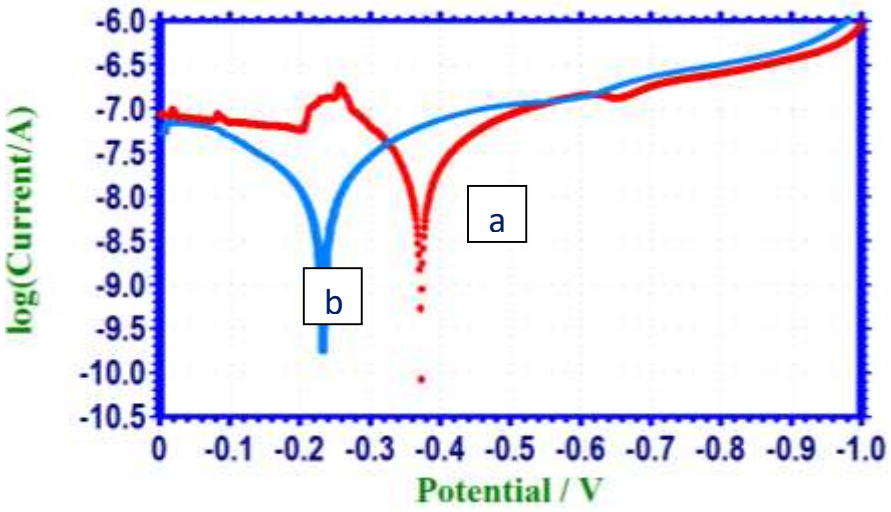

Figure 1. Polarization curves of 18 Karat Gold immersed in various test solution
a) AS b) AS+cinnamon powder

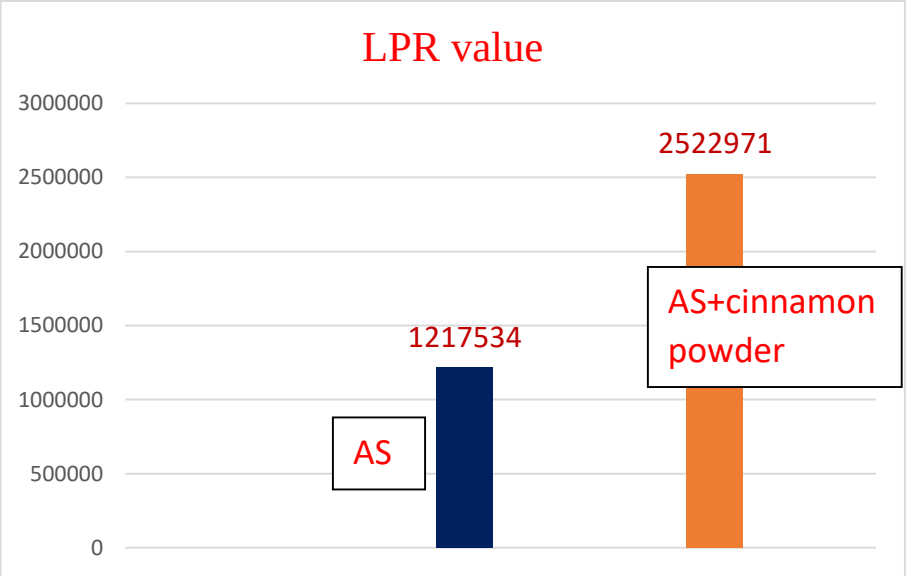

Figure 2. Comparison of LPR values of 18 K gold alloy immersed in artificial saliva (AS) with and without of cinnamon powder

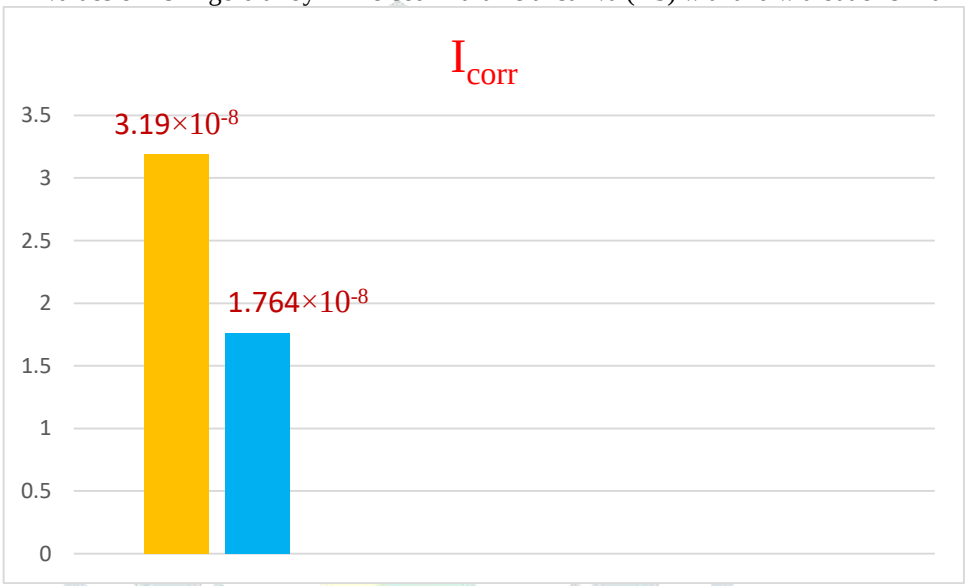

Figure 3. Comparison of Icorr values of 18 K Gold alloy immersed in artificial saliva (AS) with and without of cinnamon powder.

In the presence of Cinnamon 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 Cinnamon powder, the corrosion resistance of 18 Karat gold in artificial saliva increased.

3.1.1 Implication

The corrosion resistance of the 18 K gold alloy in artificial saliva increased in the presence of cinnamon 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 cinnamon powder orally.

3.2 Ac impedance spectra

The AC impedance spectra (Nyquist plot) of 18 Karat gold immersed in artificial saliva are shown in Figure 4 and AC impedance spectra (3D Interaction) of 18 Karat gold immersed in artificial saliva (AS) + cinnamon powder are shown in Figure 5. The AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva are shown in Figure 6, and the AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva (AS) + Cinnamon powder are shown in Figure 7. The corrosion parameters are compared in Figures 8 and 9, 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 metals immersed in artificial saliva (AS) with and without of Cinnamon powder, obtained from AC impedance spectra.

Metal	**System**	**Nyquist plot**		**Bode plot impedance log(Z/ohm)**
		R_t ohm cm^2	C_{dl} F/cm^2	
18 Karat gold	Artificial saliva	122938	$4.144X10^{-11}$	6.403
18 Karat gold	Artificial saliva + Cinnamon powder	767797	$6.642X10^{-11}$	6. 103

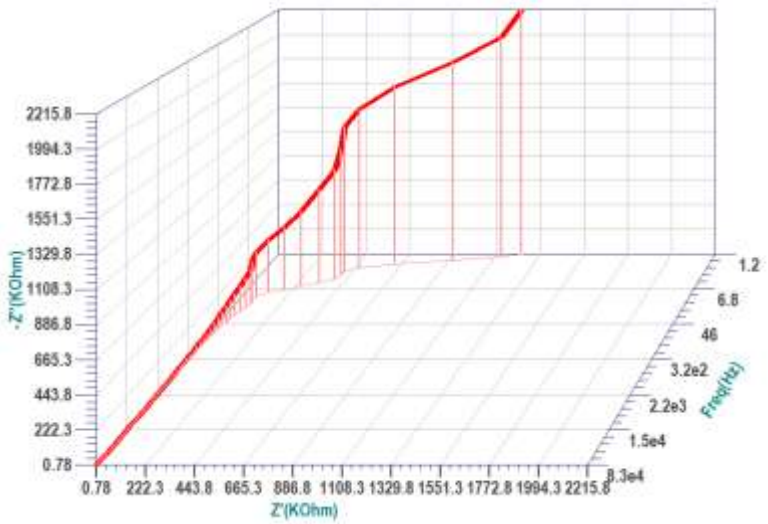

Figure 4: AC impedance spectra of 18 Karat gold immersed in artificial saliva.

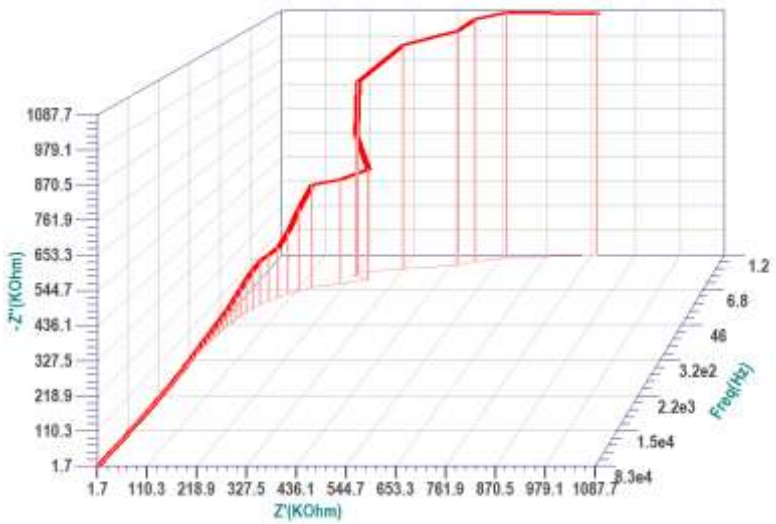

Figure 5: AC impedance spectra (3D Interaction) of 18 Karat gold immersed in artificial saliva (AS)+ Cinnamon powder

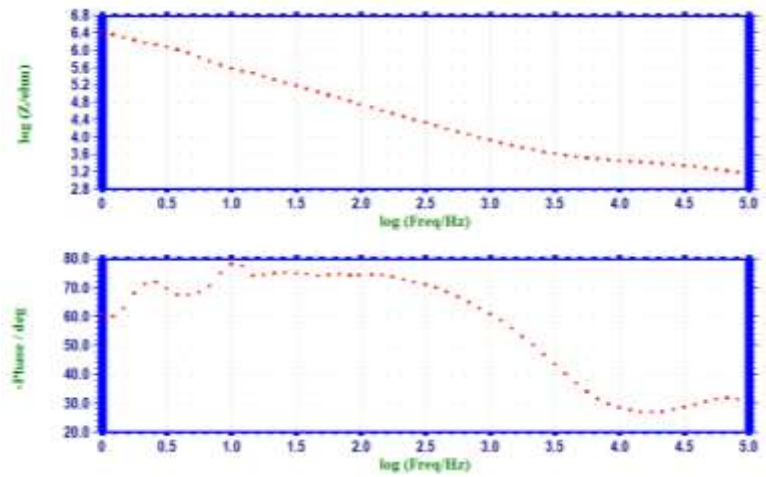

Fig 6. The AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva

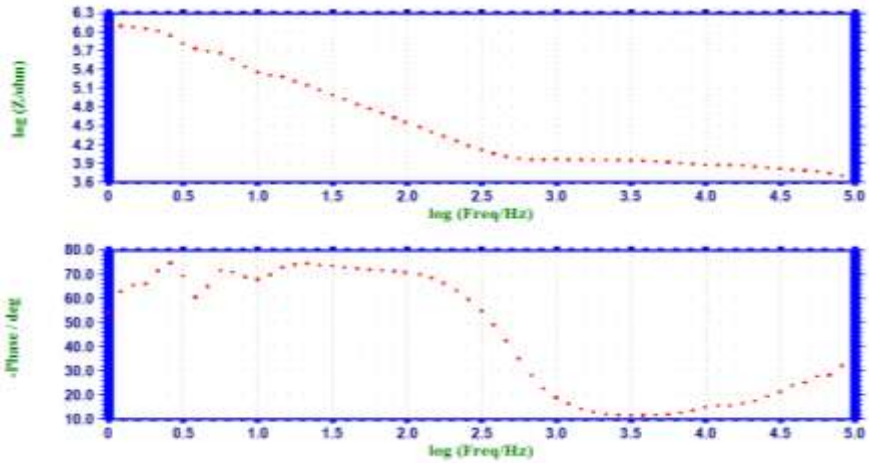

Figure 7. AC impedance spectra (Bode plot) of 18 Karat gold immersed in artificial saliva (AS)+ Cinnamon powder

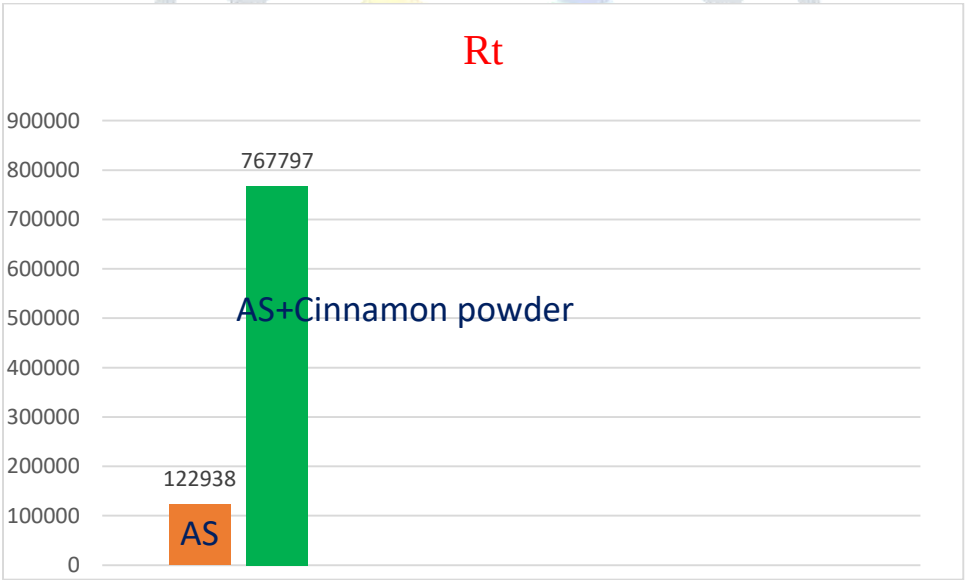

Figure 8. Comparison of Rt values of 18 K gold alloy immersed in artificial saliva (AS) with and without of cinnamon powder

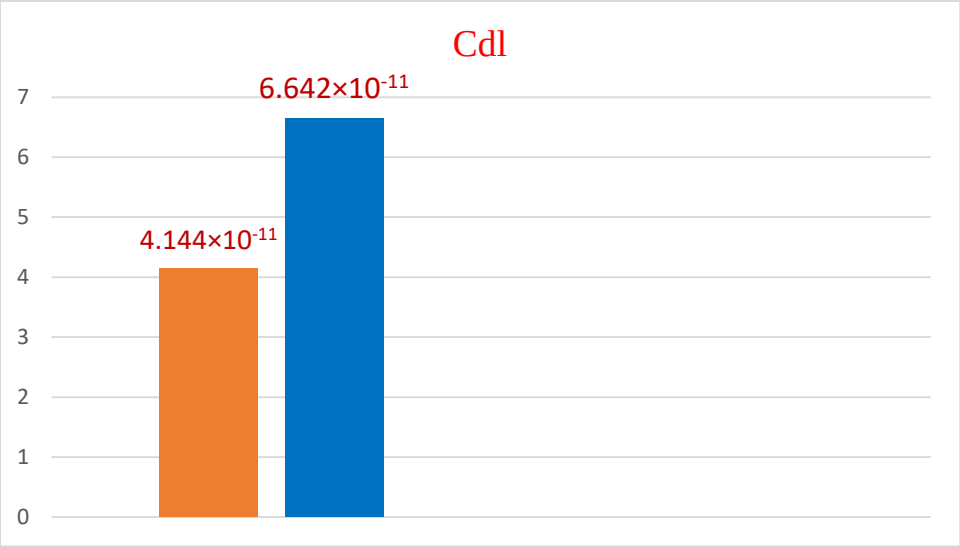

Figure 9. Comparison of C_{dl} values of 18 K gold alloy immersed in various test Solutions

When 18 Karat gold was immersed in AS, the charge transfer resistance (R_t) value was 122938 ohm cm^2 (Figure 2). The double layer capacitance (**C_{dl}**) was 4.144 X 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. (Figure 2). When 18 Karat gold was immersed in AS containing cinnamon powder, the charge transfer resistance(R_t) value was 767797 ohm cm^2 (Figure 3)

The double layer capacitance (**C_{dl}**) was 6.642X 10^{-11}, and the impedance value log(Z/ohm) was 6.103. (Figure 3). These observations indicate that the corrosion resistance of 18 Karat gold in AS increased in the presence of Cinnamon 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.

3.2.1 Implication

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

IV. SUMMARY AND CONCLUSIONS

The corrosion resistance of 18K gold alloy in artificial saliva (AS), with and without of cinnamon 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 cinnamon powder. This was revealed by an increase in the LPR value, an increase in the Rt 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 cinnamon powder. (Table 3).

Table 3. Summary of the study

Corrosion parameters	**Artificial Saliva (AS)**	**AS+ cinnamon powder (increases/decreases)**
LPR	435713	437277 **(increases)**
Rt	21356	160472 **(increases)**
Corrosion Current	2.026 x 10^{-7}	1.023 x 10^{-8}**(decreases)**

Double-layer Capacitance	2.406×10^{-10}	3.203×10^{-11}**(decreases)**

V. References

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