International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Electrochemical Studies on the Corrosion Behaviour of Orthodontic Wire Made of Ni –Cr Alloy in Artificial Saliva in the Presence of Cinnamon Powder

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Abstract
This study investigates the electrochemical corrosion behaviour of orthodontic wire made from nickel-chromium (Ni–Cr) alloy in artificial saliva (AS), with a specific focus on the effect of cinnamon powder. Electrochemical techniques including potentiodynamic polarization and AC impedance spectroscopy were employed to assess the corrosion resistance of the alloy in the absence and presence of cinnamon. Corrosion parameters, including corrosion potential (Ecorr), linear polarization resistance (LPR), and corrosion current (icorr), were obtained from the polarization measurements. Meanwhile, charge transfer resistance (Rt) and double layer capacitance (Cdl) were derived from the AC impedance spectra. The effect of cinnamon powder on the corrosion resistance of Ni-Cr in artificial saliva was also examined, and the corresponding corrosion parameters were compared.

Keywords: Corrosion Resistance, Ni-Cr alloy, Artificial Saliva, Cinnamon powder, Polarization study, AC impedance spectroscopy

1. Introduction

Currently, the demand for orthodontic treatment is increasing, making it one of the most significant areas in dental care [1]. A key component of this treatment is the orthodontic bracket, which is commonly made from stainless steel composed primarily of iron (Fe), chromium (Cr), and nickel (Ni)[2].

(A. S. Toloei, et al., 2014) have shown that both potentiodynamic polarization and EIS measurements of nickel samples in a 0.5 M H_2SO_4 solution indicate that the corrosion rate increases with higher levels of unidirectional surface roughness[3].

(Mary, et al., 2021) have investigated the electrochemical behavior of various implant biomaterials in the presence of different simulated body fluids[4].

Bioaccessibility of nickel and cobalt in powders and massive forms of stainless steel, nickel- or cobalt-based alloys, and nickel and cobalt metals in artificial sweat has been investigated by (Wang, et al., 2019)[5].

Daniel Mareci and Romeu Chelariu studied the corrosion behavior of titanium in artificial saliva, both

with and without lactic acid, using open-circuit potentials (OCP), polarization curves, and electrochemical impedance spectroscopy (EIS) [6].

Aleksandra Kocijan and Darja Kek Merl[7] have investigated the evolution of the passive films on 2205 duplex stainless steel (2205 DSS) and AISI 316L stainless steelin artificial saliva, and with the addition of fluoride, was studied using electrochemical impedance spectroscopy (EIS) and potentiodynamic measurement.

Doctors use orthodontic wires such as SS 18/8, Ni–Cr, Ni–Ti, SS 316 and 22K gold to regulate the teeth movement. These wires are exposed to corrosion in the saliva environment. Additionally, they are susceptible to corrosion caused by food, beverages, candies, and orally consumed medications.

The present study aims to investigate the effect of cinnamon powder on the corrosion resistance of Ni-Cr alloy in artificial saliva using electrochemical techniques, including polarization studies and AC impedance spectroscopy.

2. EXPERIMENTAL METHODS

Preparation of the metal specimens

A thin wire of Ni-Cr alloy was used as the test material in this work. Ni-Cr alloy consists of 75 parts of Ni, 15 parts of chromium, 5 parts of Molybdenum, and 1.5 parts of beryllium.

The preparation of artificial Saliva was done using the composition of Fusayama Meyer's artificial saliva [8]. Artificial saliva was prepared in the laboratory, and the composition of artificial saliva was as follows: KCl-0.4g/L, NaCl-0.4g/L, $CaCl_2 \cdot 2H_2O$-0.906g/L, $NaH_2PO_4.2H_2O$-0.78g/L, $Na_2S.9H_2O$-0.05g/L, Urea-1g/L.

Preparation of Cinnamon powder:

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

Composition[9]

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

Electrochemical study

In the present work, the corrosion resistance of Ni-Cr alloy immersed in various test solutions was measured by polarization study and AC impedance spectra. In the present exploration, polarization studies were carried out in a CHI Electrochemical work station/analyzer, model 604 E.

Polarization study

Polarization studies were carried out in a three-electrode cell assembly. A SCE was the reference electrode. Platinum was the counter electrode. Ni-Cr alloy was the working electrode. From polarization study, corrosion parameters such as corrosion potential (Ecorr), corrosion current (icorr), Tafel slopes anodic=ba, and cathodic=bc and LPR (linear polarization resistance) values were measured.

AC impedance spectra

In the present investigation, the same instrument and set-up used for polarization study were used to record AC impedance spectra. A time interval of 5 to 10 minutes 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. AC impedance spectra were recorded with initial E(v)=0, high frequency (Hz=1·105), low frequency (Hz=1), amplitude (V) = 0.005 and quiet time (s) = 2. From Nyquist plot, the values of charge transfer resistance (Rt) and double layer capacitance (Cdl) were calculated. From the Bode plots, impedance values were calculated.

3. RESULTS AND DISCUSSION

Polarization study

The influence of cinnamon powder on the corrosion resistance of Ni-Cr alloy in artificial saliva (AS) has been investigated by polarization study.

The Polarization curves of Ni-Cr alloy in AS in the absence and presence of cinnamon powder are shown in Figure 1. The corrosion parameters are given in Table 1. The corrosion parameters are compared in Figures 2 and 3.

Table 1 : Corrosion parameters of Ni-Cr alloy immersed in artificial saliva (AS) in the absence and presence of 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
Ni -Cr	Artificial saliva	-0.548	5.144	3.910	345908	$1.388x10^{-7}$
Ni –Cr	Artificial saliva + cinnamon powder	-0.563	5.467	3.922	434820	$1.065 X10^{-7}$

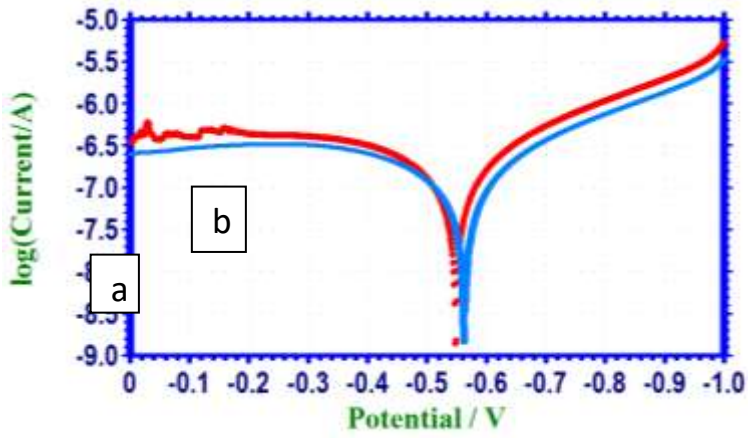

Figure 1: Polarization curves of Ni- Cr alloy immersed in various test solutions.

a) AS b) As+Cinnamon powder

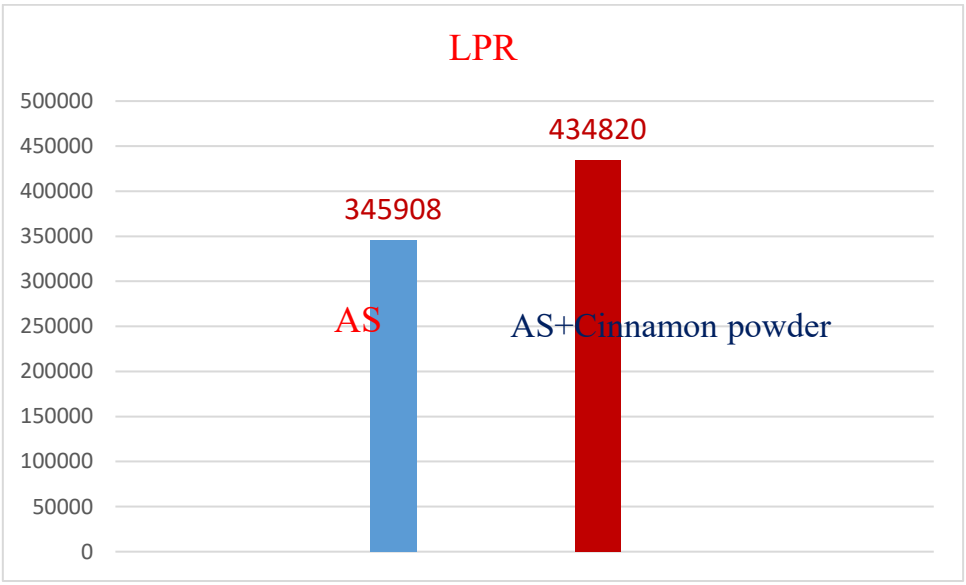

Figure 2. Comparison of LPR values of Ni-Cr alloy immersed in artificial saliva (AS) in the presence and absence of cinnamon powder

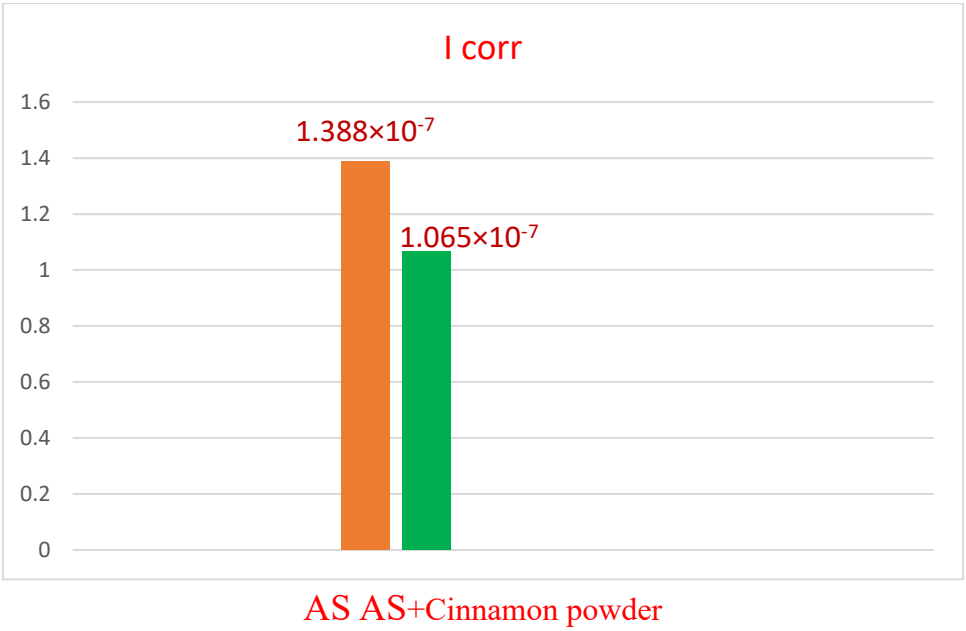

Figure 3. Comparison of Icorr values of Ni-Cr alloy immersed in artificial saliva (AS) in the presence and absence of cinnamon powder.

In the presence of Cinnamon powder, the corrosion resistance of Ni- Cr in Artificial Saliva increased. This was revealed by the increase in LPR value and decrease in corrosion current.

Thus, polarization study has led to the conclusion that in the presence of Cinnamon powder, the corrosion resistance of Ni –Cr in artificial saliva increased.

AC Impedance spectra

The AC impedance spectra of Ni-Cr alloy in AS in the absence and presence of cinnamon powder are shown in Figures 4-7. The Nyquist plots are shown in Figures 4 and 5. The Bode plots are shown in Figures 6and 7. The corrosion parameters are compared in Figures 8 and 9.

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

Table 2: Corrosion parameters of Ni-Cr alloy immersed in artificial saliva (AS) in the absence and presence of Cinnamon powder obtained by polarization study.

Metal	System	Nyquist plot		Bode plot impedance log(Z/ohm)
		R_t ohm cm^2	C_{dl} F/cm^2	
Ni -Cr	Artificial saliva	60339	$5.5443X10^{-11}$	5.220
21 Karat gold	Artificial saliva + Cinnamon powder	91986	$5.330X10^{-11}$	5.330

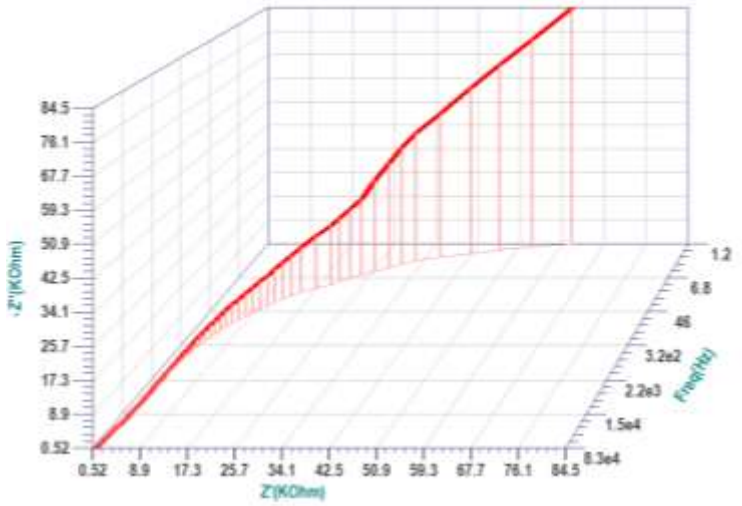

Figure 4: AC impedance spectra of Ni-Cr alloy immersed in artificial saliva

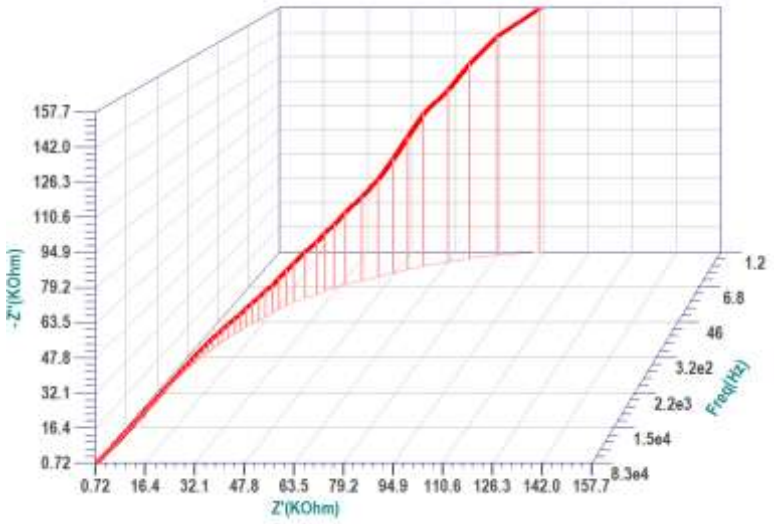

Figure 5: AC impedance spectra (3D Interaction) of Ni-Cr immersed in artificial saliva (AS)+ Cinnamon powder

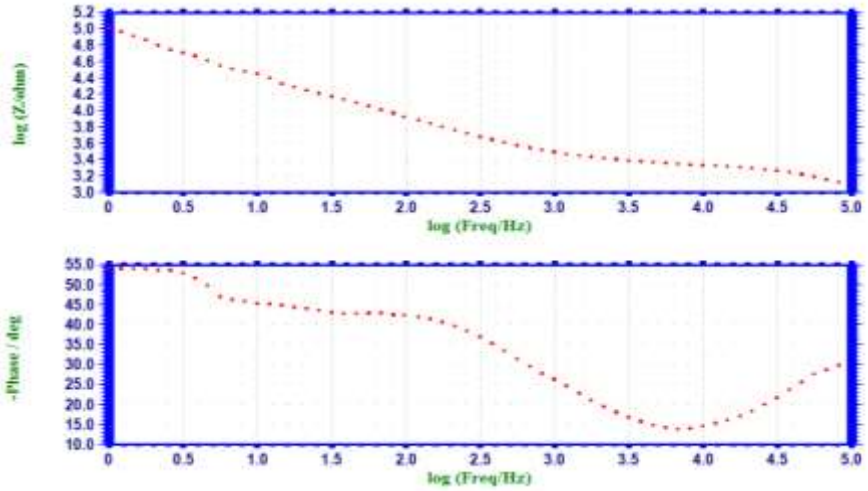

Fig 6. The AC impedance spectra (Bode plot) of Ni-Cr immersed in artificial saliva

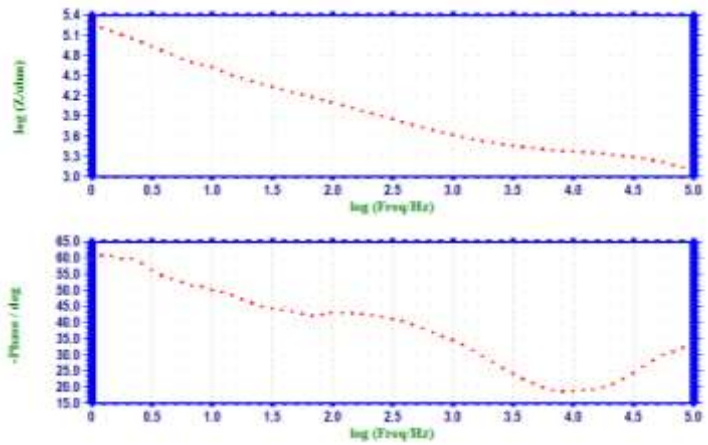

Fig 7. AC impedance spectra (Bode plot) of Ni-Cr immersed in artificial saliva (AS)+ Cinnamon powder

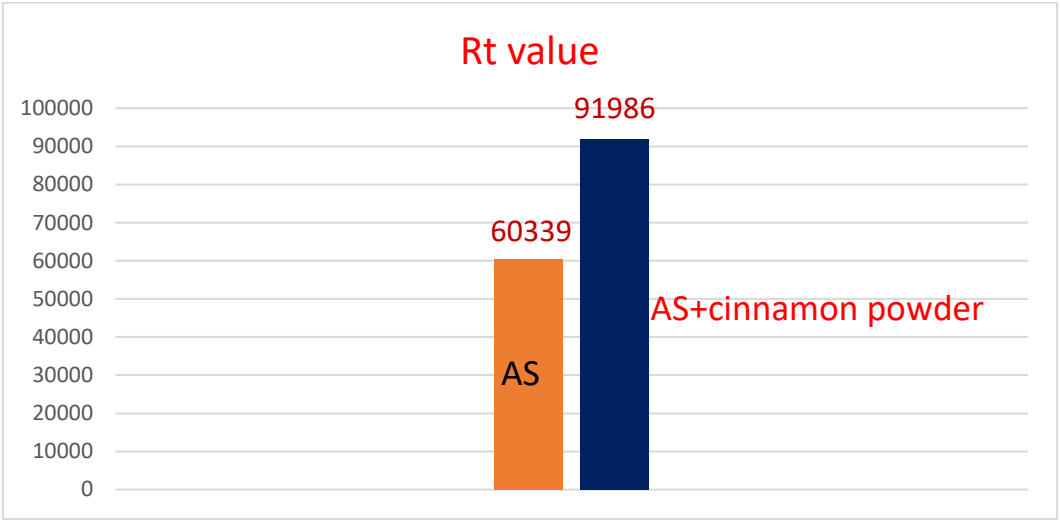

Figure 8. Comparison of Rt values of Ni-Cr alloy immersed in artificial saliva (AS) in the presence and absence of cinnamon powder

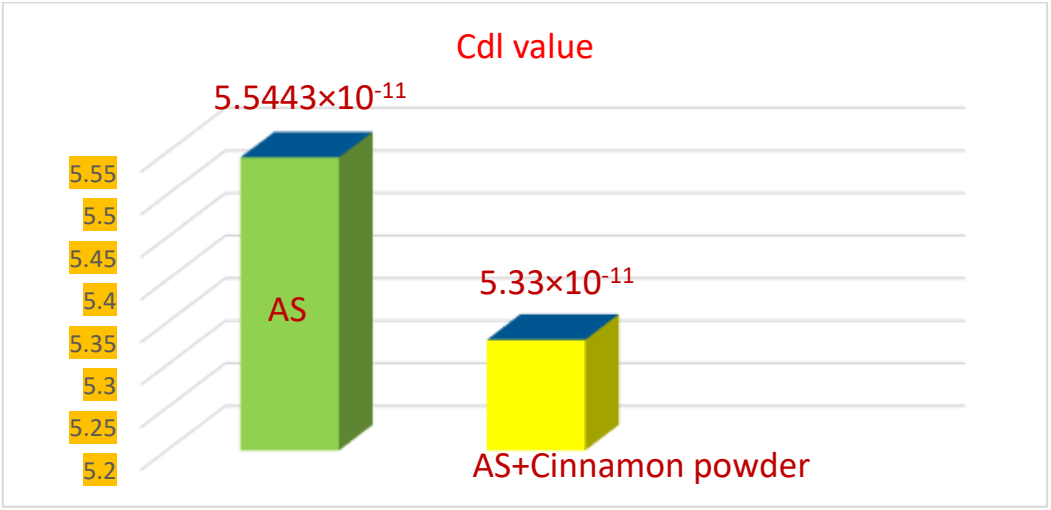

Figure 9. Comparison of Cdl values of Ni-Cr alloy immersed in artificial saliva (AS) in the presence and absence of cinnamon powder

When Ni-Cr alloy was immersed in AS, the charge transfer resistance(R_t) value was 60339 ohm $cm^{2.}$ The double layer capacitance (C_{dl}) was 5.5443 X $10^{-11,}$ and the impedance value log(Z/ohm) was 5.220. These observations indicate the protective film formed on Ni –Cr electrode was more stable. When Ni-Cr alloy was immersed in AS containing cinnamon powder, the charge transfer resistance(R_t) value was 91986 ohm $cm^{2.}$

The double layer capacitance (C_{dl}) was 5.33X 10^{-11}, and the impedance value log(Z/ohm) was 5.330. These observations indicate that the corrosion resistance of Ni-Cr in AS increased in the presence of Cinnamon powder. The film formed on the metal surface 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.

Implication:

People who make use of orthodontic wire made of Ni-Cr alloy can take orally cinnamon powder without any hesitation because Artificial Saliva in the presence of cinnamon powder the corrosion resistance of Ni – Cr alloy increases.

4. SUMMARY AND CONCLUSIONS

Corrosion resistance of Ni-Cr alloy in artificial saliva (AS), in the presence of cinnamon powder, was investigated using polarization studies and AC impedance spectra. The corrosion resistance of the Ni-Cr 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 Ni-Cr 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	345908	434820 **(increases)**
Rt	60339	91986 **(increases)**
Corrosion Current	$1.388x10^{-7}$	$1.065\ X10^{-7}$ **(decreases)**
Double-layer Capacitance	$5.5443X10^{-11}$	$5.330X10^{-1}$ **(decreases)**

6. References

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