

Research Article

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## Influence of Metformin Hydrochloride- 250 mg (MFH) tablet on Corrosion Resistance of orthodontic wire made of NiCr alloy in Artificial Saliva

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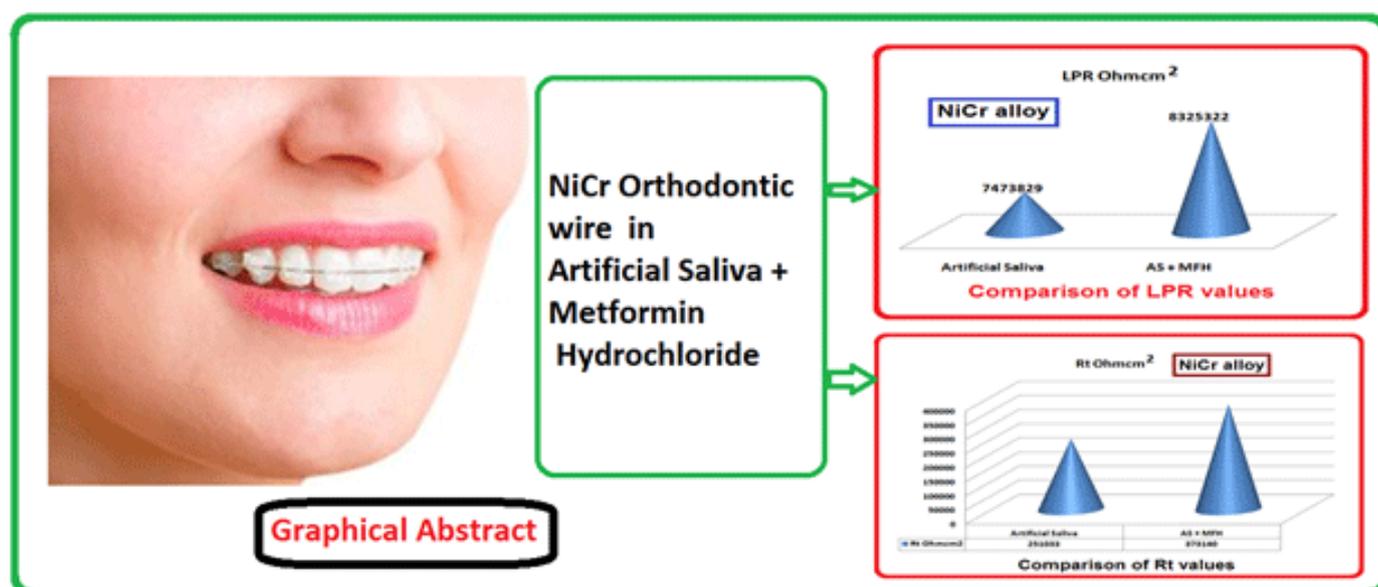
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### Abstract

The corrosion resistance of orthodontic wire made of NiCr alloy in artificial saliva, in the absence and presence of Metformin Hydrochloride- 250 mg (MFH) has been evaluated by polarization study and AC impedance spectra. Polarisation study reveals that in the presence of Metformin Hydrochloride- 250 mg (MFH), linear polarisation resistance (LPR) value increases and corrosion current decreases. That is, in presence of Metformin Hydrochloride- 250 mg (MFH), the corrosion resistance of NiCr alloy in artificial saliva increases. AC impedance study reveals that in the presence of Metformin Hydrochloride- 250 mg (MFH), Charge transfer resistance ( $R_t$ ) value increases and double layer capacitance value ( $C_{dl}$ ) decreases. That is in the presence of Metformin Hydrochloride- 250 mg (MFH) the corrosion resistance of NiCr alloy in AS increases. It is concluded that people clipped with orthodontic wire made of NiCr alloy need not vacillate to take Metformin Hydrochloride- 250 mg (MFH) orally.

**Keywords:** Artificial Saliva; Corrosion; Metformin Hydrochloride- 250 mg (MFH); Orthodontic Wires; NiCr Alloy; Electrochemical Studies



## Introduction

Symmetry leads to beauty. Beautiful objects are symmetrical in nature. 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 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 [1-10].

Kamiński et al. have investigated the corrosion resistance orthodontic arch-wires AISI304 steel in artificial saliva 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 snakefruit 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 found 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 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 presence of watermelon rind extract increases [4]. Corrosion behavior of stainless steel and three types of NiTi orthodontic wires in artificial saliva in the presence of *Lactobacillus reuteri* has been studied by Musa Trolic et al. It was observed that the added substances from probiotic supplement are accountable for the localized corrosion of studied wires [5]. The effect of oral antiseptics on the corrosion of nickel-titanium (NiTi) alloys with various coating was investigated by Rincic Mlinaric et al., It is concluded that in most cases changes of mechanical characteristics induced by antiseptics are small and would not have a clinically significant impact [6]. The consequences of simulated erosive conditions on the frictional behavior of different orthodontic bracket-wire combinations have been investigated by Stefański et al., [7]. It has been observed that erosive conditions do not affect the frictional behavior of SS, Ni-Ti and TMA orthodontic archwires at a clinically significant level. Simionescu et al. have studied corrosion resistance of 316L stainless steel for orthodontic applications in artificial saliva by using electrochemical studies. It

is observed that the corrosion resistance is high when pH is low and chloride ion concentration is less [8]. Effect of fruit juices and chloride ions on the corrosion behavior of AISI 316L stainless steel orthodontic archwire has been investigated by electrochemical studies by Sharma et al., There is formation of blisters onto the steel surface which are remnants of passive film. This is confirmed by SEM Micrographs of the specimens [9]. Electrochemical study on the corrosion behavior of AISI 316L stainless steel orthodontic archwire in different fruit juices has been carried out. Surface analytical techniques such as SEM and AFM were also employed. It was noticed that pitting corrosion was controlled [10].

Recent works on corrosion resistance of orthodontic wires made of various alloys in presence of various media are given in Table A.

After clipping with various types of orthodontic wires, people take many tablets during their ailments. During this treatment the orthodontic wires may undergo corrosion. This is an interesting aspect to be investigated.

In the present work corrosion resistance of NiCr alloy in artificial saliva in presence and absence of Metformin Hydrochloride- 250 mg (MFH) tablet has been investigated.

## Materials and methods

### Preparation of the metal specimens

A thin wire metal specimen namely NiCr alloy is utilized as test material for this work. This wire is used as orthodontic wire. NiCr alloys contain generally 69–81% nickel.

### Procedure

The orthodontic wire was encapsulated in Teflon rod. Prior to the surface treatment, the specimens were subjected to surface polishing. They were degreased with trichloroethylene followed by mechanical polishing with different polishing papers (Course, Medium, Fine and Extra fine). The specimens were rinsed with ethanol followed by distilled water and dried with a clean tissue paper. Finally the specimens were kept in desiccators until use.

### Preparation of artificial saliva

The corrosion resistance of orthodontic wire made of NiCr alloy in artificial saliva (AS) was evaluated in the absence and presence of Metformin Hydrochloride- 250 mg (MFH) tablet. The preparation of artificial saliva was done using the composition of Fusayama Meyer artificial saliva (AS). Artificial saliva was prepared in laboratory and the composition of artificial saliva was as follows:

KCl - 0.4 g/lit, NaCl - 0.4 g/lit, CaCl<sub>2</sub>.2H<sub>2</sub>O - 0.906 g/lit, NaH<sub>2</sub>PO<sub>4</sub>.2H<sub>2</sub>O - 0.690 g/lit, Na<sub>2</sub>S<sub>9</sub>H<sub>2</sub>O - 0.005 g/lit, urea - 1 g/lit.

**Table A:** Summary of recent works on corrosion resistance of orthodontic wires made of various alloys in presence of various media

SNo	Orthodontic wire/ material	Medium/Method/Treatment	Findings	Ref
1	Orthodontic arch-wires AISI304 steel	before and after low temperature plasma nitriding carried out at cathodic potential (conventional) and at plasma potential Corrosion resistance of Orthodontic arch-wires AISI304 steel inartificial saliva solution at 37°C, determined by electrochemical studies	An increase in corrosion resistance of AISI304 steel after conventional glow-discharge nitriding observed	1
2	New Type Titanium Alloy, Ti-29Nb-13Ta-4.6Zr, commercial Ti6Al4V ELI	In artificial saliva on fluctuating temperatures range between 10°C and 50°C by immersion testing.	Corrosion rate increases. Hardness of metal decreases.	2
3	Stainless steel orthodontic wire	The purpose of this investigation was to determine the effect snake fruit extract (Salacca zalacca) in inhibiting the release of chromium (Cr) and nickel (Ni) ions from stainless steel orthodontic wire to saliva. Cr and Ni ion release was measured using Atomic Absorption Spectrophotometer.	Snake fruit seeds extract successfully inhibits the Ni ions release from stainless steel orthodontic wire at a concentration of 300 ppm.	3
4	stainless steel orthodontic wire	Aim of the study was to determine the effectiveness of watermelon rind extract as corrosion inhibitor in stainless steel orthodontic wire. Electrochemical study was employed.	Watermelon rind has the inhibiting effect on stainless steel orthodontic wire's corrosion rate.	4
5	Stainless steel and three types of NiTi orthodontic wires.	The intend of this work was to examine the influence of probiotic supplements, recommended for use in orthodontic patients, on the corrosion stability of stainless steel and three types of NiTi orthodontic wires.	The added substances from probiotic supplement are responsible for the localized corrosion of studied wires rather than probiotic bacteria <i>L. reuteri</i> alone.	5
6	Nickel –titanium (NiTi) alloys	The effect of oral antiseptics on the corrosion of nickel–titanium (NiTi) alloys with various coating, inartificial saliva at pH 4.8. Spring back ratio and modulus of resilience were assessed by three-point bending test.	It is concluded that except for Listerine, changes of mechanical characteristics induced by antiseptics are small and would not have a clinically important impact.	6
7	Three types of twin orthodontic brackets (stainless steel (SS), monocystal-line ceramic and titanium) and 3 types of archwires of the same dimension (SS, nickel-titanium (Ni-Ti) and beta-titanium (titanium-molybdenum alloy – TMA)	The aim was to investigate the effect of simulated erosive conditions on the frictional behavior of different orthodontic bracket-wire combinations. Static and kinetic frictions were determined by measuring the force needed to move the wire through the bracket. A three-way analysis of variance and pair wise comparisons with the Student–Newman–Keuls test were performed.	Erosive conditions do not affect the frictional behavior of SS, Ni-Ti and TMA orthodontic archwires at a clinically significant level.	7
8	316L stainless steel for orthodontic applications	Electrochemical in vitro properties investigated in artificial saliva solutions	It is inferred that the increase of the pH with a higher concentration of chloride contents leads to a lowest corrosion resistance while a decrease of the pH with a lowest concentration of chlorides contents reveals a higher corrosion resistance.	8
9	AISI 316L stainless steel orthodontic archwire in different fruit juices	Effect of fruit juices and chloride ions on the corrosion behavior of orthodontic archwire has been investigated by electrochemical studies.	SEM Micrographs of the specimens show formation of blisters onto the steel surface which are remnants of passive film. <i>Solanum lycopersicum</i> (Tomato) and <i>Durio zibethinus</i> (Amra) are rated as most detrimental to the surface followed by <i>Prunus domestica</i> Linn. (Plum) juice.	9
10	Orthodontic archwire	Analysis of the surface geometry of the orthodontic archwire and their influence on the bacterial adhesion has been investigated. SEM/EDS analysis, AFM and Confocal Microscopy were presented. The pitting corrosion test and surface roughness and micro hardness measurements were performed.	The oral environment is an extremely aggressive corrosive environment. The orthodontic elements should have very good corrosion resistance and biocompatibility.	10

*Metformin Hydrochloride- 250 mg (MFH)* is used with a proper diet and exercise program and possibly with other medications to control high blood sugar. It is used in patients with type 2 diabetes. Controlling high blood sugar helps prevent kidney damage, blindness, nerve problems, loss of limbs, and sexual function

problems [11].

#### Potentiodynamic polarization study

Polarization studies were carried out in a CHI Electrochemical

work station I analyzer, model 660A. It was provided with automatic *i*R compensation facility. A three electrodes cell assembly was used. The working electrode was NiCr alloy. A saturated calomel electrode (SCE) was the reference electrode and Platinum was the counter electrode. From the polarization study, corrosion parameters such as corrosion potential ( $E_{\text{corr}}$ ), corrosion current ( $I_{\text{corr}}$ ), Tafel slopes ( $b_a$  and  $b_c$ ) and linear polarization resistance (LPR) were calculated. During the polarization study, the scan rate (V/s) was 0.01; Hold time at Ef(s) was zero and quiet time (s) was two.

### AC impedance spectra

AC impedance studies were carried out in electrochemical impedance work station analyzer model CHI 660A three electrodes cell assembly was used. The working electrode was used as NiCr alloy. A saturated calomel electrode (SCE) was used as the reference electrode and a rectangular platinum foil was used as the counter electrode. The real part ( $Z'$ ) and imaginary part ( $Z''$ ) of the cell impedance were measured in ohms at various frequencies. The corrosion parameters such as charge transfer resistance ( $R_t$ ) and the double layer capacitance ( $C_{dl}$ ) were calculated. During AC impedance spectra were recorded the scan rate (V/s) was 0.005; Hold time at Ef(s) was zero and quiet time (s) was 2.  $C_{dl}$  values were calculated using the following relationship.  $R_t = (R_s + R_p) - R_s$  and  $C_{dl} = 1/2\pi R_t f_{\text{max}}$ .

Where  $R_s$  is the solution resistance and  $f_{\text{max}}$  is the frequency at maximum imaginary impedance.

## Results and discussion

### Influence of Metformin Hydrochloride- 250 mg (MFH) on NiCr alloy

#### Analysis of potentiodynamic polarization study

Corrosion resistance of NiCr alloy in artificial saliva in presence of Metformin Hydrochloride- 250 mg (MFH) is given in the Table 1. The polarization curves of NiCr alloy immersed in various test solutions are shown in Figures 1 and 2. The Linear polarization resistance values of NiCr in artificial saliva in the absence and presence of Metformin Hydrochloride- 250 mg (MFH) tablet are compared in Table 2 and graphically shown in Figure 3.

It is observed from Table 1 that when NiCr alloy is immersed in artificial saliva,  $E_{\text{corr}}$  (corrosion potential) is -0.540 V vs SCE. The corrosion current ( $I_{\text{corr}}$ ) is  $5.176 \times 10^{-9}$  A/cm<sup>2</sup>. Cathodic Tafel slope

( $b_c$ ) is 7.272 V/decade. The anodic Tafel slope ( $b_a$ ) is 4.165 V/decade. The linear polarization resistance (LPR) is 7473829 ohmcm<sup>2</sup>.

### Influence of Metformin Hydrochloride- 250 mg (MFH)

When Metformin Hydrochloride- 250 mg (MFH) is added to artificial saliva, the corrosion potential ( $E_{\text{corr}}$ ) is -0.486. The corrosion current ( $I_{\text{corr}}$ ) is  $4.771 \times 10^{-9}$  A/cm<sup>2</sup>. Cathodic Tafel slope ( $b_c$ ) is 7.029 V/decade. The anodic Tafel slope ( $b_a$ ) is 3.917 V/decade. The linear polarization resistance (LPR) is 8325322 ohm cm<sup>2</sup>.

It is observed from the Table 1 that when Metformin Hydrochloride- 250 mg (MFH) is added to AS, The LPR value increases from 7473829 ohm cm<sup>2</sup> to 8325322 ohm cm<sup>2</sup>. The corrosion current decreases from  $5.176 \times 10^{-9}$  to  $4.771 \times 10^{-9}$  A/cm<sup>2</sup>.

This indicates that in presence of Metformin Hydrochloride- 250 mg (MFH), the corrosion resistance of NiCr alloy in artificial saliva increases [12-16]. It must be recollected that when corrosion resistance increases, linear polarisation resistance value increases and corrosion current values decreases [12-16]. Hence people clipped with orthodontic wire made of NiCr alloy need not hesitate to take Metformin Hydrochloride- 250 mg (MFH) orally.

### Implication

It is concluded that people clipped with orthodontic wire made of NiCr alloy need not hesitate to take Metformin Hydrochloride- 250 mg (MFH) orally.

### Analysis of AC impedance spectra

The AC impedance parameters of NiCr alloy immersed in various test solutions are given in Table 3. The Nyquist plots are shown in Figure 4 and Figure 5. The Bode plots are shown in Figures 6 and 7. The charge transfer resistance ( $R_t$ ) and double layer capacitance values ( $C_{dl}$ ) are derived from Nyquist plot. The impedance values are derived from Bode plot.

The charge transfer resistance ( $R_t$ ) values of NiCr alloy in artificial saliva in the absence and presence of Metformin Hydrochloride- 250 mg (MFH) tablet are compared in Table 4 and graphically in Figure 8.

When NiCr alloy is immersed in artificial saliva,  $R_t$  (charge transfer resistance) value is 251033 ohmcm<sup>2</sup>.  $C_{dl}$  (double layer capacitance) is  $2.0316 \times 10^{-11}$  F/cm<sup>2</sup>. Impedance is  $5.950 \log z/$

**Table 1:** Corrosion parameters of NiCr alloy immersed in artificial saliva (AS) in the absence and presence of Metformin Hydrochloride-250 mg (MFH) obtained by polarization study

System	E corr V SCE	bc V/decade	ba V/decade	LPR Ohmcm <sup>2</sup>	Icorr A/cm <sup>2</sup>
Artificial Saliva	-0.540	7.272	4.165	7473829	$5.176 \times 10^{-9}$
AS + Metformin Hydrochloride- 250 mg	-0.486	7.029	3.917	8325322	$4.771 \times 10^{-9}$

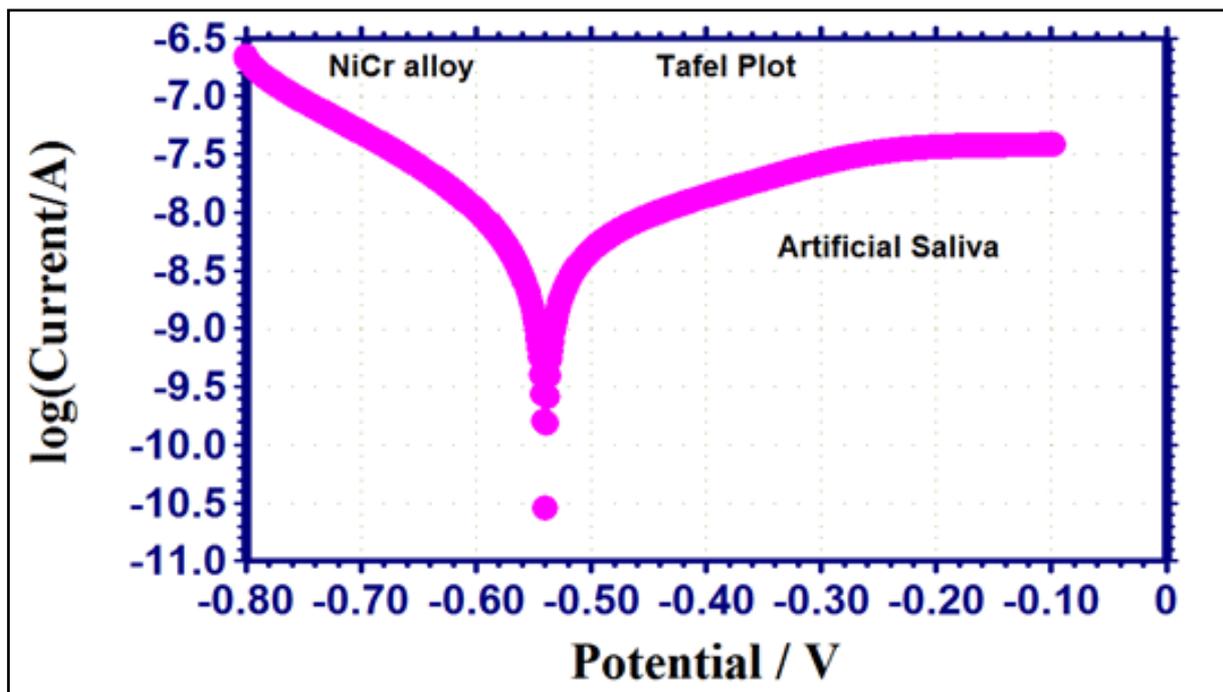


Figure 1: Polarization curve of NiCr alloy immersed in Artificial Saliva

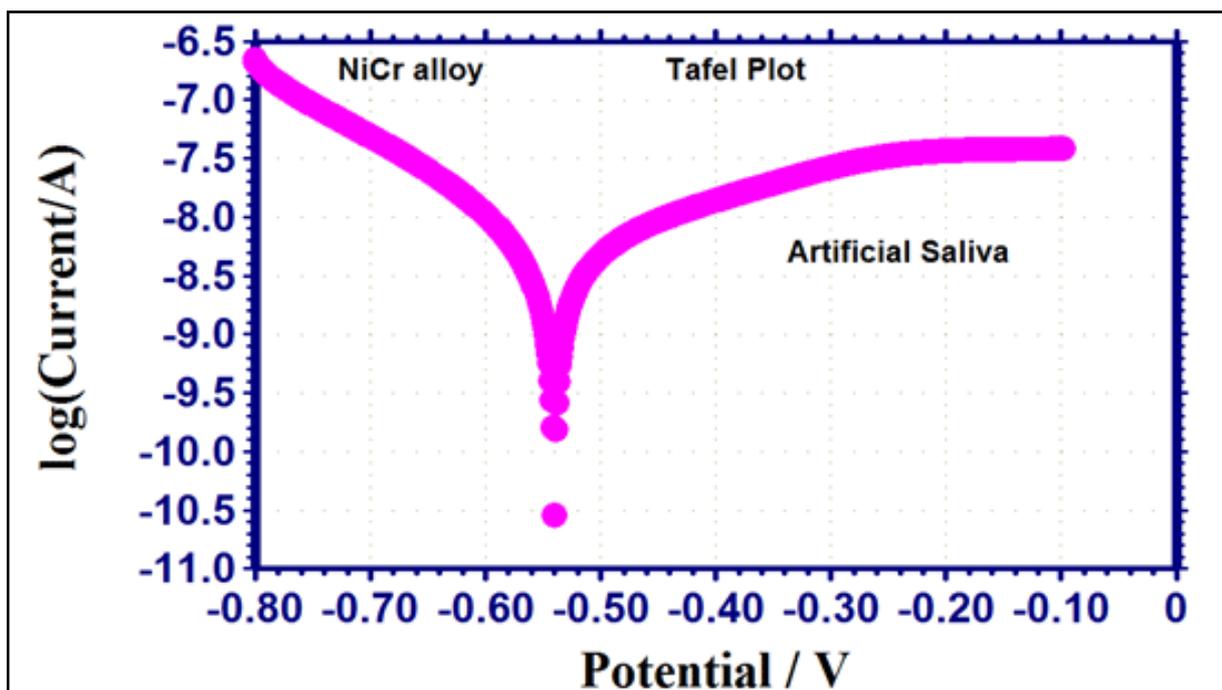


Figure 2: Polarization curve of NiCr alloy immersed in artificial saliva in the presence of Metformin Hydrochloride- 250 mg

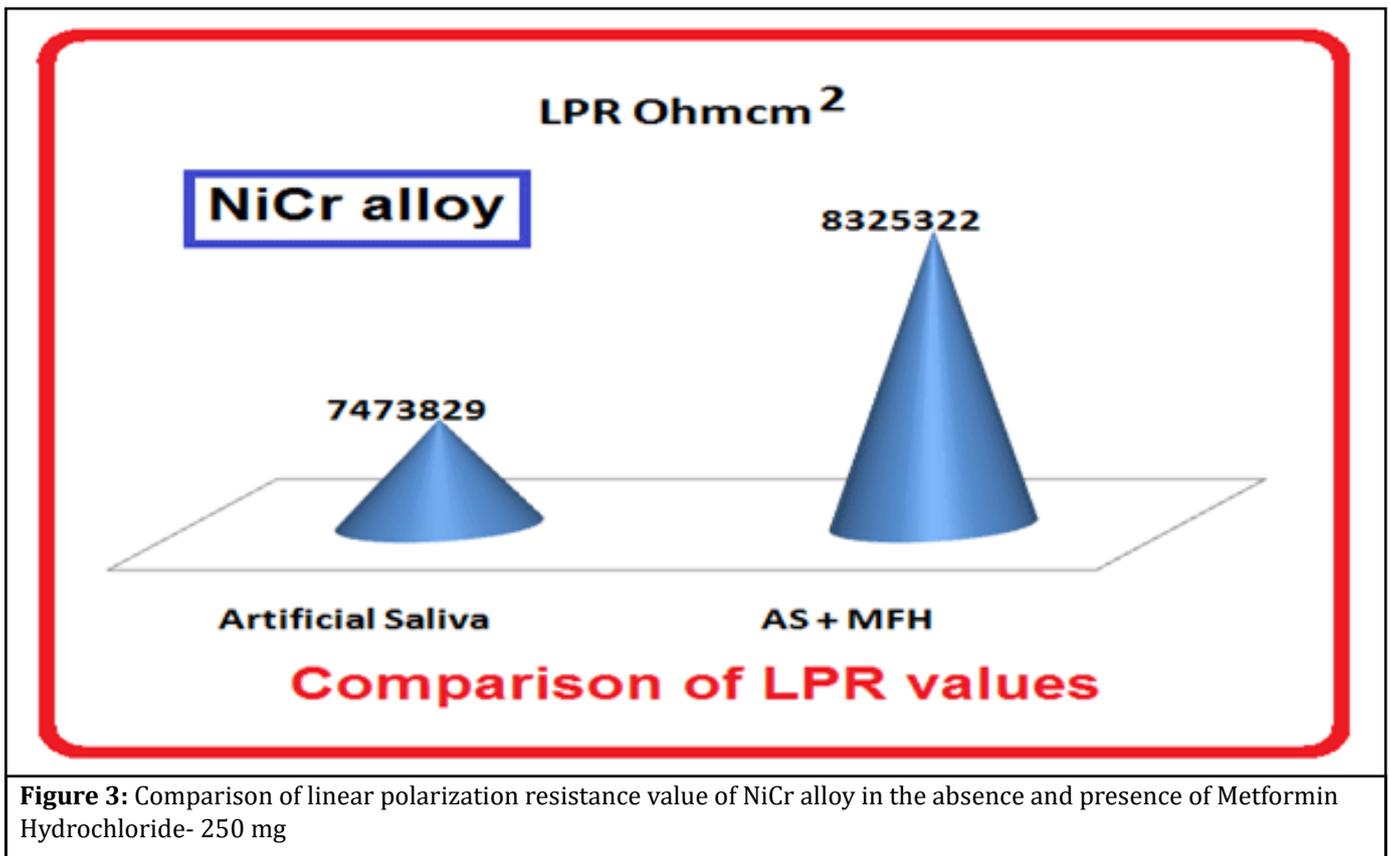
**Table 2:** Comparison of linear polarization resistances of NiCr alloy immersed in artificial saliva (AS) in the absence and presence of Metformin Hydrochloride- 250 mg

System	LPR Ohmcm <sup>2</sup>
Artificial Saliva	7473829
AS + MFH	8325322

ohm.

#### Influence of Metformin Hydrochloride- 250 mg (MFH)

When Metformin Hydrochloride- 250 mg (MFH) is added to artificial saliva, the corrosion potential  $R_t$  (charge transfer resistance) is 373140 ohm cm<sup>2</sup>.  $C_{dl}$  (double layer capacitance) is  $1.3667 \times 10^{-11}$  F/cm<sup>2</sup>. Impedance is 5.952 log z/ohm. It is observed from the Table 3 that when Metformin Hydrochloride- 250 mg (MFH) is added to AS, the  $R_t$  value increases from 251033 to 373140

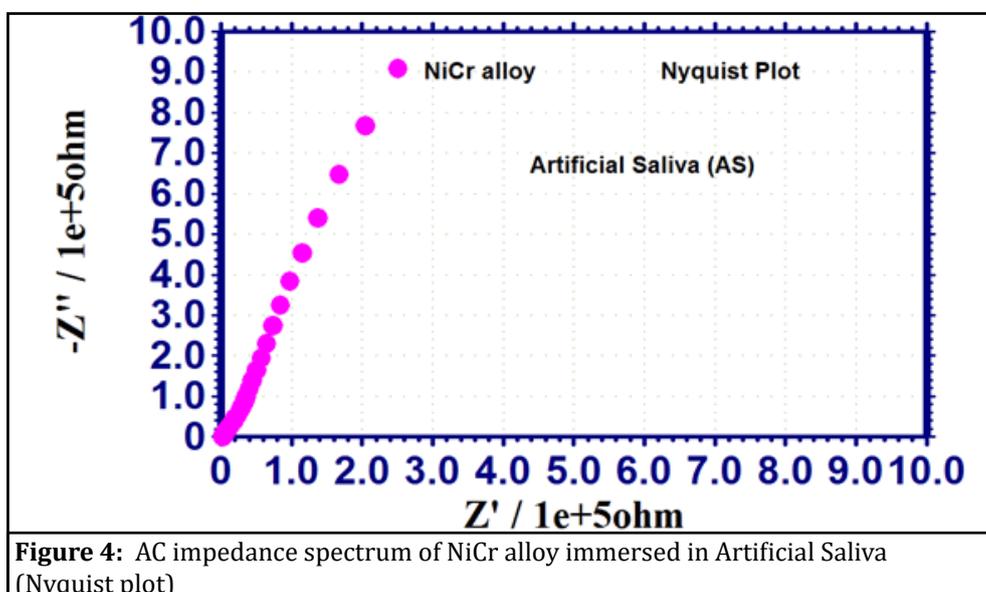


**Table 3:** Corrosion parameters of NiCr alloy immersed in Artificial Saliva (AS) in the absence and presence of Metformin Hydrochloride- 250 mg (MFH) obtained by AC impedance spectra

System	Rt Ohmcm <sup>2</sup>	Cdl F/ cm <sup>2</sup>	Impedance Log(z/ohm)
Artificial Saliva	251033	2.0316 x10 <sup>-11</sup>	5.950
AS + Metformin Hydrochloride- 250 mg	373140	1.3667 x10 <sup>-11</sup>	5.952

ohmcm<sup>2</sup>. Double layer capacitance decreases from 2.0316 x10<sup>-11</sup> to 1.3667 x10<sup>-11</sup> F/ cm<sup>2</sup>.

This indicates that in presence of Metformin Hydrochloride- 250 mg (MFH), the corrosion resistance of NiCr alloy in artificial saliva increases [17-21]. It must be remembered that when corrosion resistance increases, charge transfer resistance value increases, impedance value increases and double layer capacitance value decreases [17-21]. Hence people clipped with orthodontic wire made of NiCr alloy need not hesitate to take Metformin Hydrochloride- 250 mg (MFH) orally.



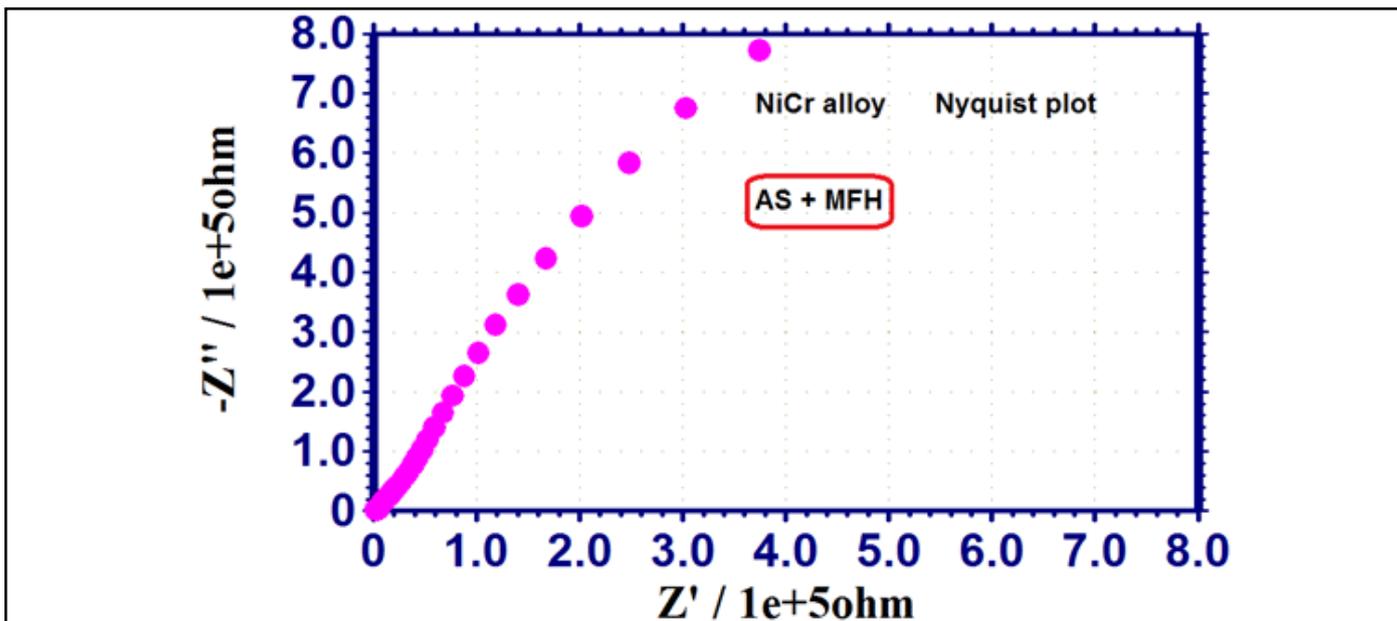


Figure 5: AC impedance spectrum of NiCr alloy immersed in Artificial Saliva in the presence of Metformin Hydrochloride-250 mg

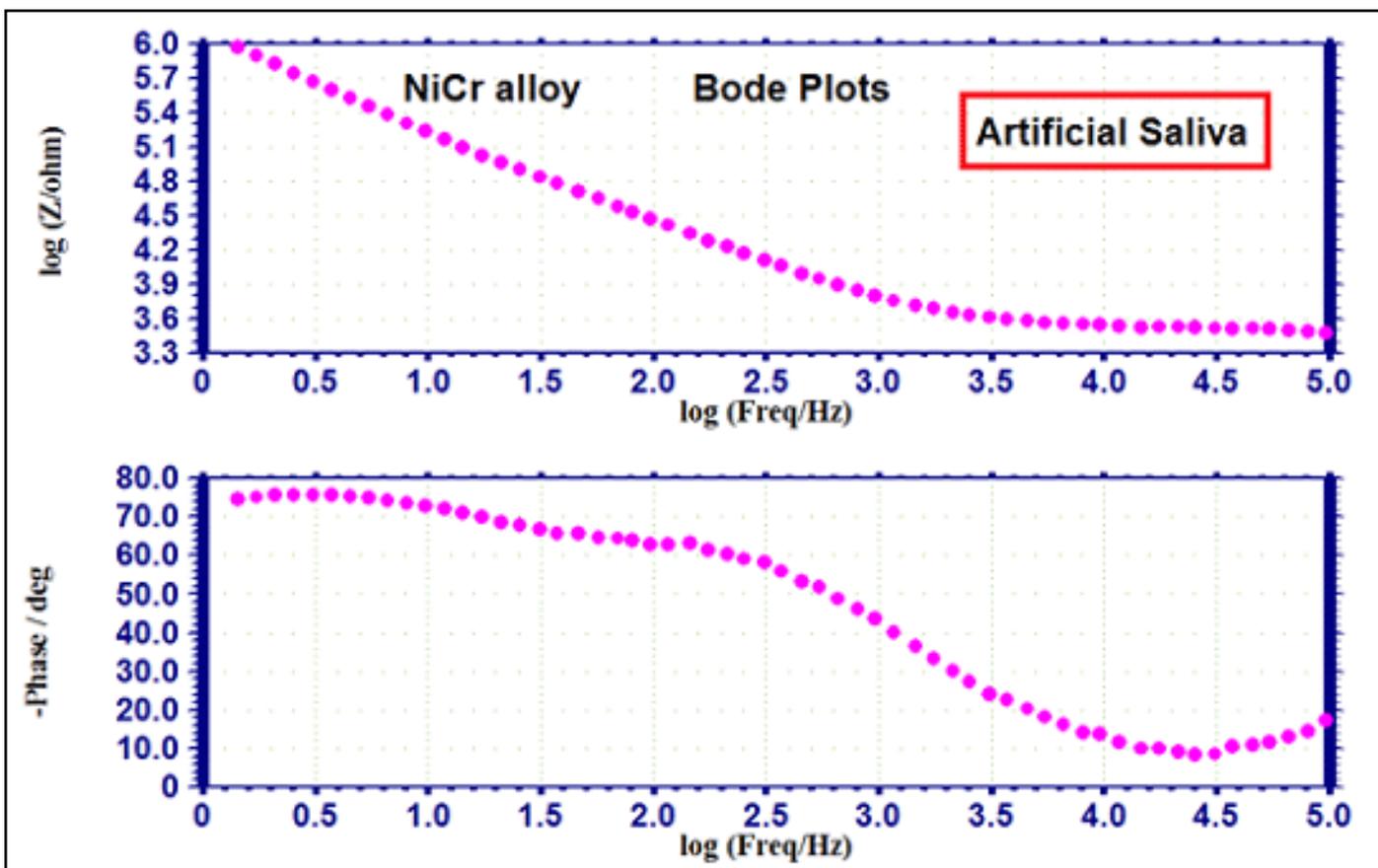
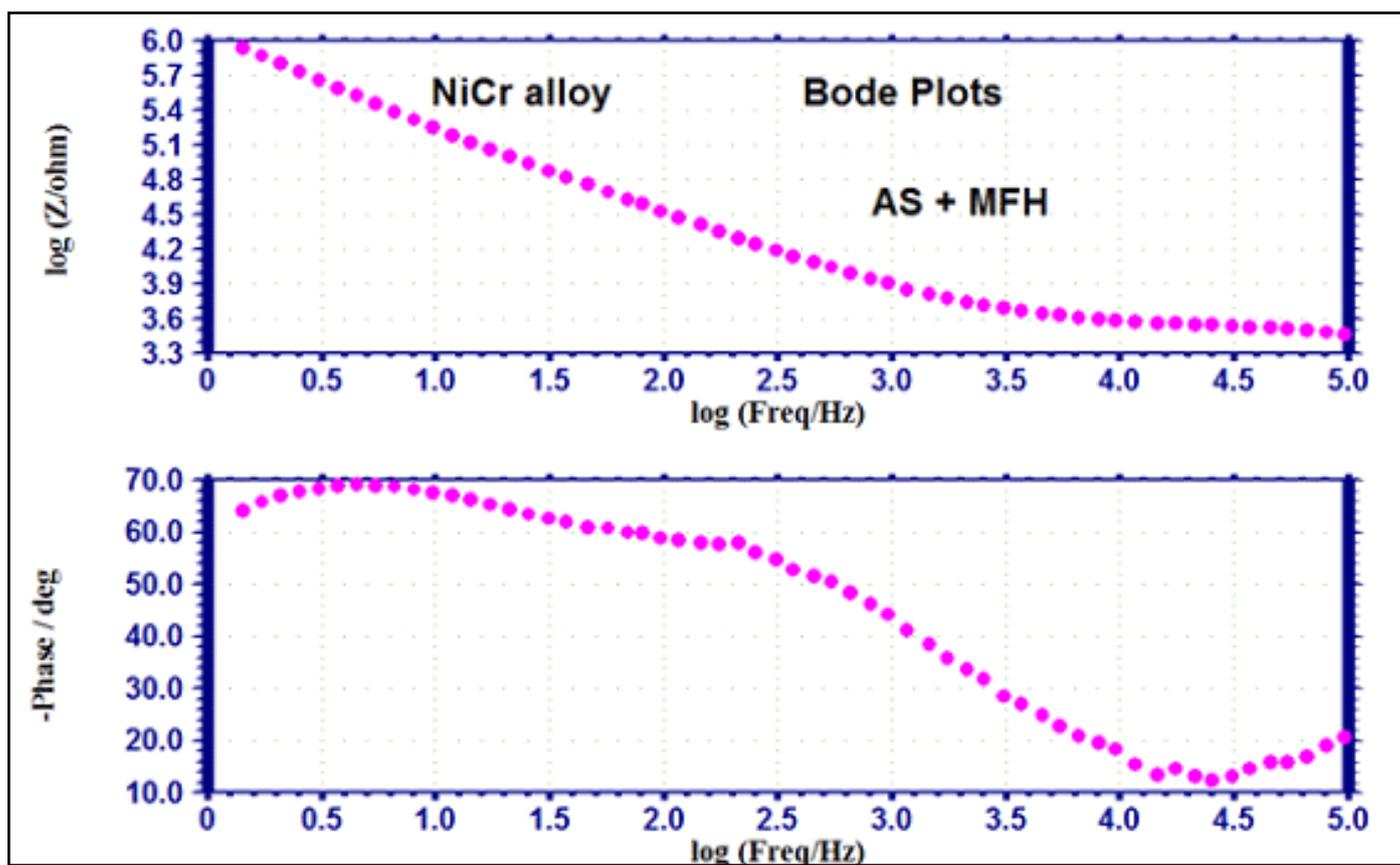


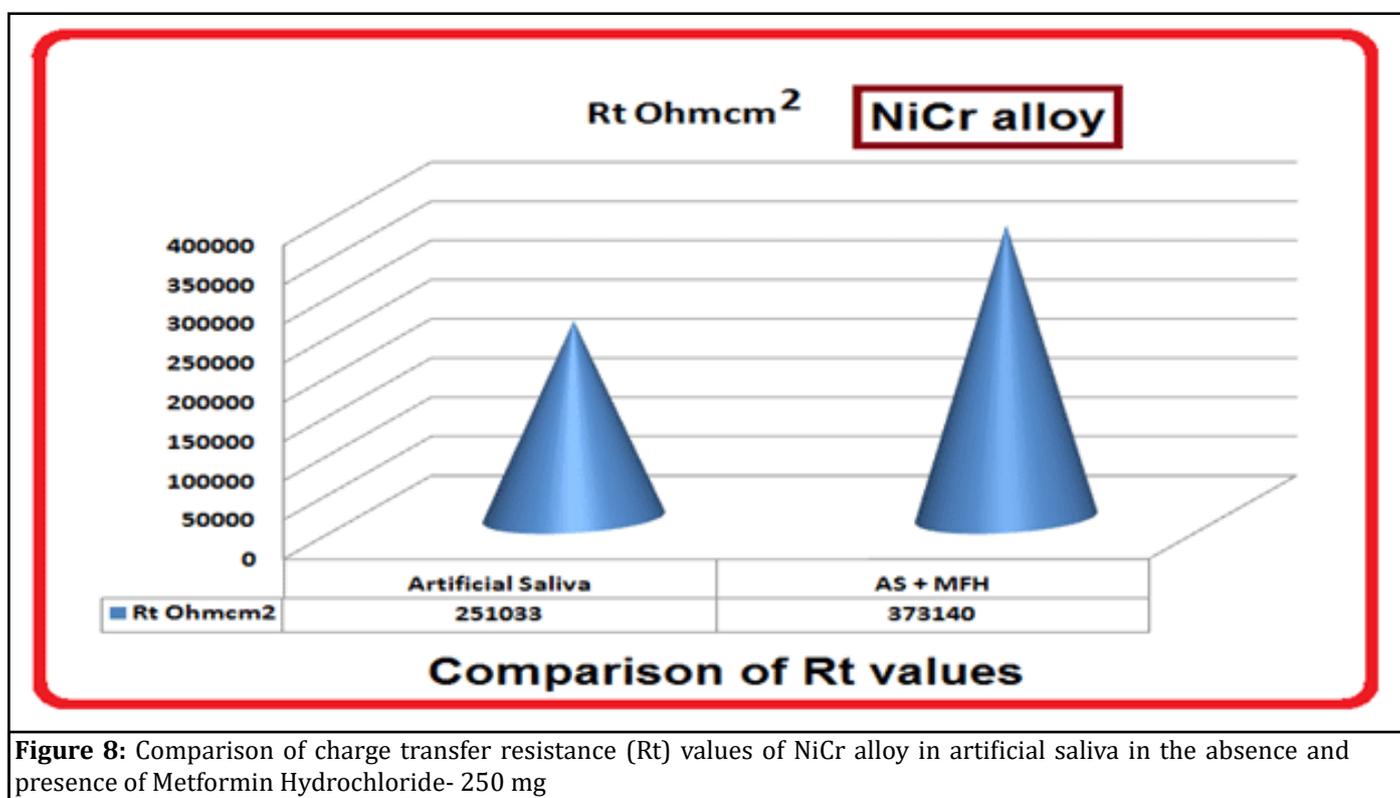
Figure 6: AC impedance spectra of NiCr alloy immersed in Artificial Saliva (Bode Plot)

### Implication

It is concluded that people clipped with orthodontic wire made of NiCr alloy need not hesitate to take Metformin Hydrochloride-250 mg (MFH) orally.



**Figure 7:** AC impedance spectra of NiCr alloy immersed in Artificial Saliva in the presence of Metformin Hydrochloride-250 mg (Bode Plot)



**Figure 8:** Comparison of charge transfer resistance ( $R_t$ ) values of NiCr alloy in artificial saliva in the absence and presence of Metformin Hydrochloride- 250 mg

**Table 4:** Comparison of charge transfer resistance values NiCr alloy immersed in artificial saliva (AS) in the absence and presence of Metformin Hydrochloride- 250 mg

System	Rt ohmcm <sup>2</sup>
Artificial Saliva	251033
AS + MFH	373140

## Conclusions

- The corrosion resistance of NiCr alloy in artificial saliva, in the absence and presence of Metformin Hydrochloride-250 mg (MFH) has been evaluated by polarization study and AC impedance spectra.
- Polarisation study reveals that in the presence of Metformin Hydrochloride-250 mg (MFH), LPR value increases and corrosion current decreases.
- That is, in presence of Metformin Hydrochloride-250 mg (MFH), the corrosion resistance of NiCr alloy in artificial saliva increases.
- AC impedance study reveals that in the presence of Metformin Hydrochloride- 250 mg (MFH),  $R_t$  value increases and  $C_{dl}$  decreases.
- That is in the presence of Metformin Hydrochloride- 250 mg (MFH) the corrosion resistance of NiCr alloy in AS increases.
- It is concluded that people clipped with orthodontic wire made of NiCr alloy need not hesitate to take Metformin Hydrochloride-250 mg (MFH) orally.

## Conclusion

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