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## Influence of Vicks ginger candy (VGC) and Glucose D on corrosion resistance of orthodontic wire made of Ni-Ti alloy in artificial saliva

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### Abstract

Orthodontic wires are used by dentists to regulate the growth of teeth of their patients. They are always in contact with the saliva and they undergo corrosion in the oral environment. Orthodontic wires made of various alloys are used. Nickel- and titanium-based alloys are promising materials for dental orthodontic wires due to their superior mechanical properties and corrosion resistance. Influence of Vicks ginger candy (VGC) and Glucose D on corrosion resistance of orthodontic wire made of Ni-Ti alloy (Nitinol) in artificial saliva has been evaluated by electrochemical studies such as polarization technique and AC impedance spectra. Corrosion resistance of Nitinol alloy in artificial saliva increases in the presence of 1000 ppm of Vicks ginger candy (VGC). Hence people clipped with orthodontic wire made of Ni-Ti alloy need not hesitate take 1000 ppm of Vicks ginger candy (VGC) orally. Corrosion resistance of Ni-Ti alloy in artificial saliva decreases in the presence of 1000 Glucose D. Therefore, the chances of orthodontic wire undergoing corrosion are greater in those who consume Glucose D juice excessively. Hence people clipped with orthodontic wire made of Ni-Ti alloy should avoid taking Glucose D orally. In the presence of 1000 ppm of Vicks ginger candy (VGC), LPR value of Ni-Ti alloy increases and corrosion current decreases. Vicks ginger candy (VGC) controls the anodic reaction and cathodic reaction to an equal extent. This is due to the fact that in the presence of Vicks ginger candy (VGC), the shift in corrosion potential is very small (from  $-535$  to  $-549$  mV vs. SCE). In the presence of 1000 ppm of Glucose D, the corrosion resistance of Ni-Ti alloy (Nitinol) in AS decreases. This is revealed by the fact that, in the presence of 1000 ppm of Glucose D, LPR value of Ni-Ti alloy decreases and corrosion current increases. Glucose D controls the anodic reaction predominantly. This is due to the fact that in the presence of Glucose D, the shift in corrosion potential is towards the anodic side (from  $-535$  to  $-456$  mV vs. SCE).

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**Keywords:** artificial saliva, corrosion, orthodontic wires, candies, Vicks ginger, Glucose D, electrochemical studies.

## Introduction

Orthodontic wires are used by dentists to regulate the growth of teeth of their patients. They are always in contact with the saliva and they undergo corrosion in the oral environment. Orthodontic wires made of various alloys are used.

At present, orthodontists principally use wires of four major base metal alloy types: stainless steel, cobalt-chromium-nickel, nickel-titanium and  $\beta$ -titanium. These wires are subjected to biodegradation leading to corrosion. Apart from this food items and candies taken by children may lead to corrosion of archwire. Many research works have been undertaken in this line.

Chemical, electrochemical, and surface study on microbial attack of Co-Cr-Mo dental alloy by streptococcus mutans have been studied by Mouflih *et al.* [1]. The passive properties of TA10 in Coca-Cola containing oral environment have been studied by Liu *et al.* The results have important guiding significance for the safe use of the alloy in the complex oral environments [2]. Barabás *et al.* have investigated the influence of hydroxyapatite (HAP), on the morpho-structural properties and corrosion resistance of ZrO<sub>2</sub>-based composites for biomedical applications. The obtained results using the two investigated metallic dental alloys have shown quasi-similar anticorrosive properties [3]. The effect of surface modification by laser on Ti-Nb-Mo powder metallurgical alloys to improve their mechano-chemical behavior and their application as a biomedical implant has been studied by Tendero *et al.* It was noted that the corrosion rate was lower in Ti-27Nb-8Mo and Ti-35Nb-6Mo. Niobium release was significant, but below the physiological limit [4]. Surface modification has been used by Jażdżewska and Bartmański to extend the life of implants. To increase the corrosion resistance and improve the biocompatibility of metal implant materials, oxidation of the Ti-13Nb-13Zr titanium alloy has been used. The samples used for the research had the shape of a helix with a metric thread, with their geometry imitating a dental implant [5]. Golgovici *et al.* have compared the behavior of two reprocessed dental alloys (Ni-Cr and CoCr) at different temperatures considering the idea that food and drinks in the oral cavity create various compositions at different pH levels. It was noted that with increasing temperature, the quantities of ions released from the alloys immersed in artificial saliva also increased, though they still remain small, less than 20 ppm [6]. Corrosion of Ni-Cr alloys for dental applications has been studied by Kassab *et al.* The influence of environment, chemical composition and casting route has also been explored. The corrosion morphology was localized exhibiting a peculiar dissolution pattern as observed in scanning droplet cell microscopy analysis. Furthermore, it was concluded that titanium segregation in the alloy after casting process was responsible for the lower localized corrosion resistance observed [7]. The corrosion behavior of Ti6Al4V fabricated by selective laser melting in the artificial saliva with different fluoride concentrations and pH values has been investigated by Zhang *et al.* It was noted that the crystallinity and the Al and F contents decrease when the NaF concentration and pH value rise [8]. The positive and negative alloying effects in synthetic body fluids have been analysed by Wang *et al.* The high passivity of the stainless steels

related to the Cr(III)-rich surface oxide was observed [9]. An artificial intelligence (AI) framework has been proposed by Nazarahari and Canadinc to predict the optimum composition of the Ni-Ti shape memory alloy (SMA) to be used in dental applications. A multilayer feed forward neural network (MLFFNN) was adopted for machine learning (ML) model to train the readily available experimental data in literature on the Ni ion release from a variety of Ni-Ti compositions into artificial saliva (AS) solutions to predict the Ni-Ti SMA composition to exhibit the lowest amount of Ni ion release into oral cavity [10]. The resistance to general and pitting corrosion of stainless steel and titanium-based orthodontic mini implants in an oral environment has been explored by Curkovic *et al.* Studies were performed in artificial saliva and in the presence of two oral hygiene products (one containing chlorhexidine digluconate with sodium fluoride and another containing probiotic bacteria) that are usually recommended to orthodontic patients. The results showed that mini implants made from stainless steel have lower resistance to corrosion than titanium implants [11].

Ni-Ti wires are designed to help our teeth move into their proper positions more effectively, making your treatment shorter and much more comfortable. Dentists use heat-activated Ni-Ti wires because they combine shape memory and elasticity with excellent mechanical properties.

Nickel- and titanium-based alloys are promising materials for dental orthodontic wires due to their superior mechanical properties and corrosion resistance. The studies of the corrosion resistance of these materials according to their surface characterization in artificial salivas are limited.

The present work is undertaken to investigate the corrosion behavior of Ni-Ti wire in artificial saliva in the presence of Vicks ginger candy and Glucose D.

## Experimental

### *Vicks Ginger candy*

Vicks Ginger candy contains menthol, mint and flavoured sugar as active ingredients. It acts as a cough suppressant and comes in ginger, honey and menthol flavors.

### *Glucose D*

Glucose D powder is ideal for young and growing children as well as athletes and helps their bodies replenish essential body salts, minerals and vitamins. It gives the body a boost of energy and helps to fight fatigue and exhaustion. It is also excellent for the all-round development of children [12].

Nutrition information per 100G: Calcium 350 Mg, Phosphorous 100 Mg, Vitamin C 50 Mg, Energy 356 kcal, Protein 0G, Carbohydrates 89G, of which sugar (Sucrose) 44G, fats and all type of fatty acid 0G.

### Preparation of the metal specimens

Ni-Ti alloy (also known as Nitinol) is an alloy with a near-equiatomic composition (*i.e.*, 49–51%) of nickel and titanium. Ni-Ti belongs to the class of shape memory alloys that can be deformed at a low temperature and are able to recover their original, permanent shape when exposed to a high temperature. It is used in Dentistry.

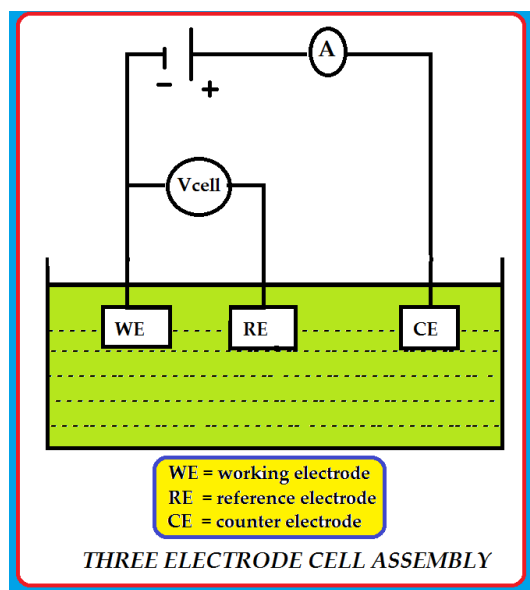
A thin wire of Ni-Ti alloy was used as test material for this work. The orthodontic wire was encapsulated in Teflon rod. It was polished to mirror finish and used for electrochemical studies.

### Preparation of artificial saliva

The preparation of artificial saliva was done using the composition of Fusayama Meyer artificial saliva (AS). 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<sub>2</sub>·2H<sub>2</sub>O = 0.906 g/L, NaH<sub>2</sub>PO<sub>4</sub>·2H<sub>2</sub>O = 0.690 g/L, Na<sub>2</sub>S·9H<sub>2</sub>O = 0.005 g/L, urea = 1 g/L.

### Potentiodynamic polarization technique

A CHI 660 A workstation model was used in the electrochemical studies. Polarization study was carried out using a three electrode cell assembly (Figure 1). Ni-Ti alloy was used as working electrode, platinum as counter electrode and saturated calomel electrode (SCE) as reference electrode. After having done  $i_R$  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  $E_{\text{corr}}$ , corrosion current  $I_{\text{corr}}$  and Tafel slopes ( $b_a$  and  $b_c$ ) were measured.



**Figure 1.** Three electrode cell assembly.

### *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 calculated.

## **Results and Discussion**

### *Influence of Vicks ginger candy (VGC) and Glucose D on corrosion resistance of Ni-Ti alloy in artificial saliva*

Influence of Vicks ginger candy (VGC) and Glucose D on corrosion resistance of Ni-Ti alloy in artificial saliva, has been investigated by polarization technique and AC impedance spectra [13–32].

### **Polarization technique**

In the present investigation Tafel plots were carried out in a CHI Electrochemical workstation/ analyzer, model 660 A. It was provided with automatic  $i_R$  compensation facility. A three electrode cell assembly was used (Figure 1).

The electrodes were immersed in artificial saliva, in the absence and presence of Vicks ginger candy (VGC) and Glucose D. 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.

In polarization technique, when corrosion resistance increases LPR increases and corrosion current decreases. It implies that when corrosion resistance decreases, LPR decreases and corrosion current increases.

The polarization parameters of Ni-Ti alloy immersed in Artificial Saliva (AS), in the absence and presence of 1000 ppm each of Vicks ginger candy (VGC) and Glucose D are given in Table 1. The polarization curves are shown in Figures 2–4.

### *Influence of 1000 ppm of Vicks ginger candy (VGC) on corrosion resistance of Ni-Ti alloy immersed in Artificial Saliva (AS)*

It is observed from Table 1, that in the presence of 1000 ppm of Vicks ginger candy (VGC), the corrosion resistance of Ni-Ti alloy in AS increases. This is revealed by the fact that, in the presence of 1000 ppm of Vicks ginger candy (VGC), LPR value of Ni-Ti alloy increases and corrosion current decreases. Vicks ginger candy (VGC) behaves as a mixed type of inhibitor. This is due to the fact that in the presence of Vicks ginger candy (VGC), the shift in corrosion potential is very small (from  $-535$  to  $-549$  mV vs. SCE). The characteristic peaks in Figure 3 indicate the processes of film formation and film breaking the corresponding potentials. The film formed is thin and less stable. So it is easily broken at these potentials.

### Implication

Corrosion resistance of Ni-Ti alloy in artificial saliva increases in the presence of presence of 1000 ppm of Vicks ginger candy (VGC) increases. Hence people clipped with orthodontic wire made Ni-Ti alloy need not hesitate take 1000 ppm of Vicks ginger candy (VGC) orally.

### Influence of 1000 ppm of Glucose D on corrosion resistance of Ni-Ti alloy immersed in Artificial Saliva (AS)

It is observed from Table 1, that in the presence of 1000 ppm of Glucose D, the corrosion resistance of Ni-Ti alloy in AS decreases. This is revealed by the fact that, in the presence of 1000 ppm of Glucose D, LPR value of Ni-Ti alloy decreases and corrosion current increases.

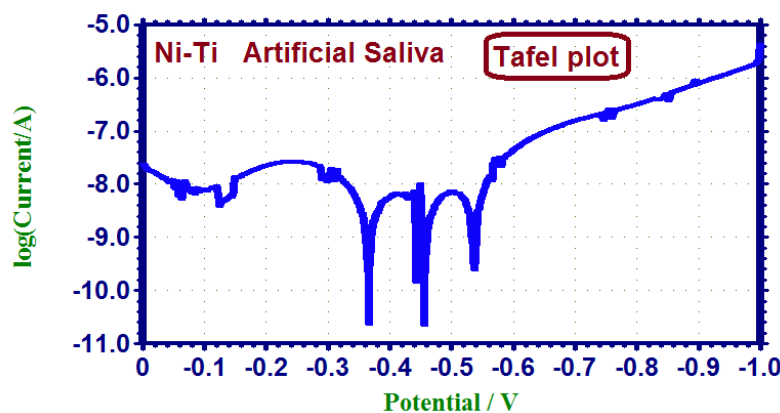
Glucose D behaves as anodic of inhibitor. This is due to the fact that in the presence of Glucose D), the shift in corrosion potential is towards anodic side (from  $-535$  to  $-456$  mV vs. SCE).

### Implication

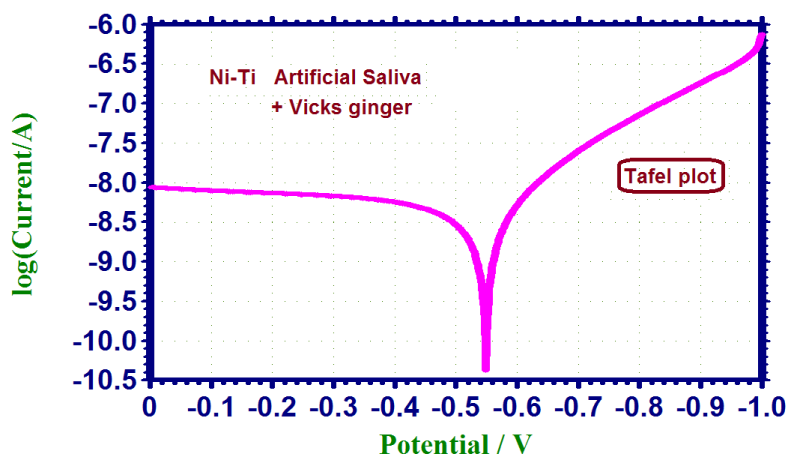
Corrosion resistance of Ni-Ti alloy in artificial saliva decreases in the presence of presence of 1000 Glucose D. Therefore, the chances of orthodontic wire undergoing corrosion are greater in those who consume Glucose D excessively.

**Table 1.** Corrosion parameters of Ni-Ti alloy in AS in the absence and presence of 1000 ppm each of Vicks ginger candy (VGC) and Glucose D obtained from polarization study.

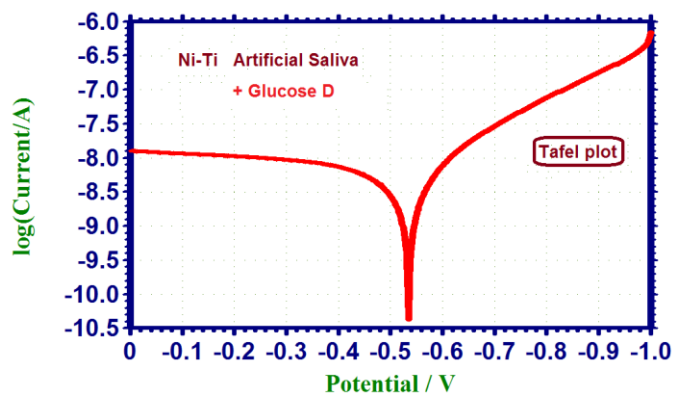
System	$E_{\text{corr}}$ , mV vs. SCE	$b_c$ , mV/decade	$b_a$ , mV/decade	LPR, Ohm·cm <sup>2</sup>	$I_{\text{corr}}$ , A/cm <sup>2</sup>
AS	-535	147	306	10497489	$4.117 \cdot 10^{-9}$
AS+VGC	-549	148	367	12802557	$3.492 \cdot 10^{-9}$
AS+Glucose D	-456	97	282	2483226	$12.64 \cdot 10^{-9}$



**Figure 2.** Polarization curve of Ni-Ti alloy immersed in artificial saliva (AS).



**Figure 3.** Polarisation curve of Ni-Ti alloy immersed in artificial saliva (AS) + Vicks ginger candy (VGC).



**Figure 4.** Polarisation curve of Ni-Ti alloy immersed in artificial saliva (AS) + Glucose D.

### AC Impedance spectra

In the present investigation the same instrument set-up used for polarization study was also used to record AC impedance spectra. 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. AC impedance spectra were recorded with initial  $E$  (V) = 0, high frequency (Hz =  $1 \cdot 10^5$ ), low frequency (Hz = 1), amplitude (V) = 0.005 and quiet time (s) = 2. From Nyquist plot the Values of charge transfer resistance ( $R_t$ ) and the double layer capacitance ( $C_{dl}$ ) were calculated.

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

where  $R_s$  is the solution resistance.  $C_{dl}$  values were calculated using the relationship:

$$C_{dl} = 1/2 \cdot 3.14 \cdot R_t \cdot f_{max}$$

where  $f_{max}$  is the frequency at maximum imaginary impedance.

When corrosion resistance increases,  $R_t$  values and impedance values increase whereas  $C_{dl}$  values decreases.



The AC impedance spectra of Ni-Ti alloy in AS in the absence and presence of 1000 ppm each of Vicks ginger candy (VGC) and Glucose D are shown in Figures 5–10. The Nyquist plots are shown in Figures 5–7. The Bode plots are shown in Figures 8–10.

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

#### *Influence of 1000 ppm of Vicks ginger candy (VGC) on corrosion resistance of Ni-Ti alloy immersed in Artificial Saliva (AS)*

It is observed from Table 2, that in the presence of 1000 ppm of Vicks ginger candy (VGC), the corrosion resistance of Ni-Ti alloy in AS increases. This is revealed by the fact that in the presence of Vicks ginger candy (VGC),  $R_t$  value increases, impedance value increases, phase angle increases and  $C_{dl}$  value decreases.

#### *Implication*

Corrosion resistance of Ni-Ti alloy in artificial saliva increases in the presence of 1000 ppm of Vicks ginger candy (VGC). Hence people clipped with orthodontic wire made Ni-Ti alloy need not hesitate to take Vicks ginger candy (VGC) orally.

#### *Influence of 1000 ppm of Glucose D on corrosion resistance of Ni-Ti alloy immersed in Artificial Saliva (AS)*

It is also observed from Table 2, that in the presence of Glucose D, the corrosion resistance of Ni-Ti alloy in AS decreases. This is revealed by the fact that in the presence of Glucose D,  $R_t$  value decreases, impedance value decreases, phase angle decreases and  $C_{dl}$  value increases.

#### *Implication*

- Corrosion resistance of Ni-Ti alloy in artificial saliva decreases in the presence of 1000 ppm of Glucose D. Therefore, the chances of orthodontic wire undergoing corrosion are greater in those who consume Glucose D juice excessively.

**Table 2.** Corrosion parameters of Ni-Ti alloy in AS in the absence and presence of 1000 ppm each of Vicks ginger candy (VGC) and Glucose D obtained from AC impedance spectra.

System	$R_t$ , Ohm·cm <sup>2</sup>	Impedance, log (Z/Ohm)	$C_{dl}$ , F/cm <sup>2</sup>	Phase angle
AS	71.42	5.255	$71.408 \cdot 10^{-11}$	45.80
AS+ VGC	84.35	5.373	$6.0463 \cdot 10^{-11}$	49.38
AS+ Glucose D	17.64	4.176	$289.12 \cdot 10^{-11}$	43.06

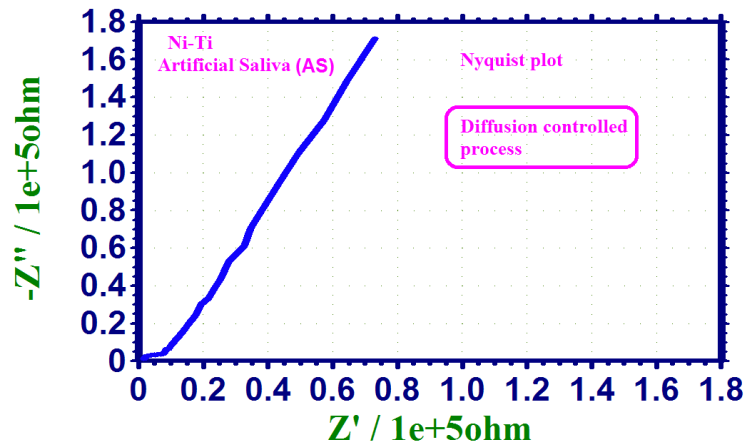


Figure 5. Nyquist plot of Ni-Ti alloy immersed in artificial saliva (AS).

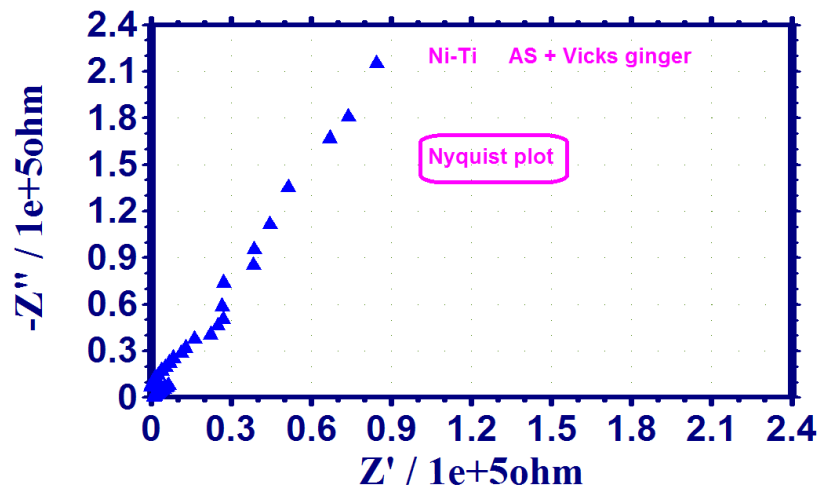


Figure 6. Nyquist plot of Ni-Ti alloy immersed in artificial saliva (AS) + Vicks ginger.

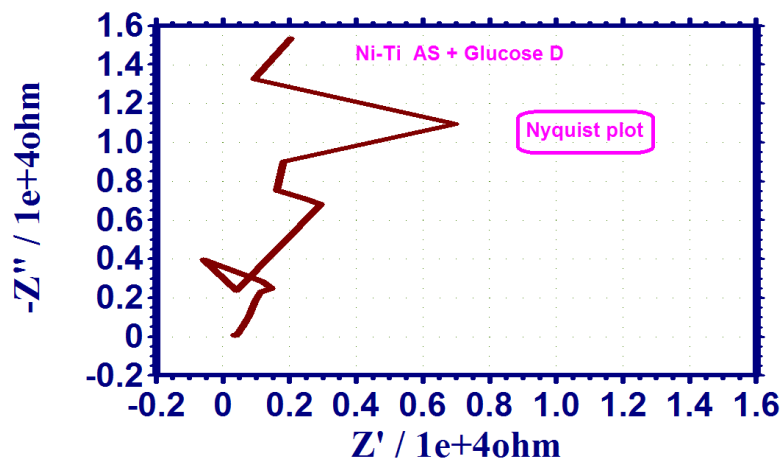


Figure 7. Nyquist plot of Ni-Ti alloy immersed in artificial saliva (AS) + Glucose D.

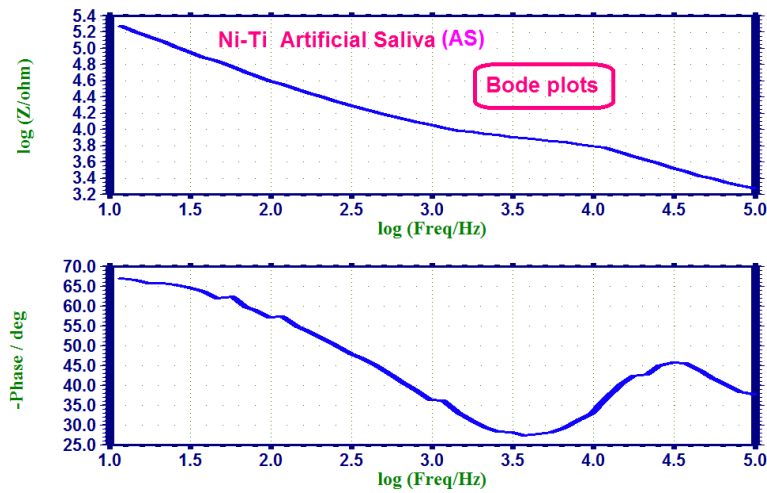


Figure 8. Bode plots of Ni-Ti alloy immersed in artificial saliva (AS).

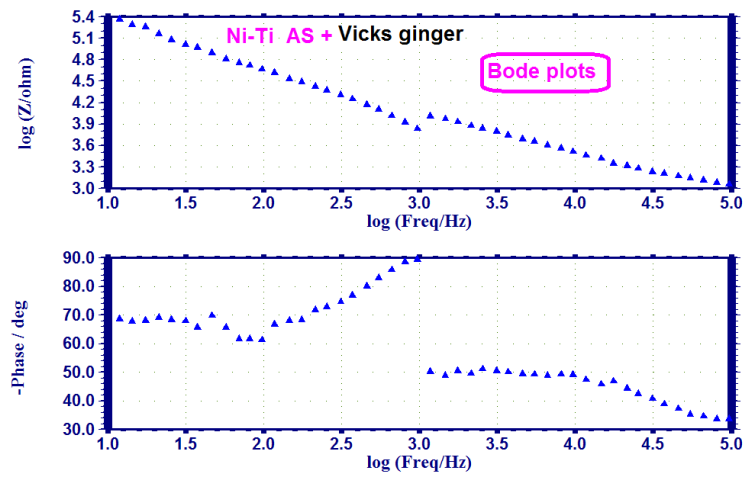


Figure 9. Bode plots of Ni-Ti alloy immersed in artificial saliva (AS) + Vicks ginger.

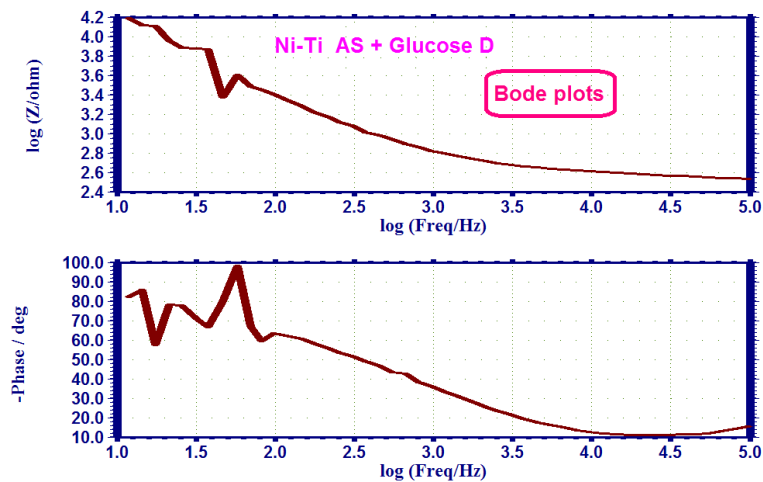


Figure 10. Bode plots of Ni-Ti alloy immersed in artificial saliva (AS) + Glucose D.

## Conclusions

Influence of Vicks ginger candy (VGC) and Glucose D on corrosion resistance of orthodontic wire made of Ni-Ti alloy in artificial saliva has been evaluated by electrochemical studies such as polarization technique and AC impedance spectra.

- Corrosion resistance of Ni-Ti alloy in artificial saliva increases in the presence of 1000 ppm of Vicks ginger candy (VGC) increases. Hence people clipped with orthodontic wire made Ni-Ti alloy need not hesitate take 1000 ppm of Vicks ginger candy (VGC) orally.
- Corrosion resistance of Ni-Ti alloy in artificial saliva decreases in the presence of 1000 ppm of Glucose D. Therefore, the chances of orthodontic wire undergoing corrosion are greater in those who consume Glucose D juice excessively.
- In presence of 1000 ppm of Vicks ginger candy (VGC), LPR value of Ni-Ti alloy increases and corrosion current decreases.
- Vicks ginger candy (VGC) controls the anodic reaction and cathodic reaction to an equal extent. This is due to the fact that in the presence of Vicks ginger candy (VGC), the shift in corrosion potential is very small (from  $-535$  to  $-549$  mV vs. SCE).
- In the presence of 1000 ppm of Glucose D juice, the corrosion resistance of Ni-Ti alloy in AS decreases. This is revealed by the fact that, in the presence of 1000 ppm of Glucose D juice, LPR value of Ni-Ti alloy decreases and corrosion current increases.
- Glucose D juice controls the anodic reaction predominantly.
- This is due to the fact that in the presence of Glucose D juice, the shift in corrosion potential is towards anodic side (from  $-535$  to  $-456$  mV vs. SCE).

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