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Electrochemical Behaviour of NI-TI Super Elastic Shape Memory Alloy in Artificial Saliva

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Abstract : The aim of present study is to investigate corrosion resistance of orthodontic wire made of Ni-Ti Super Elastic Shape Memory alloy in artificial saliva in the presence of Limcee-500 mg and Shelcal-500 mg has been evaluated by polarization study and AC impedance spectra, artificial saliva taken as control. It is observed that in presence of the Limcee-500 mg the corrosion resistances of Ni-Ti SESM alloy increases. On the other hand in the presence of the Shelcal-500 mg the corrosion resistances of Ni-Ti SESM alloy decreases. Corrosion resistance increases due to linear polarisation resistance increases and corrosion current values decreases. It is suggested that people implanted with orthodontic wire made of Ni-Ti SESM alloy need not hesitate to take Limcee-500 mg but Shelcal-500 mg should avoid orally. The increase or decrease in corrosion resistance of Ni-Ti SESM alloy in presence of these tablets in artificial saliva is due to the ingredients present in tablets.
Keywords : Ni-Ti Super Elastic Shape Memory alloy (SESM), Artificial saliva, Limcee-500 mg, Shelcal-500 mg, Corrosion resistance, Polarization study and AC Impedance spectra.

1.Introduction

In orthodontics, Ni-Ti based shape memory alloys have been widely used due to its biocompatibility and ductility [1]. Dental implants made of metal exhibit high corrosion resistance and prevent metal release in the oral multivariate environment [2]. The acidic beverages and salty food are corrosive which plays a vital role in accelerating corrosion [3,4]. Comparison of chemical properties and Ni release of stainless steel and nickel titanium wires was evaluated by a Potentiodynamic polarization technique. Stainless steel had more Ni release at pH 5.14 than pH 6.69 but NiTi had greater Ni release at pH 6.69 than pH 5.14 [5]. The effect of Ni-Ti SMA has been determined for corrosion rate of orthodontic wires by inductively coupled plasma-optical emission spectroscopy (ICP-OES) after 3, 7, 14, 21 and 28 days of immersion in artificial saliva [6]. Corrosion behaviour of titanium nitride/titanium coatings on the stress corrosion of nickel-titanium orthodontic arch wires[7] Ni-Ti

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alloy[8] five non-precious Ni-Co based alloys in artificial saliva[9]. The present work is undertaken to investigate the corrosion behaviour of orthodontic wire made of Ni-Ti SESM alloy in artificial saliva in the absence and presence of Limcee-500 mg and Shelcal-500 mg by using electrochemical studies such as Polarization study and AC impedance spectra.

2. Experimental

2.1. Preparation of Artificial saliva solution

Artificial saliva is prepared and its composition is: KCl - 0.4 g/lit, NaCl - 0.4 g/lit, $CaCl_2.2H_2O$ - 0.906 g/lit, $NaH_2PO_4.2H_2O$ - 0.690 g/lit, $Na_2S.9H_2O$ -0.005 g/lit, Urea – 1 g/lit.

2.2. Composition of Tablets

Compositions of Tablet are given in Table 1.

Table: 1

Tablet names	Composition	Represented by
Limcee- 500 mg (Vitamin-C Chewable)	1.Ascorbic acid -100 mg 2.Sodium Ascorbate-450 mg	Tablet-B
Shelcal-500 mg (Calcium withVitamin-D3)	1.calcium carbonate from an organic Source -1250 mg 2.vitamin D3 -259 Iu	Tablet-C

2.3. Potentiodynamic Polarization

Polarization studies were carried out in a CHI- electrochemical work station with impedance model 660A. It was provided with iR compensation facility. A three electrode cell assembly was used. The working electrode was Ni-Ti SESM alloy, A SCE was the reference electrode and Platinum was the counter electrode. From polarisation study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes anodic = b_a and cathodic = b_c were calculated and polarization study was done. The scan rate (V/S) was 0.01. Hold time at (Efcs) was zero and quiet time (s) was two.

2.4. AC impedance measurements

A CHI 660A electrochemical impedance analyzer model was used to record AC impedance measurements. The cell set up was the same as that used for polarization measurements. The real part (Z’) and imaginary part (-Z”) of the cell impedance were measured in ohms for various frequencies. The charge transfer resistance (Rt) and double layer capacitance (Cdl) values were calculated.

3. Results and Discussion

3.1. Analysis of Potentiodynamic polarization curves of Ni-Ti SESM alloy

Polarization studies have been used to confirm the formation of protective film formed on the metal surface during corrosion inhibition process [10-17]. If a protective film is formed on the metal surface, linear polarisation resistance (LPR) increases and corrosion current value (I_{corr}) decreases. The potentiodynamic polarization corrosion parameters are given in Table 2 and Fig.1.

Table 2: Corrosion parameters of Ni-Ti SESM alloy immersed in Artificial Saliva (AS) in the absence and presence of Tablets obtained from polarization study

System	E_{corr} mV vs SCE	b_c mV/ decade	b_a mV/ decade	LPR ohm .cm^2	I_{corr} A/cm^2
AS	-521	205	249	419028	11.68×10^{-8}
AS + Tablet B (300 ppm)	-478	209	287	548343	9.619×10^{-8}
AS + Tablet C (300 ppm)	-490	232	549	368464	19.27×10^{-8}

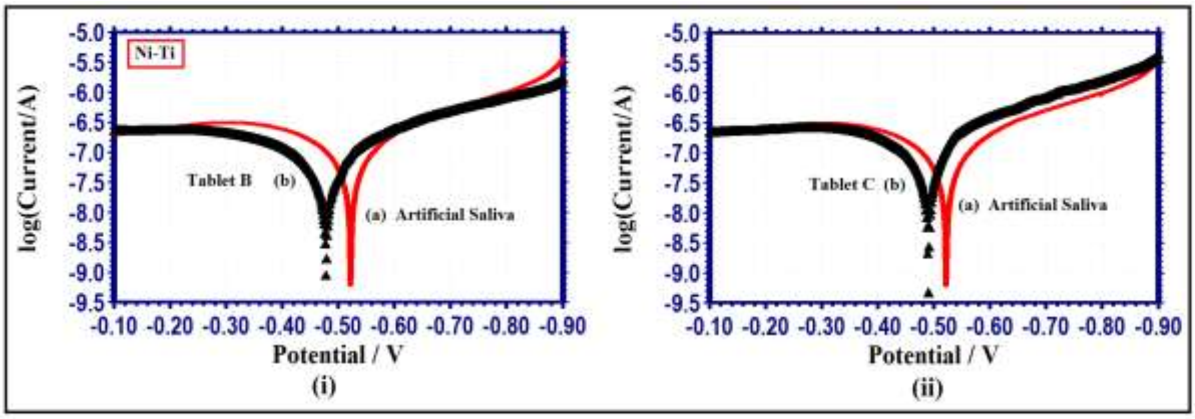

Figure 1: Polarization curves of Ni-Ti SESM alloy immersed in Artificial Saliva in the absence and presence of Tablets (i) AS + Tablet B (ii) AS + Tablet C

When Ni-Ti SESM alloy immersed in Artificial Saliva in the presence of Tablet B, the corrosion potential is shifted from -521 mV vs SCE to -478 mV vs SCE [Fig 1(i)]. Similarly in the presence of Tablet C, the corrosion potential is shifted from -521 mV vs SCE to -490 mV vs SCE [Fig 1(ii)]. Both indicate that the anodic reaction is controlled predominantly. However the shift in corrosion potential is not much. Hence these two tablets functions as mixed type of inhibitor. The corrosion resistance of Ni-Ti SESM alloy increases in the presence of Tablet B is confirmed by the LPR value increases from 419028 ohmcm^2 to 548343 ohmcm^2 whereby the corrosion current decreases from 11.68×10^{-8} A/cm^2 to 9.619×10^{-8} A/cm^2. But corrosion resistances of Ni-Ti SESM alloy decreases in the presence Tablet C is confirmed by the LPR value decreases from 419028 ohmcm^2 to 368464 ohmcm^2 whereby the corrosion current increases from 11.68×10^{-8} A/cm^2 to 19.27×10^{-8} A/cm^2. Thus from the polarization study it is concluded that the people having orthodontic wire made of Ni-Ti SESM alloy need not hesitate to take Tablet B but should avoid Tablet C.

3.2. Analysis of AC Impedance spectra

The formation of protective film on the metal surface is confirmed by electrochemical impedance spectra [18-24]. If a protective film is formed on the metal surface, charge transfer resistance (R_t) increases and double layer capacitance value (C_{dl}) decreases, Impedance value increases. The AC impedance spectra values are given in Table 3 and Nyquist plots (Fig.2), Bode plots (Fig.3).

Table 3: AC impedance parameters of Ni-Ti SESM alloy immersed in Artificial Saliva (AS) in the absence and presence of Tables obtained by AC impedance spectra

System	R_t ohm cm^2	C_{dl} F/ cm^2	Impedance Log(z/ohm)
AS	7281	7.004×10^{-10}	4.167
AS + Tablet B (300 ppm)	8025	6.355×10^{-10}	4.181
AS + Tablet C (300 ppm)	5994	8.508×10^{-10}	4.042

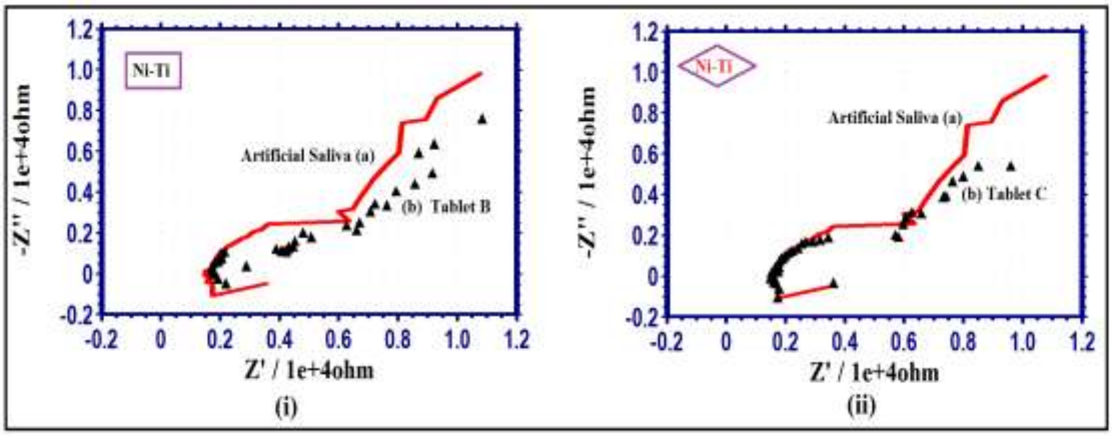

Figure 2: AC impedance spectra of Ni-Ti SESM alloy immersed in Artificial Saliva (AS) in the absence and presence of Tablets (Nyquist Plots) (i) AS + Tablet B (ii) AS + Tablet C

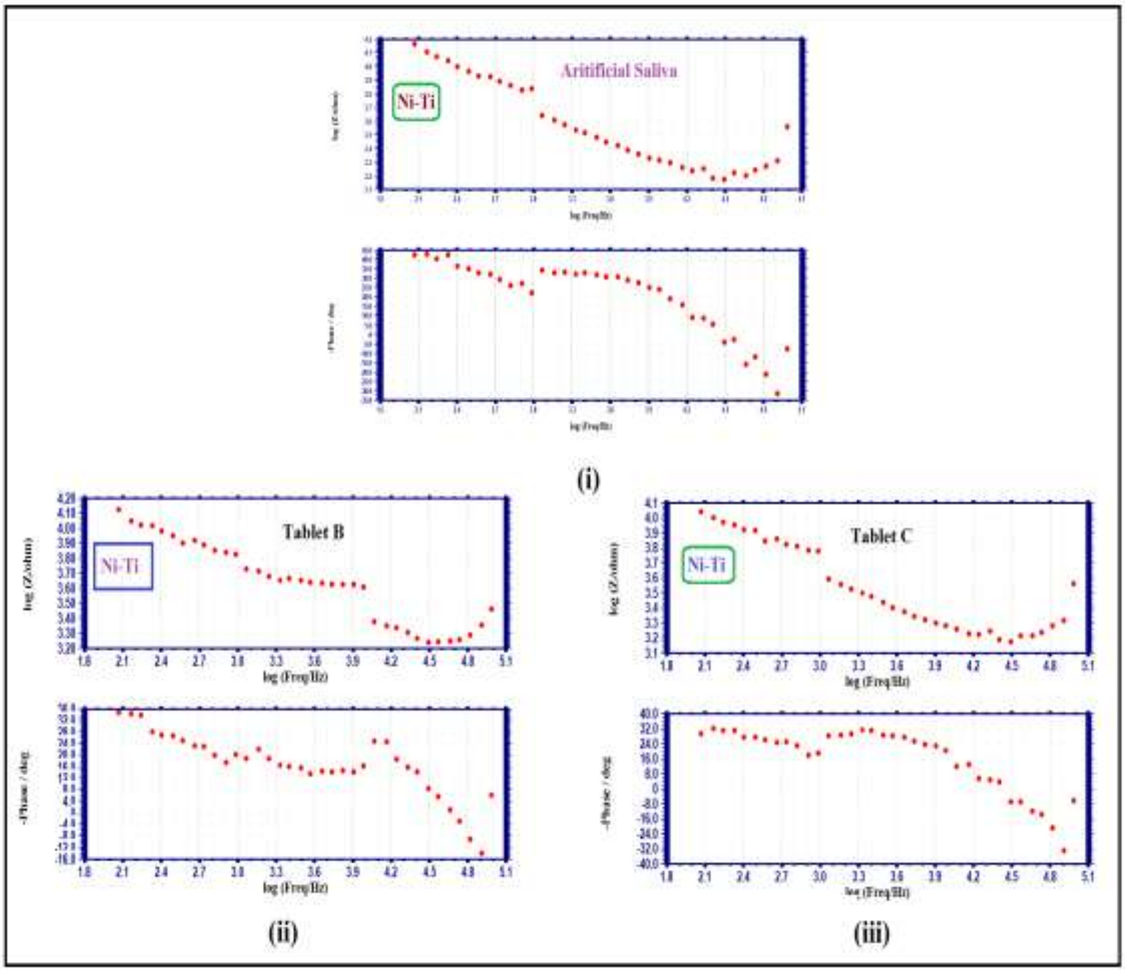

Figure 3: AC impedance spectra of Ni-Ti SESM alloy immersed in Artificial Saliva in the absence and presence of Tablets (Bode Plots) (i) AS (ii) AS + Tablet B (iii) AS + Tablet C

It is inferred from Table 3 that the charge transfer resistance (R_t) increases from 7281 ohm cm^2 to 8025 ohm cm^2, the C_{dl} value decreases from $7.004x10^{-10}$ F/cm^2 to $6.355x10^{-10}$ F/cm^2 [Fig.2 (i)], the impedance value increases from 4.167 to 4.181 [Fig.3 (ii)]. The analysis of AC impedance spectra leads to the conclusion that a protective and stable film is formed on the metal surface in the presence Tablet B in artificial saliva. Consequently the corrosion resistances of Ni-Ti SESM alloy in contact with artificial saliva increases due to active ingredients of the Tablet B have not corroded the orthodontic wire. But in the presence of Tablet C that the charge transfer resistance (R_t) decreases from 7281 ohm cm^2 to 5994 ohm cm^2, the C_{dl} value increases from 7.004×10^{-10} F/cm^2 to 8.508×10^{-10} F/cm^2 [Fig.2(ii)], the impedance value decreases from 4.167 to 4.042 [Fig.3(iii)]. The analysis of AC impedance spectra leads to the conclusion that a protective film is not formed on the metal surface. The corrosion resistance decreases due to the active ingredients of the tablet have corroded the orthodontic wire made of Ni-Ti SESM alloy.

4. Conclusion

The electrochemical studies lead to the following conclusions;

- Polarization study reveals that Limcee-500 mg and shelcal-500 mg both act as mixed type of inhibitors.
- AC impedance spectra suggest the presence Limcee-500 mg that a protective film is formed on the Ni-Ti SESM alloy surface due to active ingredients of the tablet but in the presence of Shelcal-500 mg protective film not formed on the metal surface.
- People implanted with orthodontic wire made of Ni-Ti SESM alloy should avoid the use of tablet Shelcal-500 mg.
- People implanted with orthodontic wire made of Ni-Ti SESM alloy can use of tablet Limcee-500 mg, without any hesitation.

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