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FLEXIBLE ECO-FRIENDLY CORROSION ANALYSIS BY VEGETABLE- FRUIT EXTRACTS ON NICKEL-TITANIUM ORTHODONTIC WIRE

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Abstract: Untreated orthodontic problems can lead to significant dental public health issues and by means of practitioner's point of view children and adult patients especially female in the 26 to 40 age can most likely to treat their problems. Orthodontic wires are devices made of a various metal composition used as an anchor to rectify tooth positioning abnormalities. These materials have a longer history than fixed orthodontic procedures, and they have unique characteristics. In the present study Electrochemical analysis by polarization, AC impedance, and surface analysis by atomic force microscopy (AFM) are used to evaluate the corrosion resistance behaviour of Ni-Ti arch wire in artificial saliva (AS) in the presence and absence of vegetable extracts such as Carrot Juice(CJ), Beetroot Juice(BJ) and fruit extract as Pomegranate Juice(PJ) with and without adding sugar(S) has been evaluated which led to the conclusion that the corrosion resistance of the alloy present in various medium decreases in the following order:

AS + PJ + S < AS+ PJ < AS + BJ + S < AS + BJ < AS < AS + CJ +S< AS + CJ

Index Terms - Orthodontic Ni-Ti arch wire, Artificial saliva, Vegetable-fruit juice medium, Polarization study, AC impedance spectra, Atomic Force Microscopy, Comparison study.

I. INTRODUCTION

Orthodontic wires are devices made of a various metal composition that conforms to the alveolar or dental arch and is used as an anchor to rectify tooth positioning abnormalities. These materials have a longer history than fixed orthodontic procedures, and they have unique characteristics. Metallic materials such as Au, Ni-Ti, Ag, Ni-Cr, SS18/8etc., are applied as implants in oral treatment to the array of the teeth [1]. In orthodontics, one of the most commonly used metals in wires is nickel that includes in Ni-Ti, stainless steel and other alloys. Nickel is the most common metal to induce more case of allergic reaction. However, some complexes of Ni have been considered carcinogenic, allergenic and mutagenic [2]. After clipping these wires, a person takes many tablet, food item and juices. Because of these orthodontic wires undergo corrosion in presence of saliva. Saliva contains 98% of water, which includes electrolytes, mucus, WBC, epithelial cells, glycoproteins. Under this medium antimicrobial agent in orthodontic wires undergo corrosion further [3].Corrosion inhibitor has been used in corrosion protective coatings for a long time. The concept of environmentally friendly green corrosion inhibitor has aroused increasing attentionin the field of corrosion protection[5]. Vegetable and Fruit extract are the most commonly preferred supplement in everyday diet and also recommended due to their nutritional value. Vegetable peels, leaves and fruits are rich in phytochemicalsas alkaloids, tannins, glycerides [4]. Carrot, Beetroot, Pomegranate juice also the most commonly preferred energizer in everyday diet and nutritional value [6]which also serves an excellent candidate as non-toxic and sustainable corrosion inhibitor.The present work is undertaken to study the corrosion resistance of Ni-Ti in artificial saliva in the presence and absence of vegetable extracts as Carrot and Beetroot and fruit extract as Pomegranate with and without addition of sugar. By means of polarization study, corrosion parameters such as Corrosion E(Coorr), Linear polarization Resistance (LPR), Corrosion current (ICoor) and Tafel slopes (anodic=baand cathodic=bc) have been evaluated and the alloy surface analysis was carried out by Atomic force microscopy. The objective of the study is to test the vegetable, fruit extract as an effective eco friendly corrosion inhibitor.

2. MATERIALS AND METHODS:

2.1 Composition of Ni-Ti Arch wires

The orthodontic arch wire made of Ni-Ti alloys were chosen for present study. The composition of Ni-Ti alloys are given below the table 1.

Table 1.Composition of Ni-Ti alloy

Ni-Ti alloy	
Nickel	49.16%
Titanium	49.75%

2.2 Composition of Artificial Saliva:

The composition of artificial saliva suggested as Fusayama Mayer artificial saliva [6,7]. is given as: table 2

Table 2.The Composition of Artificial Saliva

Components	Concentration in g L^{-1}
NaCl	0.4
$NaH_2PO_4.2H_2O$	0.690
KCl	0.4
$CaCl_2.2H_2O$	0.906
$Na_2S.9H_2O$	0.005
Urea	1

2.3 Preparation of Vegetable extract Medium

The Carrot and Beetroot Juice are the health drinks in everyday life. The botanical name of carrot is *Daucuscatrota L* and beetroot is named as *Beta vulgaris.* We can enlist many reasons to add beetroot and carrot juice along with add-ons in our daily diet, which makes for great detoxifier. In beetroot the presence of betanine helps healthy liver function. Carrot juice helps to excrete toxins from the body effectively.

The Carrot and Beetroot Juice are made by the following steps, first peel the fresh Carrot and Beetroot skin, and 250 gram of Carrot and Beetroot cut into the small pieces, and put it in the separate blender and added 20 ml water and blend it in food processor, blend till smooth then pour through a strainer into a bowl, then 100 ml of the juices is taken and by means of same procedure another 100ml juice are taken with the addition of 2 teaspoons of sugar. These medium are taken as the Carrot and Beetroot juice for analysis.

2.4 Preparation of fruit extract Medium

The pomegranate juice is an energy drink with oxalic and tartaric acid [7] helps in increasing hemoglobin level of human. The botanical name pomegranate is *Punicagranatum*.

Pomegranate juice is makeup by the following steps, first peel the fresh pomegranate skin, and add 250 gram of arils to added 40 ml of water and blender. Once the arils are crushed, pour through a strainer into a bowl, then 100ml of the juice is taken, then add 2 teaspoon of sugar and by means of same procedure another 100ml juice are taken with the addition of 2 teaspoons of sugar. These medium is taken as the Pomegranate juice medium for the presence study.

2.5 Electrochemical studies

The corrosion resistance of Ni -Ti alloy has been measured by electrochemical studies such as Polarization study and AC impedance spectra. A CHI electrochemical work station was used for this purpose. A three electrode cell assembly was used in the present study Ni-Ti alloy was used as working electrode; saturated calomel electrode was used as reference electrode and Platinum electrode was used as counter electrode. From the Polarizations study corrosion parameters such as corrosion potential, corrosion current and Tafel slope values were calculated [4,6] and by means of AC impedance spectra the real part (Z') and imaginary part (Z'') of the cell impedance were measured in ohms at various frequencies. Values of the charge transfer resistance (Rt) and double layer capacitance (Cdl) were calculated from the Nyquist plot and the impedance; log (z/Ohm) value was calculated from Bode plots [7].

2.6 Atomic force microscope (AFM)

The underlying principle of AFM is that this nanoscale tip is attached to a small cantilever which forms a spring. As the tip contacts the surface, the cantilever bends, and the bending is detected using a laser diode and a split photo detector. This bending is indicative of the tip-sample interaction force. An atomic force is a magnifying observation tool capable of measuring 3D textures of a minuscule area. It helps to analyze the roughness of the surface, which facilitate quantification of sample and data post-processing. The AFM also allows for measurements in normal atmospheric conditions and is free from restrictions such as the need for sample pretreatment and electrical conductivity. On the other hand, however, it is subject to the limitation of a narrow measuring range (XYZ) due to its high-resolution capabilities.

3. Results and discussion:

3.1 Analysis of Potentiodynamic polarization curves:

Corrosion resistances of Ni-Ti alloy immersed in various test solutions are given in Table 3. The Potentiodynamic polarization curves are shown in Fig 1.

Table 3. Corrosion parameters of Ni-Ti in AS in the absence and presence of vegetable/ fruit juice system

Metal	System	E_{corr} V vs SCE	b_c V/ decade	b_a V/decade	LPR Ohmcm^2	I_{corr} A/cm^2
Ni-Ti	Artificial Saliva(AS)	-0.2296	6.068	2.484	41639.3	1.221x 10^{-6}
	AS+ CJ	-0.5409	5.502	4.712	71785.7	0.5930x 10^{-6}
	AS + BJ	-0.6932	7.7	4.119	30141.7	1.220 x 10^{-6}
	AS+ PJ	-0.5307	6.7	4.681	11167.1	3.421x10^{-6}
	AS+ CJ + Sugar	-0.6773	7.501	4.587	53823.5	0.6683x10^{-6}
	AS +BJ + Sugar	-0.7365	7.411	3.789	16531.2	2.348 x 10^{-6}
	AS+ PJ +Sugar	-0.5469	6.996	4.612	9861.3	3.798 x10^{-6}

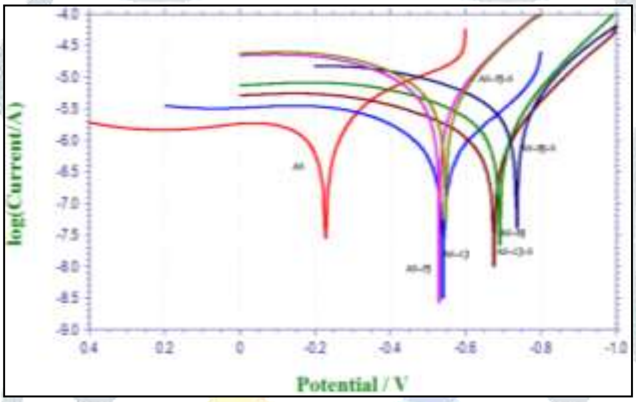


Fig.1 Polarization curves of Ni-Ti alloy in artificial saliva (AS) various Vegetable, Fruit juice medium

From the Table 3 it is found that, Linear Polarization Resistance (LPR) value of AS is 41639.3Ohm cm^2 and the Icorr is 1.221 x 10^{-6}A/cm^2. When Ni-Ti alloy immersed in Artificial Saliva with Carrot juice/with sugar the LPR and corrosion current(Icorr) value changes in comparison with AS and the observed corrosion resistance of value Ni-Ti alloy is given as:

AS + PJ + S < AS+ PJ < AS + BJ + S < AS + BJ < AS < AS + CJ +S< AS + CJ

3.2 Alternating Current Impedance Measurements

At various frequencies the actual component (Z') of the cell impedance and the imaginary part (Z') were measured in the alternating current impedance spectra. From the Nyquist plot the charging resistance (Rt) and the double layer capacitance (Cdl) were calculated and from the Bode plots the impedance log (z/ohm) value can be calculated. In the present study AC impedance parameters were calculated when Ni-Ti immersed in AS and AS containing Carrot, beetroot and Pomegranate juices with and without sugar, are given in table 4.

Table4. Corrosion parameters of Ni-Ti immersed in AS in the absence and the presence of Vegetable and Fruit juice

Alloy	System	Nyquist plot		Bode plot
		R_t ohm cm^2	C_{dl}, F cm^2	Impedance value Log(Z/ohm)
Ni-Ti	Artificial Saliva(AS)	884.3	5.654 x10^{-9}	3.8
	AS + CJ	1699.0	2.943 x10^{-9}	3.9
	AS + BJ	862.93	5.794 x10^{-9}	3.61
	AS + PJ	781.93	6.402 x10^{-9}	3.53
	AS + CJ + Sugar	900.64	5.552 x10^{-9}	3.55
	AS + BJ + Sugar	841.93	5.945 x10^{-9}	3.6
	AS + PJ + Sugar	628.1	7.961 x10^{-9}	3.8

From the Table 1 it is observed that the charge transfer resistance of Artificial saliva is 884.3ohm cm^2, double layer capacitance was 5.654x10^{-9} F cm^2 and the impedance value in log (Z ohm^{-1}) was 3.8. The presence of Beetroot, Carrot and Pomegranate juice and with additive sugar R_t value change as indicated in Table 4.

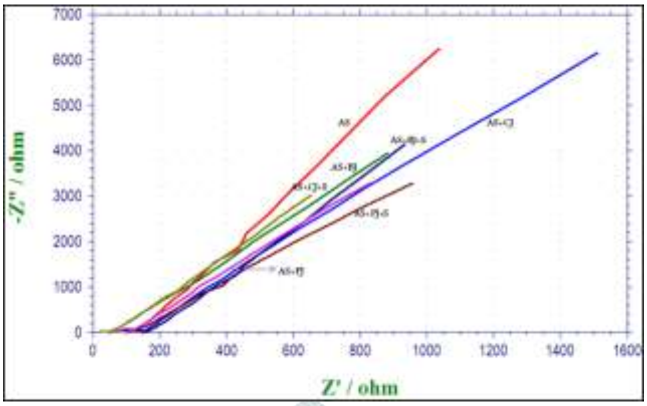


Fig 2 Alternate current impedance spectra (Nyquist plot) of Ni-Ti alloy in artificial saliva (AS) various Vegetable, Fruit juice medium

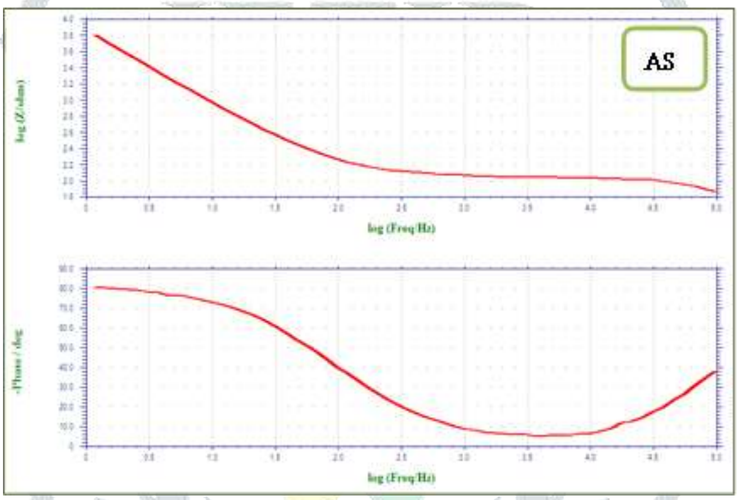
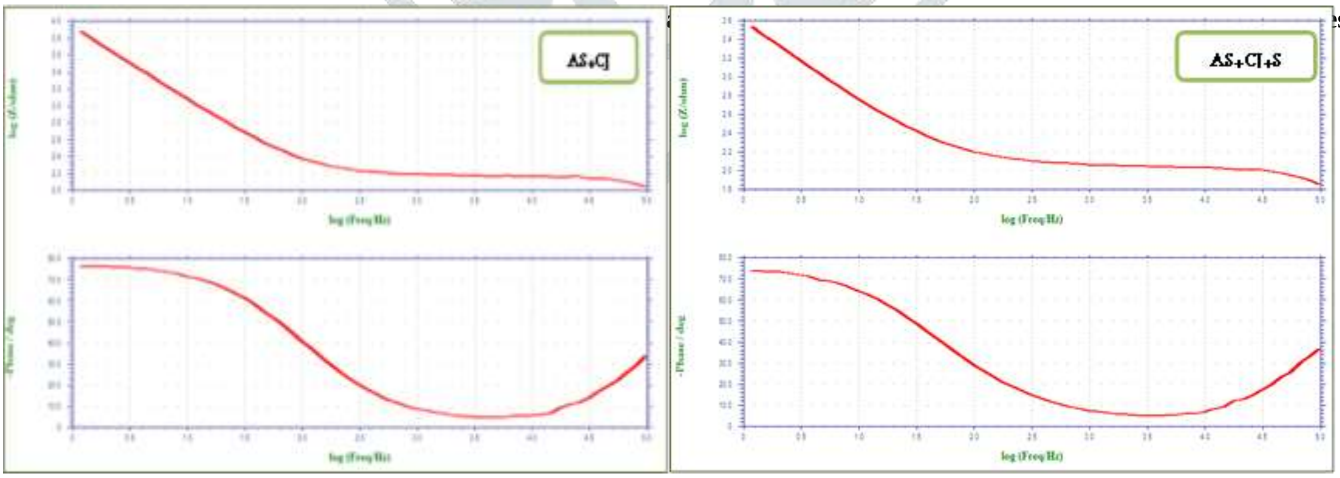
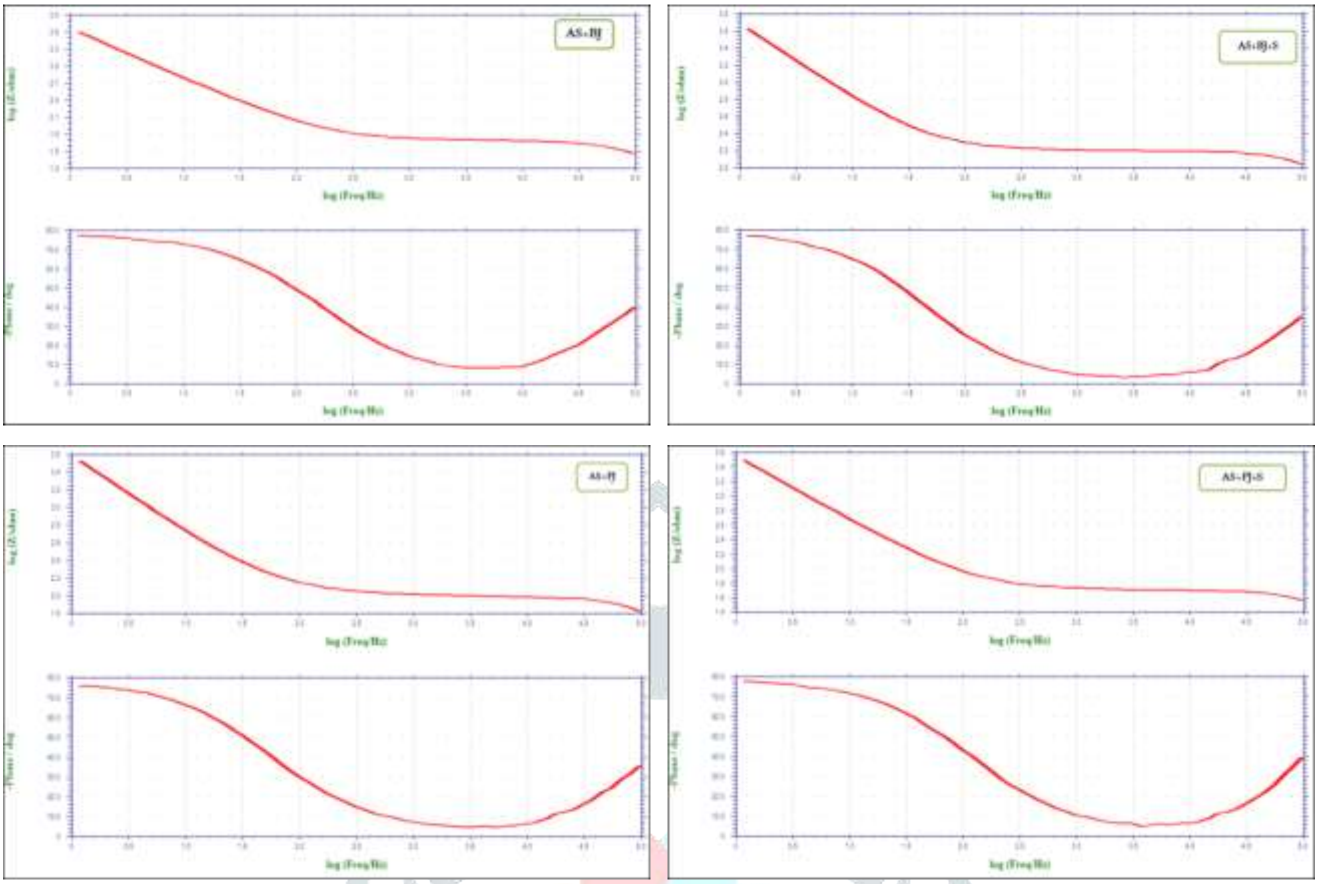


Fig 3 Alternate current impedance spectra (Bode plot) of Ni-Ti alloy in artificial saliva (AS)





3.3 Atomic Force Microscopy

Table 5 : AFM data for Ni-Ti alloy surface immersed in AS, AS+ CJ, AS+BJ and AS+PJ

System	RMS Roughness Rq(nm)	Average Roughness Ra (nm)
Artificial saliva(AS)	36.15	28.81
AS+ CJ	30.17	23.40
AS+ BJ	58.88	48.24
AS+ PJ	85.37	75.25

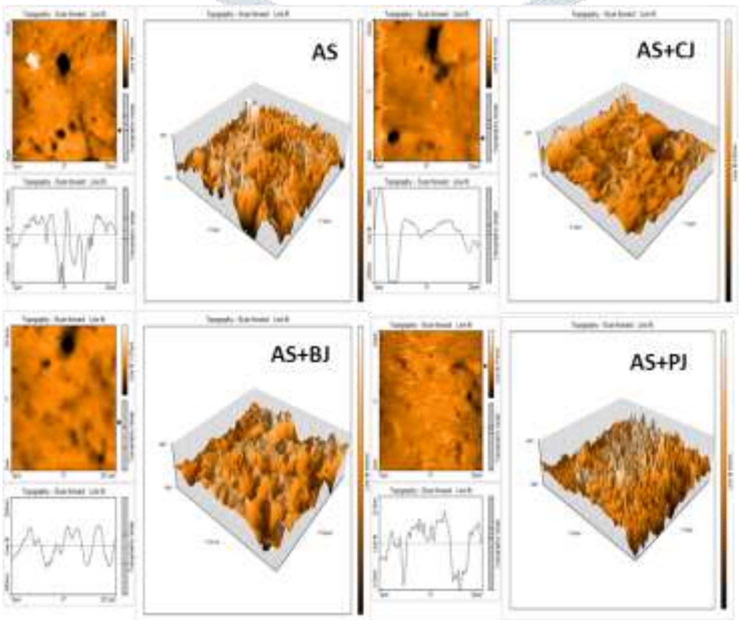


Fig 5 Surface morphology of Ni-Ti alloy in AS, AS + CJ, AS + BJ and AS + PJ

The value of R_{RMS}, and R_a for the Ni-Ti alloys surface in AS are 36.15nm and 28.81nm respectively, which show a more homogeneous surface, with some places in which the height is lower than the average depth. The slight roughness observed on the

Ni-Ti alloy surface in AS is due to atmosphere corrosion. The value of R_{RMS}, and R_a for the Ni-Ti alloy surface in AS+ CJ are 30.17nm and 23.40nm respectively. And the value of R $_{RMS}$, and R_a for the Ni-Ti alloy surface in AS+BJ are 58.88 nm and 48.24nm respectively. The value of R_{RMS}, and R_a for the Ni-Ti alloy surface in AS+ PJ are 85.37 nm and 75.25nmrespectively.These data suggest that Ni-Ti alloy surface in AS+ CJ has a lower surface roughness than the other medium in AS and other testing solutions.

5. CONCLUSION

- The corrosion study of Ni-Ti alloy in artificial saliva in vegetable-fruit extract and with added sugar was studied by electrochemical methods. From polarization studies and AC impedance spectral studies, the corrosion resistance of the Ni-Ti alloy decreases in the following order:

  AS + PJ + S < AS+ PJ < AS + BJ + S < AS + BJ < AS < AS + CJ +S< AS + CJ

  And in the present study carrot juice is observed as the best medium towards oral supplement.
- AFM Study also reveals surface smoothness of **AS + CJ** system
- Hence, it is recommended that the people clipped with orthodontic wires made of Ni-Ti alloy may take carrot juice orally without any hesitation.

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