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Effect of Tobacco Smoking on the Corrosion Behavior of Three Dental Alloys in Artificial Saliva

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Abstract

This work involves study the effect of tobacco smoking (cigarette, water-pipe smoking) yields on the corrosion of dental alloys (Co-Cr-Mo, Ni-Cr and Ti-Al-V alloy) in artificial saliva with pH=4 and temperature of 37^{o}C. This study was performed with electrochemical technique by using potentiostat to predict the potentiodynamic polarization and cyclic polarization. Some corrosion parameters were measured for comparison among the dental alloys. Generally, the presence of tobacco smoking yields shift the corrosion rate (C_R) to higher values, and the data of corrosion rate indicate that the risk of waterpipe smoking more than cigarette smoking for three dental alloys. Increasing of anodic Tafel slopes inferred that the rate of change of current with change of potential was smaller during cathodic polarization than during anodic polarization.

Introduction

Dental materials within the mouth interact continuously with physiological fluids. Oral tissues are exposed to bombardment of both chemical and physical stimuli, as well as the metabolism of about 30 species of bacteria. Saliva is a hypotonic solution containing chloride, potassium, sodium, nitrogenous compounds and proteins and the pH of saliva varies from 5.2 to7.8(1,2).There are many harmful materials has been taken by human which may have positive or negative effect on the corrosion of dental materials such as water-pipe (shisha or narghile) and cigarette smoking which contain many hazardous materials; alcoholic beverages (beer, wine, and whiskey) which contain ethyl alcohol from 10 to 50 percent; and some acidic materials in food such as vinegar and fruit juices, some basic materials in drugs for healing acidity of stomach such as cimetidine, ranitidine, famotidine, and nizatidine etc.Corrosion, the graded degradation of materials by electrochemical attack, is of concern particularly when dental materials are placed in the hostile electrolytic environment provided by the human mouth. Factors such as temperature, quantity and quality of saliva, plaque, pH, proteins, physical/chemical properties of solids/liquids food and oral conditions may influence corrosion processes. Therefore, many authors were investigated in wide fields about the corrosion of dental alloys in artificial saliva with and without fluoride ions by electrochemical techniques (3-8) to predict polarization behavior and cyclic polarization of different dental alloys and measure the corrosion parameters. Other authors studied the behavior of dental materials in artificial saliva by using electrochemical impedance spectroscopy (EIS) (9-13) to measure the resistance of alloys surface. Chang et al. studied electrochemical

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behavior on microbiology related corrosion of metallic dental materials in the presence of streptococcus mutants [14]. While Kinani et al. studied effect of eugenol (occurs widely as a component of essential oils and is a major constituent of clove oil) on the titanium corrosion in artificial saliva enriched with eugenol at different concentration by utilizing electrochemical measurement and scanning electron microscopy [15]. Rajendran et al. studied corrosion behavior of mild steel (MS) , mild steel zinc coated (MS-Zn) and stainless steel 316L (SS) in artificial saliva at pH=6.5 and 37^oC in presence of D-Glucose by utilizing potentiodynamic polarization study and AC impedance spectra [16]. In other study, Rajendran et al. studied corrosion behavior of same materials in the presence of spirulina powder (a tiny aquatic plant has been eaten by human since prehistoric times) by using same technique and they showed that the corrosion resistance was SS316L > MS > MS-Zn [17]. Waterpipe smoking is now considered a global public health threat and the corresponding artifact is actually known in the world under three main terms: hookah, narghile and shisha according to the World Health Organization (WHO). Side effect of waterpipe such as tar yields, heating and burning, levels of carbon monoxide in charcoal harm reduction, nicotine addiction, and the relationship between waterpipe smoking and the use of other drugs, including marijuana were studied[18], and according to research conducted for the World Health Organization (WHO), alcohol-related harm is nearly equal to that caused by tobacco, and far greater than for illicit drugs [19]. Four percent of the global burden of disease is attributable to alcohol, compared with 4.1 percent to tobacco and 4.4 percent to high blood pressure [20].Nancy Daher et al. studied the comparison of carcinogen, carbon monoxide, and ultrafine particle emissions from narghile waterpipe and cigarette smoking; side stream smoke measurements and assessment of second – hand smoke emission factors by using smoking machine[21]. Base-metal alloys are used extensively in dentistry for appliances and instruments. Cast cobalt-chromium and nickel-chromium alloys have been used for many years for fabricating partial-denture frameworks. Cast nickel-chromium alloys are used in fabricating crowns and bridges. Nickel-chromium and cobalt-chromium alloys are used in porcelain-fused-to-metal. Titanium and titanium alloys are used in cast and wrought forms for crowns, bridges, implants, orthodontic wires, and endodontic files. Stainless steel alloys are used principally for orthodontic wires, in fabricating endodontic instruments, and for performed crowns [22].The aim of this study is to highlight effect harmful yields of tobacco smoking (cigarette and waterpipe) on the corrosion behavior of three dental alloys (Co-Cr-Mo, Ni-Cr-Mo and Ti-Al-V) in artificial saliva at pH=4 and 37^oC.

Materials and Methods

In this study we used Co-Cr-Mo alloy, Ni-Cr-Mo alloy and Ti-Al-V alloy, the chemical composition of these alloys shown in Table (1) to (3) using X-ray florescence technique (X-MET 3000TX). One sample of each dental alloys (commercially available) were cut into cylinder or square shape and made into electrode by hot mounting to insulate all but one side with an epoxy resin, the open side was polished mechanically to a mirror finish, rinsed in distilled water and stored in desiccators to new test.The electrolyte reference used was artificial saliva, which closely resembles natural saliva, with composition of (0.4 g/L KCl, 0.4g/L NaCl, 0.906 g/L $CaCl_2.2H_2O$, 0.69 g/L $NaH_2PO_4.2H_2O$, 0.005g/L $Na_2S.9H_2O$ and 1g/L urea). Lactic acid was added to adjust the pH of the solution at 4 [23].Study the effect of tobacco smoking yields was performed by using smoking machine shown in Fig. (1) by using 10cigerette and waterpipe smoking for 15min.Polarization experiments were performed in WINKING M Lab 200 Potentiostat from Bank-Elektronik with electrochemical standard cell with provision for working electrode (dental alloys), auxiliary electrode (Pt electrode), and a Luggin capillary for connection with an SCE reference electrode. Electrochemical measurements were performed with a potentiostat by SCI electrochemical software at a scan rate 0.5mA.sec^{-1}.The main results obtained were expressed in terms of the corrosion potentials (E_{corr}) and corrosion current density (i_{corr}) in addition to measure the Tafel slops. Cyclic polarization was performed on three specimens in electrolyte from –40 mA to 15 mA and back to –40 mA (vs. E_{oc}) using a scan rate of 0.5 mA/s. All potential values were referenced to the standard calomel electrode (SCE).

Results and Discussion

Potentiodynamic Curves

After immersion in the electrolyte for 20 min., a linear polarization test was carried out for the specimens in artificial saliva to determine the values of polarization data. Fig. (2) shows the polarization behavior of three dental alloys in artificial saliva without addition any materials at pH=4 and 37^{o}C. While Figs. (3) and (4) show the effect of tobacco smoking yield of cigarette and waterpipe respectively on corrosion behavior of three experimental dental alloys.The presence of these harmful materials yields increase the dissolution of metals in dental alloys to take wide range of potentials in anodic region (upper section of curve), and the dissolution of metals or oxidation can be represented in the following reactions:

$Co \rightarrow Co^{2+} + 2e$, $Ni \rightarrow Ni^{2+} + 2e$,
$Cr \rightarrow Cr^{3+} + 3e$, $Mo \rightarrow Mo^{3+} + 3e$,
$Ti \rightarrow Ti^{4+} + 4e$, $Al \rightarrow Al^{3+} + 3e$……

While the lower section represents reduction reaction which includes evolution of hydrogen molecules because acidity of electrolyte (artificial saliva) as follows:

$2H^{+} + 2e \rightarrow H_2$

In addition to reduction of oxygen to water molecules:

$O_2 + 4H^{+} + 4e \rightarrow 2H_2O$

Also can be seen that the anodic curve for three dental alloys give a narrow passive region in presence of tobacco smoking yields before unstable pitting potential was reached, indicating decrease in passive state stability. There is a tendency for polarization curves to shift “right” (to higher current densities). The width of the passive range in presence of cigarette smoking yields was larger than that observed in presence of waterpipe smoking yields. In both cases, the cause of passive occurring is presence the hydrocarbons which behave as inhibitors.

Corrosion Parameters

The corrosion parameters determined for each alloy from the potentiodynamic polarization study are listed in Table (4). These data indicate that the presence of harmful materials yields in test solution (artificial saliva) shift the corrosion potentials values (E_{corr}) either in active or in noble direction. This means that the potential of the galvanic cell becomes more positive or negative and hence the Gibbs free energy change (ΔG) for the corrosion process becomes more negative or positive respectively. The corrosion reaction is then expected to be more or less spontaneous on pure thermodynamic ground and vice versa. It is thus shown that (E_{corr}) value is a measure for the extent of the feasibility of the corrosion reaction on purely thermodynamic basis.While, in general, the corrosion current densities values (i_{corr}) shift to higher values for three dental alloys. It is known that any factor that enhances the value of (i_{corr}) results in an enhanced value of the corrosion rate on pure kinetic ground. The rate (C_R mpy) of corrosion in a given environment is directly proportional with its corrosion current density (i_{corr}) in accordance with the relation [24]:

$$C_R(mpy) = 0.13 \frac{e}{\rho} i_{corr.} \quad .....(1)$$

where $C_R(mpy)$: corrosion rate in mil per year, e: equivalent weight of alloy (gm), and ρ: density of alloy (gm/cm^3).

The data of corrosion rate show, in general, that the presence of harmful materials increases the rate of corrosion and the data are listed in table (4).The Tafel slopes were very much influenced in the presence of these harmful materials, the cathodic Tafel slope (b_c) shows various behavior in case of Co-Cr-Mo and Ni-Cr-

Mo alloy, while was increased for Ti-Al-V alloy. But the anodic Tafel slopes (b_a) were increased for three dental alloys and have values higher than that of cathodic Tafel slopes. It is inferred that the rate of charge of current with change of potential was smaller during cathodic polarization than that during anodic polarization.The polarization resistance (Rp) can be determined from the Tafel slopes and according to Stern- Geary equation [25, 26]:

$$R_p = \left(\frac{dE}{di}\right)_{i=0} = \frac{b_a b_c}{2.303(b_a + b_c)i_{corr}} ....(2)$$

The values of R_p which have been calculated from above equation are presented in Table (4). These data indicate that the polarization resistance value was decreased for three dental alloys in the presence of addiction materials.The comparison among dental alloys in the same test solution shows that Ti-Al-V alloy have more negative corrosion potential, and the corrosion potential values take the following sequence:

$-E_{corr}$ (mV) Ti-Al-V alloy > Co-Cr-Mo alloy > Ni-Cr-Mo alloy

The data of polarization resistance were various in their behavior for dental alloys. But the data of corrosion rate in the presence of harmful materials take the sequence:

Increasing of corrosion rate Ti-Al-V alloy > Co-Cr-Mo alloy > Ni-Cr-Mo alloy

Generally, the increases in corrosion rate refer to more dissolution of metals in dental alloys in presence of harmful materials because of the many materials exist in tobacco smoking (cigarette and waterpipe) yields. Kamal Chaouachi studied the specific chemicals in tobacco smoking such as nicotine, CO, aldehydes, polycyclic aromatic hydrocarbons (PAHs), phenols, benzene and toluene, nitric oxides, heavy metals, nitrosamines, acetone and 2-butanone, radiotoxic elements, and other materials are present in the side–stream smoke (SSS) and exhaled main–stream smoke (EMSS)[27].

Cyclic Polarization

Cyclic polarization method is highly useful method for determining the susceptibility of a metal or alloy to pitting [28]. From Figures (5) to (7), it can be seen that at the vertex potential of 1000 mV for Co-Cr-Mo and Ni-Cr alloys and 2000 mV for Ti-Al-V alloy when the scan reverses its direction, the reverse scan starts left of the forward scan curve, that is, towards the low current density region. This type of cyclic polarization curve is known to resist localized corrosion [29]. It is also observed that the reverse scan curves meet the forward scan curve along the passive range. The potentials for the reverse scan curves are more positive than those for the forward scan as shown in Table (5). These results show that a stable oxide film is formed during the forward scan.The cyclic polarization results also suggest that none of the alloys would be prone to pitting or crevice corrosion under in vitro conditions for Co-Cr-Mo and Ni-Cr-Mo alloys, but crevice conditions should nonetheless be avoided for these alloys in the oral environment. While the pitting corrosion can occurs in the Ti-Al-V alloy as shown from hysteresis loop in cyclic polarization, and all data of cyclic polarization were listed on the curves for three alloys.

Conclusion

Under the conditions of the studies described in this paper, the following conclusions can be drawn:

1- The presence of tobacco smoking yields in the mouth affects the corrosion of dental alloys which used in this work (Co-Cr-Mo, Ni-Cr and Ti-Al-V alloys) through increases the oxidation of metals to produce many compounds between the metal ions and smoking yields. This effect appears through the anodic curve in the polarization behavior and the data of corrosion rate.

2- The data of Tafel slopes indicate that the rate of charge of current with change of potential was smaller during cathodic polarization than that during anodic polarization for dental alloys in experimental electrolyte.

3- The data of polarization resistance were various in their behavior for dental alloys.

4- The data of corrosion rate for three dental alloys in the same condition take the following sequence:

$\mathbf{C_R}$**(mpy)***Ti-Al-V alloy>Co-Cr-Mo alloy > Ni-Cr-Mo alloy*

5- The results of the cyclic polarization results also suggest that none of the Co-Cr-Mo and Ni-Cr-Mo alloys would be prone to pitting or crevice corrosion under in vitro conditions, while the pitting corrosion can occurs in the Ti-Al-V alloy.

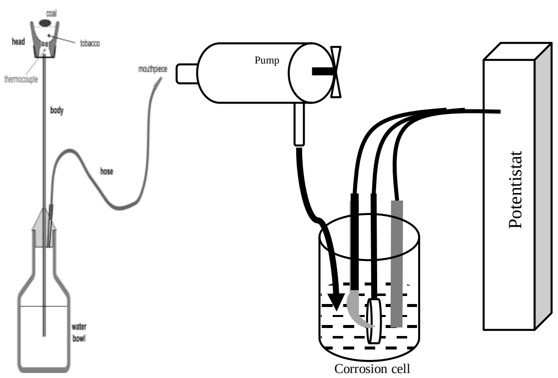

Fig. (1):- Smoking machine.

Recommendation

From the results of this study can be recommend with study the other harmful materials, in addition to study the effect of smoking on the amalgam. The corrosion behavior can be study at temperatures higher than 37^{o}C because of burning heat of charcoal.

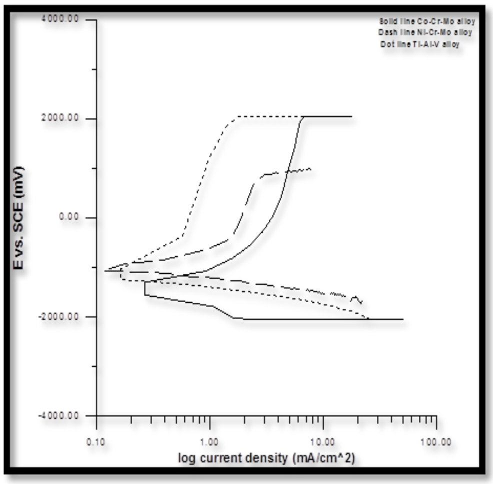

Fig. (3):- Potentiodynamic curve of dental alloys in artificial saliva + smoking yield of 10 cigarette at pH=4 and 37^{o}C.

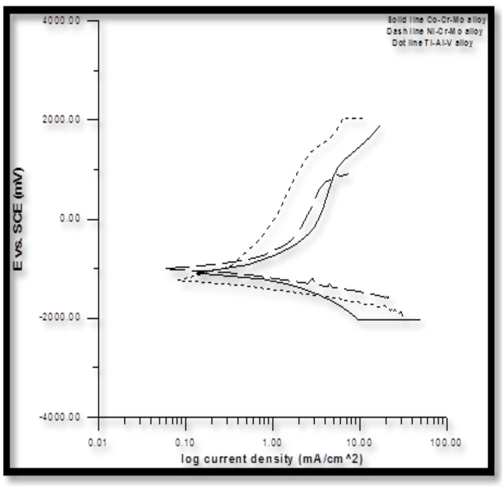

Fig.(2):- Potentiodynamic curve of dental alloys in artificial saliva at pH=4 and 37^{o}C.

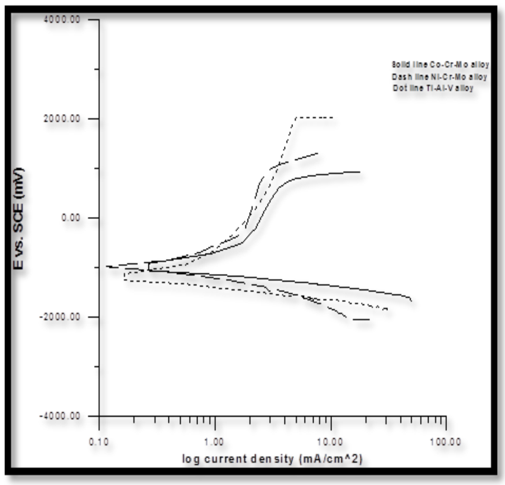

Fig.(4):- Potentiodynamic curve of dental alloys in artificial saliva + smoking yield of waterpipe at pH=4 and 37^{o}C.

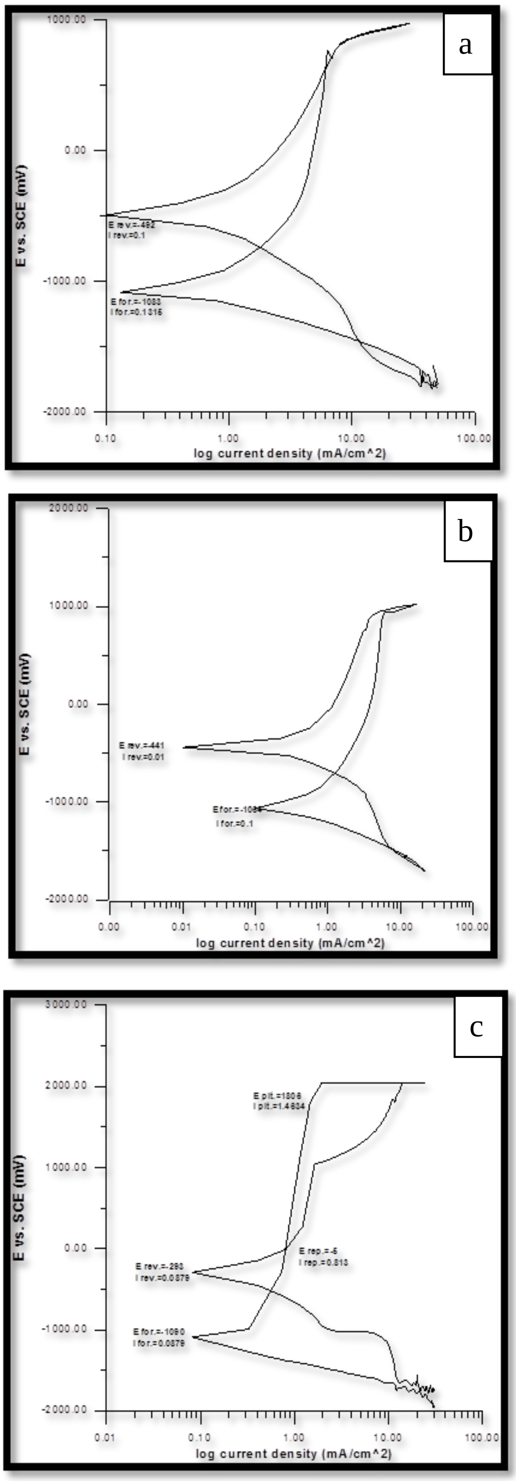

Fig.(5):- Cyclic polarization in artificial saliva at pH=4 and 37^oC for (a):Co-Cr-Mo, (b):Ni-Cr-Mo and (c):Ti-Al-V.

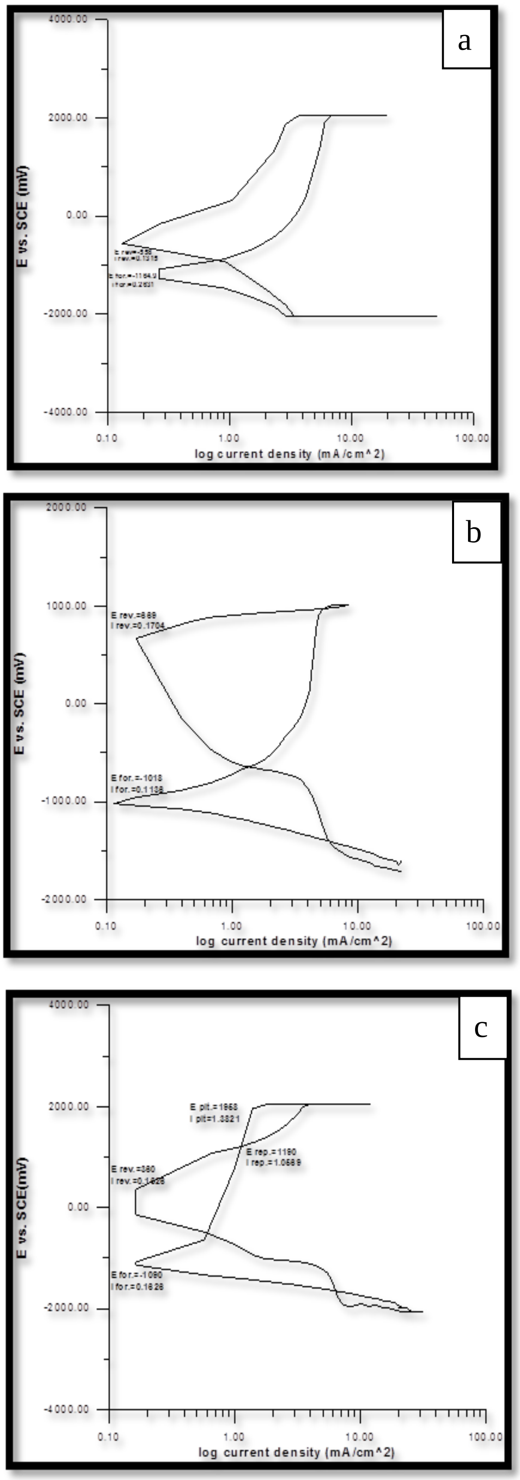

Fig.(6):- Cyclic polarization in artificial saliva+cigarette at pH=4 and 37^oC for (a):Co-Cr-Mo,(b):Ni-Cr-Mo and (c):Ti-Al-V.

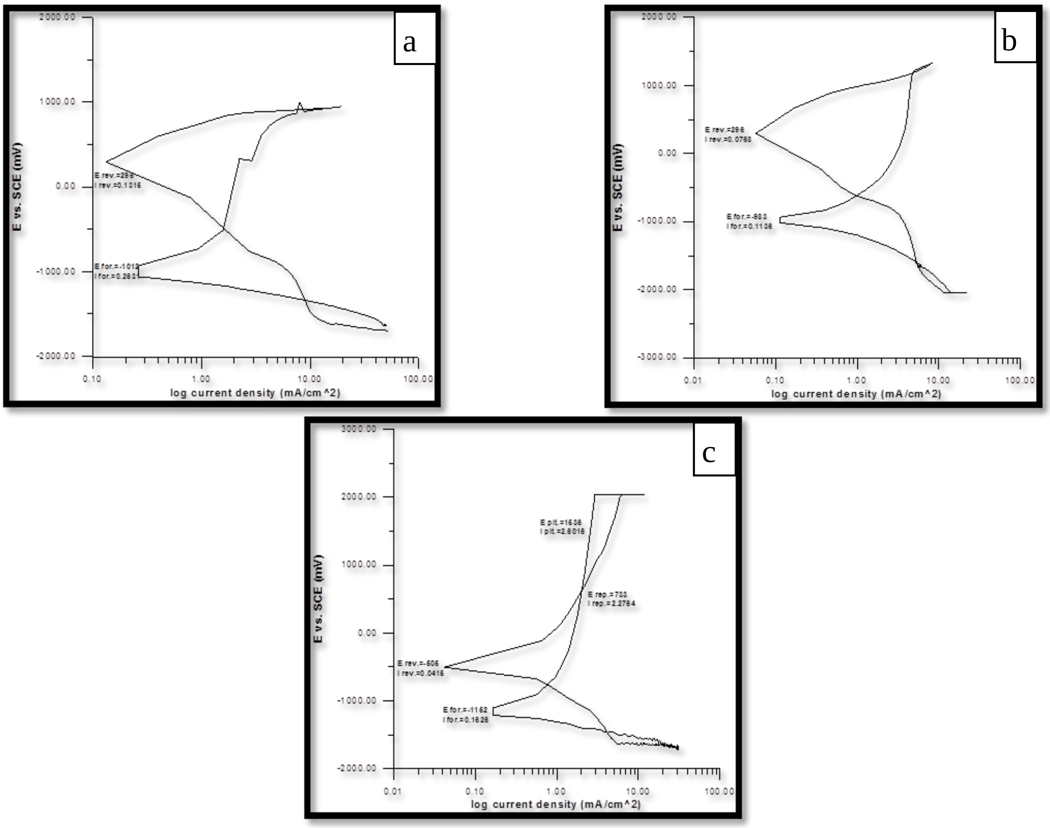

Fig.(7):- Cyclic polarization in artificial saliva+waterpipe at pH=4 and 37^{o}C for (a):Co-Cr-Mo,(b):Ni-Cr-Mo and (c):Ti-Al-V.

Table (1):- Chemical composition of Co-Cr-Mo alloy.

Elements	**Cr**	**Mo**	**W**	**Mn**	**Fe**	**Nb**	**Co**	***ASTM***
Wt%	**26.9**	**5.27**	**1.01**	**0.93**	**0.4**	**0.16**	**Balance**	***F75***

Table (2):- Chemical composition of Ni-Cr-Mo alloy.

Elements	**Cr**	**Mo**	**Nb**	**Fe**	**Cu**	**Ni**	***UNS number***
Wt%	**20.9**	**9.94**	**3.8**	**2.4**	**0.13**	**Balance**	***N08825***

Table (3):- Chemical composition of Ti-Al-V alloy.

Elements	**Al**	**V**	**Cu**	**Fe**	**Nb**	**Ti**	***UNS number***
Wt%	**5.54**	**3.6**	**0.18**	**0.17**	**0.01**	**Balance**	***R56400***

Table (4):- Corrosion parameters of dental alloys in artificial saliva at pH=4 and temperature 37°C in the presence of addiction materials include cigarette, waterpipe and beverage alcoholic.

Alloys	Medium	$-E_{corr}$ (mV)	i_{corr} ($\mu A.cm^{-2}$)	$-b_c$ ($mV.dec^{-1}$)	b_a ($mV.dec^{-1}$)	R_p ($\Omega.cm^{-2}$)	$C_R x10^3$ (mpy)
Co-Cr-Mo	Artificial saliva	1058.4	450.09	659.4	1278.0	0.978	0.1948
	Cigarette(10cig.)	1243.9	452.81	1183.4	1714.6	0.710	0.1961
	Waterpipe(15min.)	1012.9	637.01	315.0	2247.9	0.189	0.2759
Ni-Cr-Mo	Artificial saliva	997.30	299.05	258.3	433.8	0.235	0.1136
	Cigarette(10cig.)	959.10	390.61	254.3	546.0	0.193	0.1484
	Waterpipe(15min.)	906.70	602.96	548.8	1049.1	0.260	0.2291
Ti-6Al-4V	Artificial saliva	1232.2	288.44	278.9	206.9	0.370	0.1996
	Cigarette(10cig.)	1244.6	421.40	313.4	4636.2	0.303	0.2916
	Waterpipe(15min.)	1152.2	596.40	386.1	1923.6	0.234	0.4127

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