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Effect of Laser Surface Modification on the Corrosion Resistance of Dental Alloys in Artificial Saliva Containing Alcoholic Beverages

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Abstract: The objective of this study is to demonstrate the corrosion behavior of dental alloys Co-Cr-Mo, Ni-Cr-Mo and Ti-Al-V in artificial saliva at pH=4 and 37°C enriched with ethyl alcohol at 8% percentage. The linear and cyclic polarizations were investigated by electrochemical measurements. Laser surface modification was achieved for the three dental alloys to improve corrosion resistance. The results show that corrosion resistance of Co-Cr-Mo and Ni-Cr-Mo alloys only were increased after laser treatment due to the fact that laser radiation has caused a smoother surface, in addition to the decrement in corrosion current densities (i_{corr}) for Co-Cr-Mo and Ni-Cr-Mo alloys and the reverse scan in cyclic polarization became in the wider range of potentials compared with the reverse scan for untreated dental alloys, in addition to the obtainment of smaller hysteresis loop for Ti-Al-V alloy.

Introduction

Alcohol is a drug that causes about as much harm as tobacco. It is linked to more than 60 medical conditions and imposes a heavy burden on public health and finances[1]. 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 [2]. Four percent of the global burden of disease is attributed to alcohol, compared with 4.1 percent to tobacco and 4.4 percent to high blood pressure.

Ethanol or ethyl alcohol is the active ingredient in alcoholic beverages such as beer, wine and whisky. It is produced by the fermentation of carbohydrates (sugars and starches) in fruits and other plant sources (such as corn, barley, grapes, and so on), using the process that discovered thousands of years ago. During fermentation, microorganism, such as yeast, convert sugar to alcohol and carbon dioxide [3,4].

The properties of pure 100% absolute alcohol (dehydrated) are: colorless limpid volatile liquid; boiling point 78°C; freezing point 117.3°C; vinous odor; and pungent taste. It is miscible with water, methyl alcohol, ether, chloroform and acetone [5].

Ethanol is very soluble in water because it contains a polar O-H bond like those in water which makes it very compatible with water [3].

There are many authors studied the behavior of dental alloys in artificial saliva to measure the resistance of these alloys toward many materials. Chang et al. [6] studied electrochemical behavior on microbiology related corrosion of metallic dental materials in the presence of streptococcus mutants. While Latifa 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 [7].

Rajendran et al. studied corrosion behavior of mild steel (MS) , zinc coated mild steel (MS-Zn) and stainless steel 316L (SS) in artificial saliva at pH=6.5 and 37^{o}C in presence of D-Glucose by utilizing potentiodynamic polarization study and AC impedance spectra. The results of this study indicated that in the presence D-Glucose all three alloys showed better corrosion resistance than in the absence D-Glucose because in presence D-Glucose will form metal (Ni-Cr-Fe)-glucose complex on metal surface, it is compact, close packed and stable [8]. In another 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) using the same technique and they showed that the corrosion resistance was SS316L > MS > MS-Zn [9].

The aim of this work is an attempting to improve the corrosion resistance of dental alloys in artificial saliva at pH=4 and 37^{o}C in presence of 8% ethyl alcohol which represents the level of ethanol in some alcoholic beverages.

Materials and Procedure

Preparation of Samples and Electrolyte

The alloys used in this study were Co-Cr-Mo alloy, Ni-Cr-Mo alloy and Ti-Al-V alloy, the chemical composition of these alloys was determined using X-ray florescence technique (X-MET in Ministry of science and technology-Iraq) and as shown in Tables (1) to (3) by. Commercially available dental alloys were cylinder shape for Ni-Cr-Mo (15mm diameter and 5mm thickness) and square shape for Co-Cr-Mo with dimension of (5x8x9.5 mm), while Ti-Al-V was cut with dimension (13x9.5x5 mm). All three alloys were made into electrode by hot mounting to insulate all but one side with an epoxy resin.

Table (1): Chemical composition of Co based 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 based 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 based alloy.

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

The open side of mounted specimens were wet grinding by different degree of silicon carbide papers (600, 800, 1000 and 1200) with sample rotate 90^o when change paper, then polishing samples by napped cloth and alumina slurry has particle size (0.3µm) by using (Ma-Pao 160E Grinder and Polisher) machine Chine manufactured, rinsed in distilled water and stored in desiccators. 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)[10]. Lactic acid was added to adjust the pH of the solution at 4.

The presence of alcoholic beverage was performed by adding 8% ethyl alcohol to experimental solution.

Electrochemical Measurements

Polarization experiments were performed in WINKING M Lab (Germany manufactured) Potentiostat/Galvanostat from Bank-Elektronik with electrochemical standard cell with provision for working electrode (dental alloys), auxiliary electrode (Pt electrode), and a Luggin capillary as salt bridge for connection with saturated calomel electrode SCE reference electrode. Electrochemical measurements were performed with a potentiostat by 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 measuring the Tafel slops by Tafel extrapolation method.

Laser Surface Modification (LSM)

The laser that used in this work is a home built Q-switched Nd:YAG laser with an output of second harmonic generation of 1064nm, laser energy of 190mJ, 30ns pulse duration, and 0.5mm spot size. One advantages of laser surface modification LSM was the obtainment of smooth surface for treated alloys.

The surface roughness measurements of polished specimens were carried out by using a stylus profilometer, civil instrument (TR 200) with stylus tip radius 2µm. Vickers microhardness for specimens without and with LSM were by taking average of three readings.

Results and Discussion

Surface Characterization

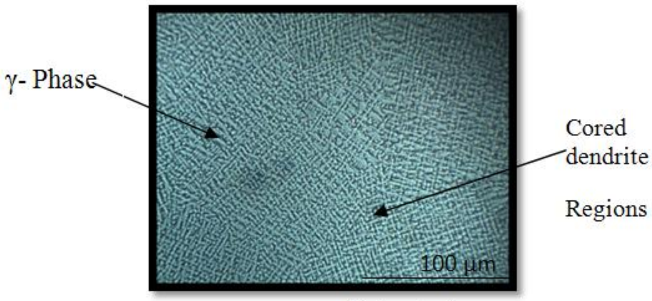
Table (4) indicates surface roughness measurements of polished specimens.

Table (4): Surface roughness measurements for specimens.

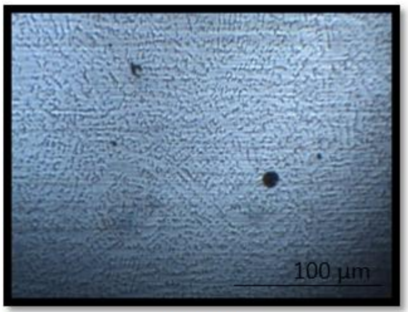
Specimens (alloys)	*Ra (µm) of untreated alloys*	*Ra (µm) of treated alloys*
Co-Cr-Mo	3.622	0.452
Ni-Cr-Mo	4.112	0.563
Ti-Al-V	4.665	0.738

The microstructures of specimens of the three dental alloys are shown in Figs. (1) to (3) for untreated and LSM treated specimens. They indicate laser spots in the specimens.

LSM treatment has effect on hardness of specimens due to laser melting and rapid cooling, while the bulk of material (which known as saturated solid solution) remained unaffected.

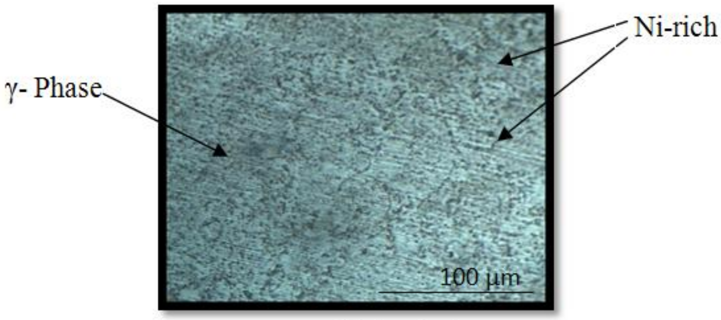


Untreated



Treated

Fig. (1): Optical micrograph for untreated and treated Co-Cr-Mo alloy without etching.



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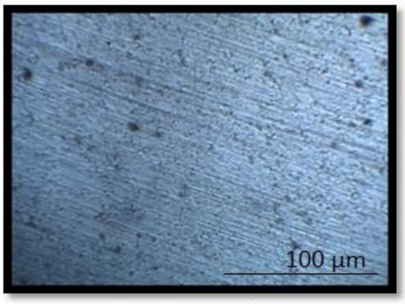
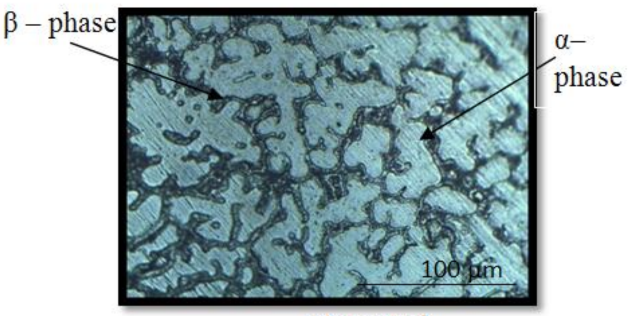
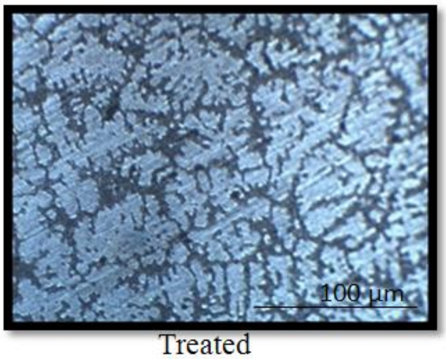


Treated

Fig. (2): Optical micrograph for untreated and treated Ni-Cr-Mo alloy without etching



Untreated



Treated

Fig. (3): Optical micrograph for untreated and treated Ti-Al-V alloy without etching.

Table (5) indicates Vickers microhardness for specimens without and with LSM

Table (5): Vickers microhardness for untreated and treated specimens by LSM.

Specimens (alloys)	***Hardness (VHN) of untreated alloys***	***Hardness (VHN) of treated alloys***
Co-Cr-Mo	410	430
Ni-Cr-Mo	229	254
Ti-Al-V	471	528

Open Circuit Potential Measurements (OCP)

The electrical potential at the metal electrolyte interface is strongly dependent on the nature and the concentration of the electrolyte, pH and surface conditions. As a result, the electrochemical reactions at this interface vary with time. The OCP-Time was measured with respect to SCE for 20 minute with scan rate 10mV in aerated electrolyte of artificial saliva at pH=4 and 37±1°C for dental alloys.

Fig.(4) shows OCP-time measurement for untreated dental alloys in artificial saliva (AS).

OCP-time measurement for Co-Cr-Mo and Ni-Cr-Mo alloys show little changes in potential magnitudes then stabilize at -565mV and -547mV respectively, while Ti-Al-V alloy shows gradual rising in potential magnitudes for all duration test to reach -586mV. The potential increase shows that the alloys become thermodynamically more stable with time. The open circuit potential (E_{oc}) for untreated Co-Cr-Mo and Ni-Cr-Mo alloys was more noble than that of Ti-Al-V alloy because of presence of chromium in these alloys which form stable passive film. Thus Ni-Cr-Mo alloy has thermodynamically less tendency to corrosion, this is agreement with the conclusion of Mareci et al. [11] that NiCr-based alloys exhibit passivity at OCP for the polarization resistance which is increasing with the immersion time because of the surface passivation.

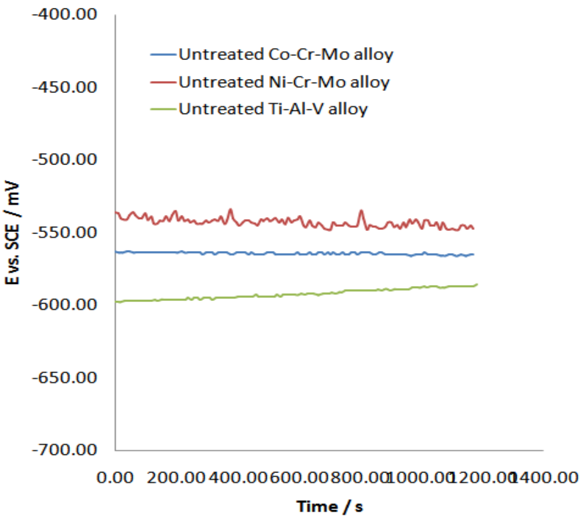
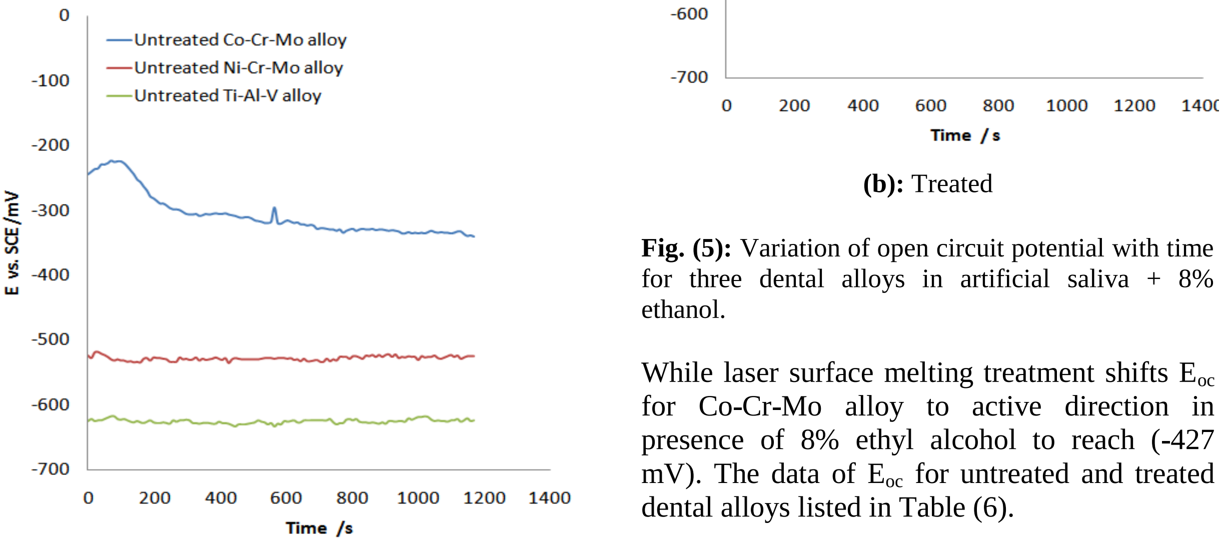


Fig. (4): Variation of open circuit potential with time for untreated three dental alloys in artificial saliva.

Fig.(5-a) shows OCP-time measurements for untreated dental alloys in artificial saliva and ethanol at pH=4 and 37°C. Co-Cr-Mo alloy begins at potential -245mV which then increased up to -233mV because of forming Cr_2O_3 and then dropped to -300mV due to gradually breakdown of passive layer and gradually decreased in potential magnitudes at -341mV because the passive layer don’t cover alloy surface completely, while potential-time test for Ni-Cr-Mo alloy begins at potential -525mV which then increased to -530mV and stabilize at -525mV indicating the stability of passive film in this alloy. Ti-Al-V alloy is stabilized at constant potential equal to -624mV with little changes. Generally, the data of E_{oc}

were shift in the noble direction for the alloys suggests the formation of passive film that acts as a barrier for metal dissolution and reduces the corrosion rate in presence of 8% ethyl alcohol as shown in Table (6). Fig. (5-b) shows OCP-time measurements for treated dental alloys with LSM treatment in artificial saliva and 8%ethanol. Ni-Cr-Mo and Ti-Al-V alloys show stabilization at constant potential and shifted to noble direction -190mV and -531mV respectively.



(a): Untreated

(b): Treated

Fig. (5): Variation of open circuit potential with time for three dental alloys in artificial saliva + 8% ethanol.

While laser surface melting treatment shifts E_{oc} for Co-Cr-Mo alloy to active direction in presence of 8% ethyl alcohol to reach (-427 mV). The data of E_{oc} for untreated and treated dental alloys listed in Table (6).

Table (6): Open circuit potentials (vs. SCE) values for three untreated and treated dental alloys with LSM in artificial saliva in presence of alcoholic beverage.

Alloys	*Medium*	*-E_{oc} (mV)*
	Untreated in artificial saliva (AS)	565
Co – Cr – Mo	Untreated alloys in AS+8%ethanol	341
	Treated alloys in AS+8%ethanol	427
	Untreated in artificial saliva (AS)	547
Ni – Cr – Mo	Untreated alloys in AS+8%ethanol	525
	Treated alloys in AS+8%ethanol	190
	Untreated in artificial saliva (AS)	586
Ti – 6Al – 4V	Untreated alloys in AS+8%ethanol	624
	Treated alloys in AS+8%ethanol	531

Linear Polarization

This test is a simple method for evaluating the corrosion rate, sufficiently sensitive to measure even a low corrosion rate [12], the test was conducted at a scanning rate of 0.5mA/sec. The current densities were calculated with reference to the samples geometrical area.

During anodic or cathodic polarization, or at open circuit, ion transfer reaction of metal ions and oxygen ions will take place. A clear process is the anodic corrosion of a passive metal in the steady state. In such a case, metal ions travel through the oxide film with a constant rate and are transferred in an ion transfer reaction at the interface oxide/electrolyte. The rate of that passive film dissolution depends on the local potential drop at the interface, the pH and the activity of the metal ions at the oxide surface [13].

The polarizations test started at a cathodic potential in relation to the corrosion potential, therefore the surface passive film was at least partially removed due to the highly reducing initial potentials as shown in Fig. (6) which illustrates the linear polarization for untreated three dental alloys in oral environments (artificial saliva) only.

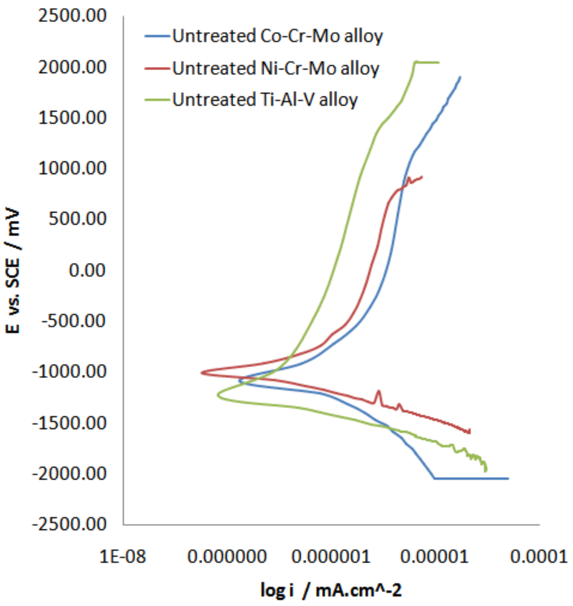


Fig. (6): Linear polarization of untreated dental alloys in artificial saliva at pH=4 and 37°C.

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. Each specimen was polarized from –40 mA to 15 mA.

Fig. (7) shows the effect of alcoholic beverage on corrosion behavior of untreated three experimental dental alloys.

The presence of ethyl alcohol increases the dissolution of dental alloys to take wide range of potentials in anodic region (upper section of curve).

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

$$2H^+ + 2e \rightarrow H_2 \; ......(1)$$

In addition to reduction of oxygen as follows[14]:

$$O_2 + 4e + 4H^+ \rightarrow 2H_2O \; ......(2)$$

The corrosion current densities (i_{corr}) were obtained from the polarization curves by extrapolation of the cathodic branch of the curves to the corrosion potential E_{corr}.

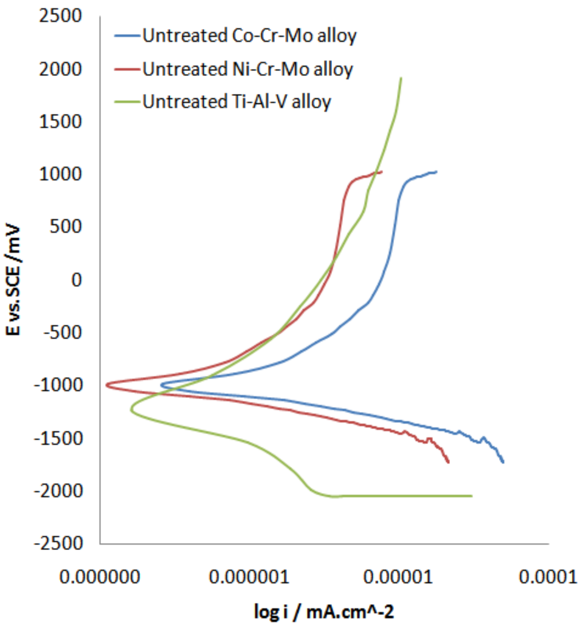


Fig. (7): Linear polarization of untreated dental alloys in artificial saliva + 8% ethanol at pH=4 and 37°C.

These data indicate that the presence of alcoholic beverages yields in test solution (artificial saliva) shift the corrosion potentials values (E_{corr}) toward active direction for Co-Cr-Mo and Ni-Cr-Mo alloys, while shifts to noble direction for Ti-Al-V alloy. 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 the corrosion current densities values (i_{corr}) shift to higher values for three dental alloys in presence of alcoholic beverages. 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 [15]:

$$C_R(mpy) = 0.13\,\frac{e}{\rho}\,i_{corr.} \;\ldots\ldots(3)$$

where $C_R(mpy)$: corrosion rate in mil per year, e: equivalent weight of alloy (gm), ρ: density of alloy (gm/cm^3) and i_{corr}: corrosion current density (µA.cm^{-2}). The average values of corrosion parameters are shown in Table (7).

Table (7): Corrosion parameters of untreated and treated dental alloys with LSM in artificial saliva at pH=4 and temperature 37^{o}C in the presence of alcoholic beverage.

Alloys	***Case***	***$-E_{corr}$ (mV)***	***$i_{corr}x10^{-6}$ (µA.cm^{-2})***	***$-b_c$ (mV.dec^{-1})***	***b_a (mV.dec^{-1})***	***R_px10^3 (Ω.cm^{-2})***	***C_Rx10^3 (mpy)***
Co-Cr-Mo	AS only	1058.4	476.09	659.4	1278.0	0.978	0.2061
	Untreated	1098.5	613.92	332.5	3046.1	0.212	0.2658
	Treated	913.80	607.70	483.7	2192.9	0.283	0.2629
Ni-Cr-Mo	AS only	997.3	299.05	258.3	433.8	0.235	0.1136
	Untreated	1019.5	593.25	288.5	772.5	0.154	0.2254
	Treated	982.0	482.96	346.9	800.9	0.217	0.1836
Ti-Al-V	AS only	1232.2	288.44	278.9	206.9	0.370	0.1996
	Untreated	1205.8	548.42	970.9	1517.2	0.469	0.3795
	Treated	1197.2	578.84	290.4	5673.3	0.207	0.4004

The data of corrosion rate show, in general, that the presence of alcoholic beverages increases the rate of corrosion for untreated dental alloys.

The Tafel slopes were very much influenced in the presence of alcoholic beverages yields, the cathodic Tafel slope (b_c) decreases for Co-Cr-Mo, while was increased for Ni-Cr-Mo and Ti-6Al-4V alloys. 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 change of current with change of potential was smaller during cathodic polarization than that during anodic polarization.

The polarization resistance (R_p) can be determined from the Tafel slopes and according to Stern- Geary equation [16,17]:

$$R_p = \left(\frac{dE}{di}\right)_{i=0} = \frac{b_a b_c}{2.303(b_a+b_c)i_{corr}} \qquad \ldots.\ (4)$$

The values of R_p which have been calculated from above equation are presented in Table (7). These data indicate that the polarization resistance value was decreased for Co-Cr-Mo and Ni-Cr-Mo alloys in the presence of alcoholic beverages yields, while increases for Ti-6Al-4V alloy.

Fig. (8) Shows the linear polarization of treated dental alloys with laser surface melting in artificial saliva and alcoholic beverages yields. The laser surface treatments shift the corrosion potentials values (E_{corr}) toward noble direction. While corrosion current densities values (i_{corr}) became lower for treated Co-Cr-Mo and Ni-Cr-Mo alloys, but became higher for Ti-Al-V alloy in presence of ethyl alcohol. Also corresponded corrosion rate value decreases for treated Co-Cr-Mo and treated Ni-Cr-Mo alloys, but increases for Ti-Al-V alloy.

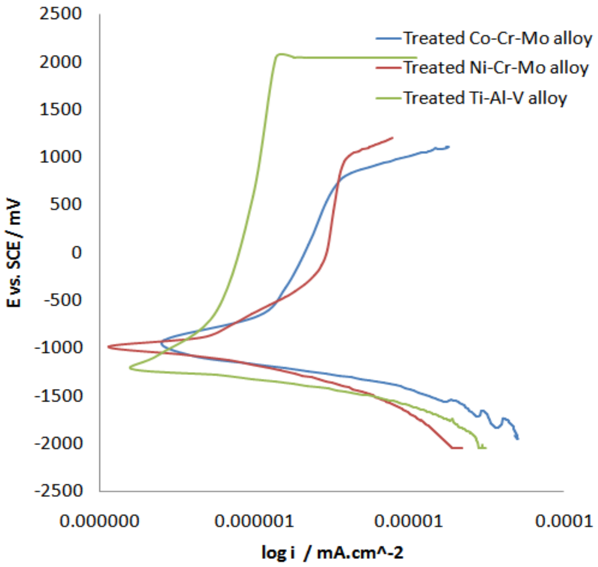


Fig. (8): Linear polarization of treated dental alloys with LSM in artificial saliva + 8% ethanol at pH=4 and 37^{o}C.

The increase in the surface hardness was very little with laser treatment in comparison with untreated specimens. This increment can be due to the fact that laser radiation has caused a smoother surface. Generally, change in surface hardness shows a microstructure modification in metallic bonds. The comparison of linear polarization curves indicate a few important points which are as follows: the corrosion rate for laser treated specimen reduced for treated Co-Cr-Mo and Ni-Cr-Mo alloys only. Also corrosion potentials shift toward noble direction after the treatment process. This implies that treated specimen release hydrogen easier and act as an electron donor to electrolyte [18].

The corrosion current, also, decreased for treated Co-Cr-Mo and Ni-Cr-Mo alloys after surface treatment, which means a better corrosion resistance. The passive region is directly affected by laser radiation and has more range in potential values. Thus a more noble metal is achieved. Increase of corrosion resistance probably means that most inclusions at the surface have been dissolved in the structure due to melting or alternatively, they are covered by molten material. Treated Ti-Al-V alloy shows no significant changes in its behavior. An interesting feature is the systematic shift of the pitting potential in the active region with a laser treatment despite the formation of a semipassive film at lower current densities, i.e. corrosion is observed. This indicates the formation of unstable passive film that is subtle to severe pitting with laser treatment. This is observed by NasserAl-Aqeeli in his work about the corrosion behavior of electrodeposited and laser irradiated Ni-Co nanostructured alloy [19].

Cyclic polarization

Cyclic polarization data were recorded by potentiostat with electrochemistry software. The polarization scan was initiated after immersing the specimen for 20 minutes and scanning the potential in the more noble direction at the scan rate of 0.5mA/sec. When 1000 or 2000mV were reached, the scanning direction was reversed.

Potentiodynamic measurements were carried out in order to determine the initiation and propagation of local corrosion, which is associated with the breakdown of passive protective film.

The breakdown potential (E_{br}) is the one at which the anodic current increases considerably with applied potential. The potential, at which the hysteresis loop is completed upon reverse polarization scan, is known as the protective potential or repassivation potential.

Breakdown potential is a sign of local corrosion but the measure of pitting susceptibility is the difference between the breakdown potential and the repassivation one. The protection potential represents the potential at the intersection of hysteresis curve with passive domain. Below this potential the propagation of existing localized corrosion will not occur. If the difference between breakdown and the repassivation potential is increasing, the chance in the appearance of pitting is greater and its propagation in depth is more intense. In other words, the hysteresis loop increases as the susceptibility of material to corrosion increases.

From Figures (9) to (11), it can be seen that at the vertex potential of 1000 mV for Co-Cr-Mo and Ni-Cr-Mo 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 [20]. 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. The data of forward and reverse scan are listed on the all curves to easily comparison among behavior of three dental alloys. These results show that a stable oxide film is formed during the forward scan.

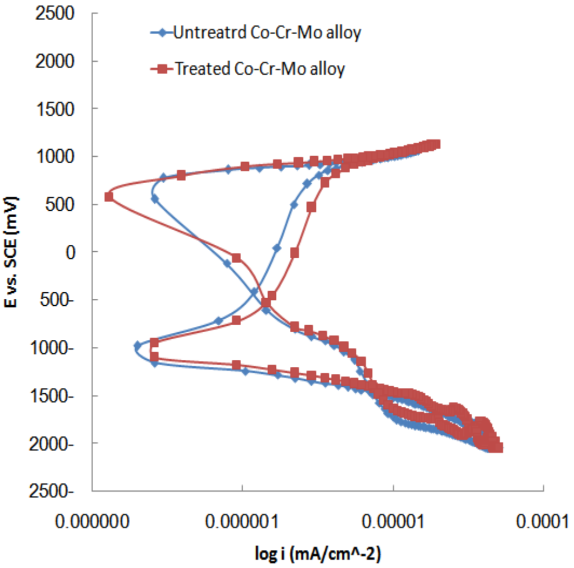


Fig. (9): Cyclic polarization of Co-Cr-Mo alloy in artificial saliva+8%ethanol at pH=4 and 37^{o}C.

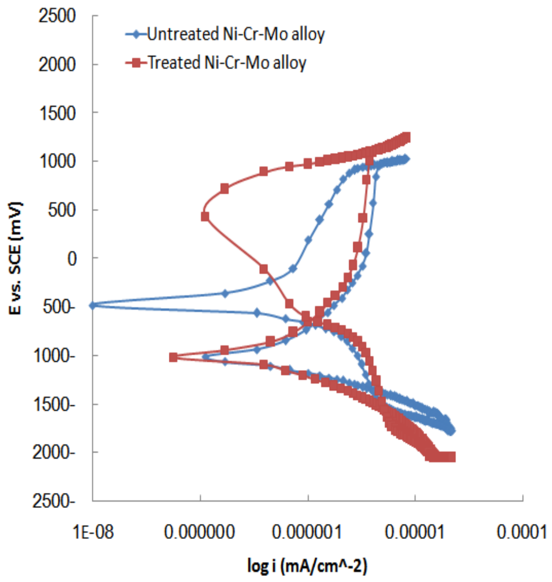


Fig. (10): Cyclic polarization of Ni-Cr-Mo alloy in artificial saliva+8%ethanol at pH=4 and 37°C.

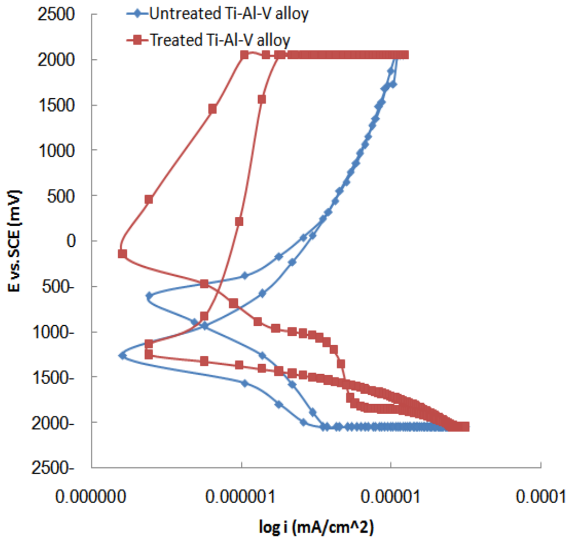


Fig. (11): Cyclic polarization of Ti-Al-V alloy in artificial saliva+8%ethanol at pH=4 and 37°C.

The cyclic polarization results also suggest that none of the dental 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. The potential where the loop was closed is referred to as the repassivated potential (E_{rep}). Pits grow between (E_{pit}) and (E_{rep}), but the nucleation of new pits only takes place above (E_{pit}). Below (E_{rep}) pit growth is not observed. The local environment chemistry affects both (E_{pit}) and (E_{rep}) [21].While the cyclic polarization of Ti-Al-V alloy exhibits a pronounced hysteresis loop, i.e. pitting corrosion was initiated.

Co-Cr-Mo alloy shows resistance to pitting due to large hysteresis potential $E_{hys.}= E_{pit.}- E_{rep.}$. While Ti-Al-V alloy shows more susceptibility to pitting corrosion due to small hysteresis potential. The presence of chromium and molybdenum in alloy determine the increase pitting corrosion resistance.

Generally, laser surface melting treatment affecting on the cyclic polarization curves as shown in the Figures (9) to (11), where observed that the reverse scan became in the wider range of potentials compared with the reverse scan for untreated dental alloys, in addition to obtain smaller hysteresis loop for Ti-Al-V alloy in the presence of alcoholic beverages yields in the artificial saliva at pH=4 and 37°C. All data of cyclic polarization were listed on the figures. Generally, the reverse potentials (E_{rev}) became nobler after laser surface treatment.

Conclusion

1- The presence of alcoholic beverages in oral environment increases the corrosion rate of dental alloys (Co-Cr-Mo, Ni-Cr-Mo and Ti-Al-V) at pH=4 and 37°C.

2- Laser surface melting (LSM) treatment with laser energy 190mJ, duration time 30ns, laser wave length 1064nm and spot size 0.5mm improve corrosion resistance for Co-Cr-Mo and Ni-Cr-Mo alloys through linear and cyclic polarization test.

3- Effect of laser surface treatment appears through the increment in the surface hardness.

4- The corrosion rate for laser treated specimen reduced for treated Co-Cr-Mo and Ni-Cr-Mo alloys only. Also corrosion potentials shift toward noble direction after the treatment process.

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تأثير المعاملة السطحية الليزرية على مقاومة التأكل لسبائك طب الاسنان في اللعاب الاصطناعي الحاوي على المشروبات الكحولية

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الخلاصة يهدف هذا البحث الى دراسة سلوك التأكل لثلاثة من سبائك طب الاسنان (Co-Cr-Mo, Ni-Cr-Mo, Ti-Al-V) في اللعاب الاصطناعي عند اس هيدروجيني 4 و37 درجة مئوية والحاوي على 8% كحول الايثانول. تم دراسة الاستقطاب الخطي والحلقي بالطريقة الكهروكيميائية واجريت المعاملة السطحية الليزرية للسبائك الثلاثة لتحسين مقاومة التاكل في اللعاب الحاوي على المشروبات الكحولية. اظهرت النتائج ان مقاومة التأكل ازدادت لسبيكة الكوبلت-كروم-موليبدنيوم و سبيكة نيكل-كروم-موليبدنيوم فقط بعد المعاملة الليزرية بسبب الاشعاع الليزري الذي سبب النعومة السطحية، بالاضافة الى نقصان كثافات تيار التأكل، وان المسح العكسي في الاستقطاب الحلقي اصبح بمدى اوسع من الجهد مقارنة مع الاستقطاب الحلقي للعينات غير المعاملة بالليزر للسبيكتين الاخيرتين بالاضافة الى نقصان الحلقة الهستيرية لسبيكة التيتانيوم-المنيوم-فناديوم.