INFLUENCE OF TEMPERATURE AND pH ON CORROSION BEHAVIOR OF NI–CR AND CO-CR DENTAL ALLOYS

*Rassam Al subari[1, 2], A Bellaouchou[3], A Guenbour[3], Nadia Merzouk[1]**

1.University mohammed V- Souisi, Faculty of Dentistry, Rabat, Morocco.
2.University mohammed V- Souisi, Faculty of Medicine and Pharmacy, Rabat, Morocco.
3.University Mohammed V- Agdal, Faculty of Sciences, Laboratory of Corrosion and Electrochemistry, Rabat, Morocco.

Abstract

The aim of this study was to evaluate the influence of temperature and pH on corrosion resistance of Ni-Cr and Co-Cr dental alloys used for fixed and removable partial dentures using potentiodynamic polarization and surface analysis by scanning electron microscopy. The three materials analyzed were Ni-Cr and Co-Cr dental alloys: Kera NH®, Kera 501® and PD Casta H®, which were tested in Fusayama-Meyer artificial saliva with different values of temperature and pH.

Our results have shown that Kera 501® and PD Casta H® alloys , which contain Co and a high Cr content, shows the best corrosion resistance in Fusayama-Meyer artificial saliva compare with that of Kera NH® alloy. In acidifid saliva and artificial saliva at 37 °C, the corrosion resistance of Kera NH®, Kera 501® and PD Casta H® alloys was low compare with that of referance solution, but the effect of temperature and pH on the corrosion resistance of Co-Cr alloy was low compared with that of Ni-Cr alloy. On the basis of the results obtained, our advise would be to recommend to avoid an increase in the oral temperature and reduced the taking of acid food which are likely to lower the oral pH and enhance the corrosion of the Ni-Cr and Co-Cr alloys when the fixed and removable partial dentures treatment.

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Introduction

Dental alloys are in direct contact with oral tissues and because of that they must be completely biocompatible: biologically tolerant (without causing antigen-antibody reaction), biochemically indifferent (remains unchanged in the body without causing any effect on the organism), electrically and magnetically inert (without causing a galvanic current or magnetic field).[1] Cobalt-chromium and nicke-chromium alloys today are widely used in prosthetic dentistry for the fabrication of fixed and removable partial dentures. Many dental casting alloys which have good mechanical properties, on the other hand aren't good enough from the aspect of corrosion because of their complex structure.[2] Organic acids, which are created after disintegration of food remains decrease pH value inside the oral cavity and may effect on ions release from dental alloys. Also, the materials used in the mouth must be resist the humidity and the changes in temperature inside the mouth, which happens during the chewing process inside the mouth.[3] A number of investigations have demonstrated that metals ions can be released from metallic materials as the results of corrosion.[4-10] Since the corrosion products of dental alloys contain metal ions and may be the reason for allergic and some other diseases.[11, 12] The aim of the present study was to evaluate the influence of temperature and pH on the corrosion resistance of Ni-Cr and Co-Cr

Corresponding author:
Prof. Nadia Merzouk
Department of prosthodontic
Faculty of Dentistry, Rabat, Morocco
Tel: 00212661303094
Fax: 0021253770443
Email address: ras9330@hotmail.com

dental alloys using potentiodynamic polarization and surface analysis by scanning electron microscopy.

Materials and methods

The origin and composition of the Ni-Cr and Co-Cr dental alloys studied are shown in table 1. Kera NH®, Kera 501® and PD Casta H® alloys were used as test materials in this study. The three samples were selected from metal used for fixed and removable partial dentures. For electrochemical measurements each specimen of each type of material was cut in the form of a cylinder of diameter 7 and 15 mm length, and then embedded with epoxy resin leaving a working area of 0.38 cm² for each specimen. The working electrodes were mechanically polished with abrasive paper of different grades (400-1000-1500), washed in distilled water and then dried with ethanol before corrosion test.

Material	Composition (wt%)	Supplier
Kera NH®	Ni: 60 % , Cr: 26 %, Mo: 12%,	Eisenbacher Dentalwaren
	Si: 1.8%, Mn: < 0.1%, C: < 0.1%	Ed Gmbh, Germany
Kera 501®	Co: 61 % , Cr: 30.25%, Mo: 5.5%, Mn : 0.25%,	Eisenbacher Dentalwaren
	Al: < 0.4% Si: 0.4%, Fe: 0.5% , Nb: 1%	Ed Gmbh, Germany
PD Casta H®	Co: 60 % , Cr: 29 %, Mo: 6.2%, Ni: 2%,	Mountain Medico,inc.
	Fe: 2%, C, Si , Mn : < 1%	U.S.A

Tabe 1. Origin and Composition of materials.

The test solutions of this study were Fusayama-Meyer artificial saliva[13-15] as reference solution, the composition of this solution, which closely resembles natural saliva is: KCl (0.4 g/l), NaCl (0.4 g/l), $CaCl_2.2H_2O$ (0.906 g/l), $NaH_2PO_4.2H_2O$ (0.690 g/l), $Na_2S.9H_2O$ (0.005 g/l), Urea (1 g/l). The pH was measured with a glass electrode (pH meter HANNA Instrument, France). The pH of this reference solution measured was 5.3 and the temperature was fixed at 20 °C. The second solution used had the same contents as the reference solution, but the pH was lowered by adding lactic acid. This acid was chosen in order to obtain conditions that were as close as possible to the clinical reality since this acid is naturally released by bacteria in the buccal cavity.[16, 17] The pH was fixed arbitrarily at 2.5. The third test solution was Fusayama-Meyer artificial saliva but the temperature of the solution was fixed at 37 °C. The pH was still around 5.3.

Electrochemical techniques were employed in this study was potentiodynamic polarization. The electrochemical measurements were performed by using a potentiostat (Voltalab® PGZ 301 radiometer analytical, France). A saturated calomel electrode (SCE) was used as reference electrode, platinum was used as counter-electrode and Ni-Cr and Co-Cr samples was used as working electrode, controlled by a personal computer with dedicated software (Volta Master 4). The measurements were performed after the establishment of a reasonable steady state condition, which was safely achieved after 30 min of immersion. The polarization curves were plotted in the potential range of -1000 mV/SCE to +1000 mV/SCE at scanning rate of 0.2 mV/s. The corrosion parameters are: corrosion potential (E_{corr}), corrosion current density (I_{corr}) and polarization resistance (R_p).

The surface analysis of the Kera NH® and Kera 501® alloys after immersion for 15 day in acidified saliva and compared to analysis of initial state materials were observed using scanning electron microscopy (SEM) (Philips, Quanta 200 X. TM-© Fei Company).

Results polarization curves

The polarization curves of Kera NH® (Fig.1) and values reported in tables 2 indicate that, the Kera NH® alloy exhibited least corrosion resistance in acidified saliva and artificial saliva at 37 °C compared with reference solution Fusayama-Meyer artificial saliva.

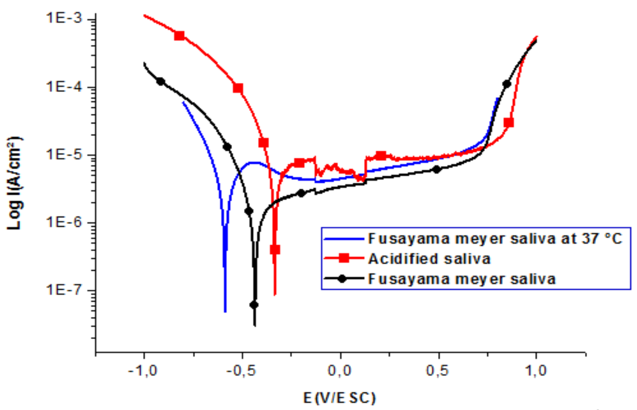

Figure 1. Polarization curves for Kera NH® in different media.

Solution	E_{corr} (mV/SCE)	I_{corr}(μA cm^{-2})	R_p (kΩcm^2)
Fusayama-Meyer artificial saliva	- 437.6	2.65	9.40
Acidified saliva	- 336.7	14.70	2.17
Fusayama-Meyer artificial saliva at 37 °C	- 590.4	6.89	3.93

Table 2. Corrosion parameters of Kera NH® obtained from potentiodynamic polarization in different media.

Fig.2 shows Polarization curves for Kera 501® and the results presented in table 3 indicate that Kera 501® alloy exhibited the highest corrosion resistance in Fusayama-Meyer artificial saliva. In acidified saliva and artificial saliva at 37 °C the polarization resistance values of Kera 501® were very low and the corrosion current density values were very high.

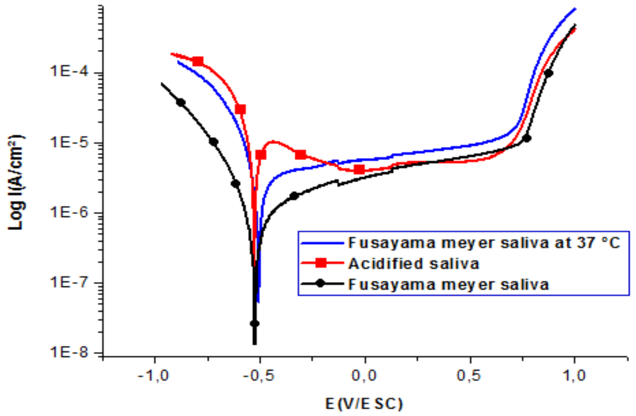

Figure 2. Polarization curves for Kera 501® in different media.

Solution	E_{corr} (mV/SCE)	I_{corr}(μA cm^{-2})	R_p (kΩcm^2)
Fusayama-Meyer artificial saliva	- 525.6	1.25	13.94
Acidified saliva	- 471.2	7.56	5.49
Fusayama-Meyer artificial saliva at 37 °C	- 509.1	4.34	5.15

Table 3. Corrosion parameters of Kera 501® obtained from potentiodynamic polarization in different media.

Thus, Kera 501® alloy presented least corrosion resistance in acidified saliva and artificial saliva at 37 °C compared with reference solution Fusayama-Meyer artificial saliva. Fig.3 shows the polarization curves for PD Casta H® alloy. The results reported in table 4 indicate that, the polarization resistance and the corrosion current density of PD Casta H® in acidified saliva were similar to that in artificial saliva at 37 °C. The polarization resistance values obtained for PD Casta H® and Kera 501® in Fusayama-Meyer artificial saliva was high compare with that of Kera NH® alloy.

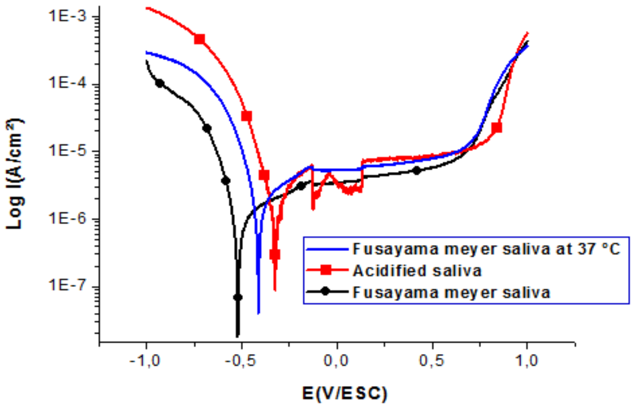

Figure 3. Polarization curves for PD Casta H® in different media

Solution	E_{corr} (mV/SCE)	I_{corr}(μA cm^{-2})	R_p (kΩcm^2)
Fusayama-Meyer artificial saliva	- 522.9	1.28	14.3
Acidified saliva	- 326.6	2.99	6.25
Fusayama-Meyer artificial saliva at 37 °C	- 446.2	2.84	6.28

Table 4. Corrosion parameters of PD Casta H® obtained from potentiodynamic polarization in different media.

Surface analysis

It was decided to perform surface analysis of the materials with the lowest resistance in the solutions that appeared to be the most aggressive: Kera NH® and Kera 501® alloys in acidified saliva. One specimen of these materials were analyzed in acidified saliva and compared to analysis of initial state materials. Figs. 4 and 5 show the SEM for the Kera NH® alloy in initial state and after immersion in acidified saliva. It is seen from the figure 5 that Kera NH® has pitting corrosion distributed at different areas after immersion in acidified saliva, while in initial state (Fig. 4) there is no corrosion on the surface of Kera NH® alloy.

Figs. 6 and 7 show the SEM for the Kera 501® alloy in initial state and after immersion in acidified saliva. The micrographs have shown that pitting corrosion concentrated in a definite area on the Kera 501® surface (Fig. 7) after immersion in acidified saliva, while in initial state (Fig. 6) there is no corrosion on the surface of Kera 501® alloy.

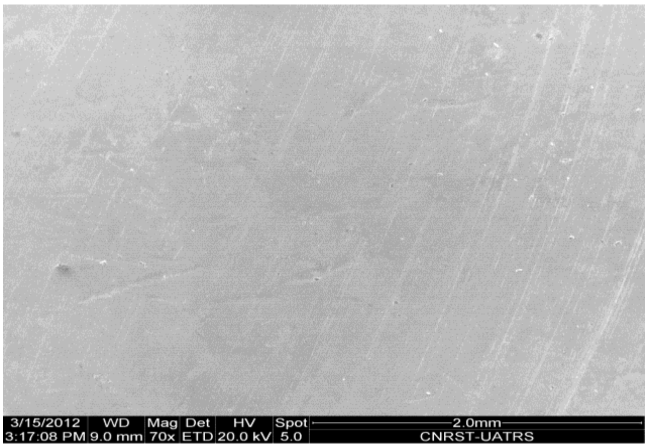

Figure 4. The scanning electron microscopy of Kera NH® in initial state.

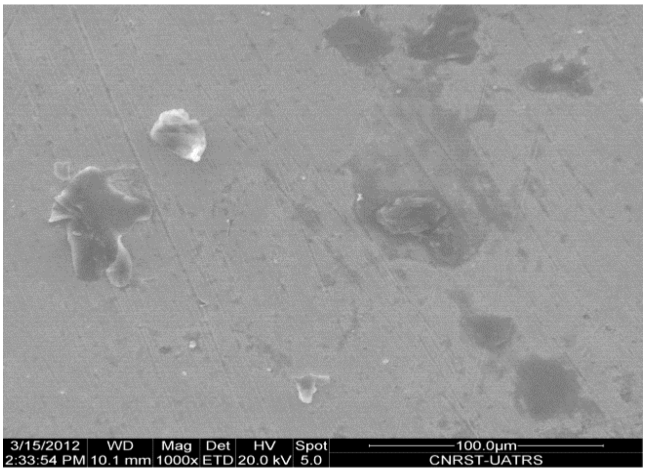

Figure 5. The scanning electron microscopy of Kera NH® in acidified saliva.

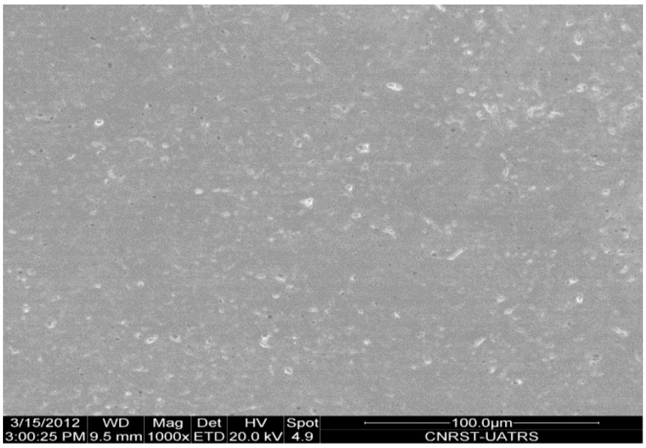

Figure 6. The scanning electron microscopy of Kera 501® in initial state.

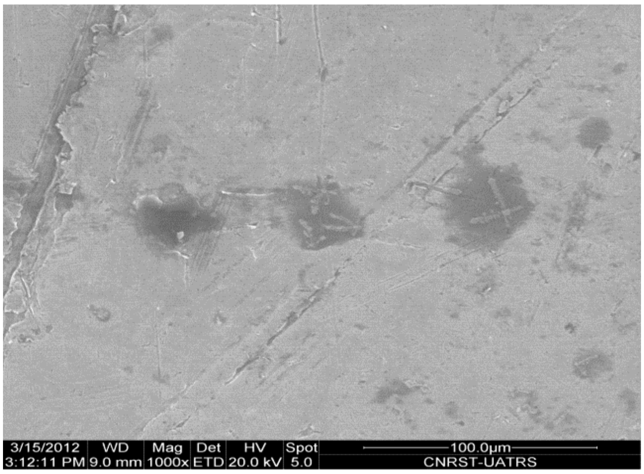

Figure 7. The scanning electron microscopy of Kera 501® in acidified saliva.

Discussion

Corrosion of dental alloys is a complex process, depending not only on alloys composition and structure, but also on many other factors such as surface treatment, environmental conditions around the alloy and composition of surrounding electrolyte selected for the study.[18-22] From the results presented in tables 2, 3 and 4, in Fusayama-Meyer artificial saliva, the corrosion results indicate that Kera 501® and PD Casta H® alloys, which contain cobalt, shows the best corrosion resistance compared with that of Kera NH® alloy. This result confirmed the results of Ameer et al [23], who showed the corrosion resistance of Co-Cr-Mo alloy exceeds that of alloys containing Ni-Cr-Mo in artificial saliva. On the other hand, Chromium is important element for determine the corrosion resistance of Ni-Cr and Co-Cr alloys due to ability to form a passive Cr_2O_3 film. In the present study indicate that Kera 501® and PD Casta H® alloys contained a high Cr content (30.25 wt. %, 29 wt. % respectively), shows the best corrosion resistance. In the current study, both the Co-Cr alloys had a similar Mo content and although Mo may be less important than Cr in terms of corrosion resistance[24], alloys which contain no Mo are known to be susceptible to pitting corrosion.[25] Thus, in Fusayama-Meyer artificial saliva, the corrosion resistance of the Co-Cr and Ni-Cr alloys are in the following order: Kera 501® ≈ PD Casta H® > Kera NH®. The acidity of the solution effect on corrosion resistance of the Ni-Cr and Co-Cr dental alloys. The corrosion resistance of Kera NH®, Kera 501® and PD Casta

H® alloys was decreased with reduced pH of artificial saliva to 2.5. The difference of corrosion behavior of three alloys was observed when the pH of the artificial saliva was reduced to 2.5. The Kera NH® alloy exhibited the lowest corrosion resistance in artificial saliva at pH 2.5 compared with that of Kera 501® and PD Casta H® alloys. It is important to assess the corrosion behavior of dental alloys in acidic solutions due to the variable pH conditions routinely encountered in the oral environment through the variety of foods and liquids ingested. On the other hand, the change in temperature inside the mouth, which happens during the taking the different foods and liquids ingested may be effect on corrosion resistance of dental alloys. In the current study, the corrosion resistance of Kera NH®, Kera 501® and PD Casta H® alloys was decreased with increased the temperature of artificial saliva to 37 °C. It is accompanied by a decrease in oxygen concentration of the solution[26], but the effect of temperature on the corrosion resistance of Co-Cr alloy was low compared with that of Ni-Cr alloy. Thus, in artificial saliva at 37 °C, the corrosion resistance of the Co-Cr and Ni-Cr alloys are in the following order: Kera 501® ≈ PD Casta H® > Kera NH®. Bennani et al. [26] showed that, the corrosion current of Ni-Cr alloy was increased with reduced pH of artificial saliva from 7.70 to 2.26 and the corrosion current of Ni-Cr alloy was increased with increased the temperature of artificial saliva.

Conclusion

In the present study, it has been shown that the corrosion behavior of Kera 501® and PD Casta H® alloys, which contain Co and a high Cr content, shows the best corrosion resistance compared with that of Kera NH® alloy in Fusayama-Meyer artificial saliva. The oral environment effect on corrosion behavior of Ni-Cr and Co-Cr dental alloys, in artificial saliva at pH 2.5 and artificial saliva at 37 °C, the corrosion resistance of Kera NH®, Kera 501® and PD Casta H® alloys was low compare with that of referance solution, but the effect of temperature and pH on the corrosion resistance of Kera 501® and PD Casta H® alloys was low compared with that of Kera NH® alloy. On the basis of the results obtained, our advise would be to recommend to avoid an increase in the oral temperature and reduced the taking of acid food which are likely to lower the oral pH and enhance the corrosion of the Ni-Cr and Co-Cr alloys when the fixed and removable partial dentures treatment.

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