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The effect of recasting on corrosion of DUCINOX prosthetic alloy

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Abstract

The effect of recasting, up to two times, Ni-Cr (DUCINOX) prosthetic alloy on its corrosion properties was carried out. The corrosion measurements were done in deoxygenated Fusayama Meyer artificial saliva solution at temperature of 37°C. In the study following electrochemical methods were used: measurement of free corrosion potential E_{cor} in open circuit, measurement of polarization resistance according to Stern-Geary's method and measurement of potentiodynamic characteristic in wide range of anodic polarization. In general, it can be stated that casting number weakly influence on corrosion properties of investigated alloy. At free corrosion potential there is no monotonic dependence of corrosion parameters versus casting number. However, at extreme anodic potentials monotonic changes of corrosion parameters with increasing casting number is observed. Obtained results and drawn conclusions are partially compatible with literature data.

Keywords: Heat Treatment, Corrosion Resistance, Electrochemical Measurements of Corrosion, Artificial Saliva Solution

1. Introduction

Alloys are widely used in dentistry, particularly in prosthodontics [1]. Dental alloys can be categorized as noble alloys (gold- and palladium-based) or base metal alloys (nickel- and cobalt-based).

Oral cavity is a specific environment very aggressive for metallic materials. Metals placed in it are undergo a few types of corrosion caused by various organic and inorganic compounds which are present in saliva and food, formation of microcells, as well as a presence of microorganisms [2]. Thus, corrosion resistance is one of the most important features of prosthetic alloys. On the one hand corrosion processes occurred on prosthetic alloys have negative effect on their durability properties, and on the other hand corrosion products have harmful effect on human organism.

Corrosion studies of prosthetic alloys are carried out in different solutions, but mostly in artificial saliva solution. Numerous artificial salivas have been used during studies in odontology. These salivas have compositions, which are more or less the same as that of natural saliva. A review of nearly 60 artificial salivas was carried out by Gal et al. [3].

One of the prosthetic alloys used for crown and bridge casting is Ni-Cr alloy called DUCINOX. It is a manganese enriched chromium-nickel steel, which composition allows using of all known melting methods. Ni-Cr alloy is one of the most harmful alloys [4], because of releasing of Ni^{2+} allergenic ions and Cr^{3+} toxic ions. However it is very often used alloy because of its low price. In order to extra reduction of material costs many prosthetic laboratories commonly use procedures of recasting dental alloys including reuse of remains untapped alloy or recast of runner stick. However as different researches report [5, 6], multiple castings of alloys may cause noticeable changes of their properties.

The main aim of the present investigation is to study the effect of recasting DUCINOX prosthetic alloy on its corrosion behavior in artificial saliva solution.

2. Materials and measurement methods

In the study there were used cylinder shaped samples sized 20 mm diameter and 7 mm height made of DUCINOX dental alloy produced by Ugin'dentaire manufacturer. Samples were casted with spin casting method in Prod-Dent WR-01 casting centrifuge and cooled together with the mold. Measurements were taken on samples made with alloy after one (casting), two (casting and recasting) and three (casting and double recasting) casting procedures. Chemical composition of alloy analyzed using X-Ray Fluorescence Method with Siemens SRS 300 Spectrometer is presented in Table 1. The composition is compatible with the one given by manufacturer [7].

Table 1.
Chemical composition of artificial saliva solution

Chemical composition [wt. %]							
Ni	Cr	Mo	Si	Mn	Co	Nb	Fe
28.36	21.47	3.12	3.85	0.23	0.12	0.04	rest

The sample surfaces were grinded with abrasive paper of 1500 grid. All sample surfaces were cleaned with felt, rinsed with ethanol and dried with argon before each experiment. Corrosion measurements were done at 37^0C ± 1^0C (310 K ± 1 K) in deoxygenated Fusayama Meyer artificial saliva solution. The composition of artificial saliva was: KCl (0.4 g), NaCl (0.4 g), $CaCl_2{\cdot}2H_2O$ (0.906 g), $NaH_2PO_4{\cdot}2H_2O$ (0.690 g), $Na_2S{\cdot}9H_2O$ (0.005 g), urea (1 g) in 1 dm^3 tripple distilled water [8]. The solution was made from analytical grade reagents. The pH was measured with a pH combination electrode EC 620-130 (Eutech Instruments) connected to a multimeter CyberScan PDC6500 (Eutech Instruments) and was found to be 5.94. Corrosion measurements were carried out using PGSTAT 30 (Autolab EcoChemie) potentiostat / galvanostat in measurement cycle consisted of the detection of free corrosion potential E_{cor}, detection of polarization resistance R_p, registration of electrochemical impedance characteristic and potentiodynamic characteristic in wide range of anodic polarization [9, 10]. The measurements were taken on two samples of each type in a glass electrolytic cell with volume ca. 25 cm^3. Working electrode was a sample with ca. 0.64 cm^2 of area being in contact with solution. Pt foil (area ca. 30 cm^2) was used as counter electrode. As reference electrode calomel electrode in saturated NaCl solution (SSCE) was used. All potentials in this paper are given versus this calomel electrode (E^0 = 0.236 V vs. SHE). All calculations were done using CorrView and ZView v. 2.90 (Scribner Associates Inc.) software.

3. Description of achieved results

3.1. Corrosion potential E_{cor}

Free corrosion potential E_{cor} is a stable open circuit potential of investigated sample versus reference electrode (typically 2000 s after the cell was filled with the corrosion solution). Average values of this potential versus casting number are presented in Fig. 1. Also, the standard deviation of data collection is marked on the diagram.

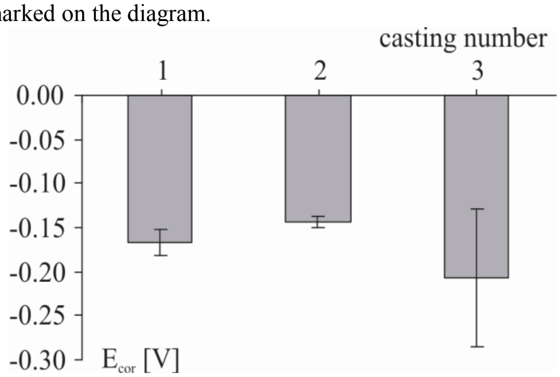

Fig. 1. Dependence of corrosion potential E_{cor} versus casting number

Analyzing this diagram, it can be stated that average values of E_{cor} for all investigated samples have negative values in the range from -0.145 V to -0.207 V. Samples after 1st and 2nd recasting have similar values of E_{cor}. Samples after 3rd recasting have the most negative value of E_{cor}, and they have also the largest standard deviation value. From this reason it can not be unequivocally stated if the observed difference is significant.

3.2. Polarization resistance R_p

Polarization resistance R_p was measured using potentiodynamic method according to Stern-Geary's methodology: each sample was polarized in potential range from E_{cor} - 0.020 V to E_{cor} + 0.020 V with scan rate of 0.0005 $V{\cdot}s^{-1}$. Average values and standard deviations of R_p (calculated using CorrView software) versus casting number are presented in Fig. 2.

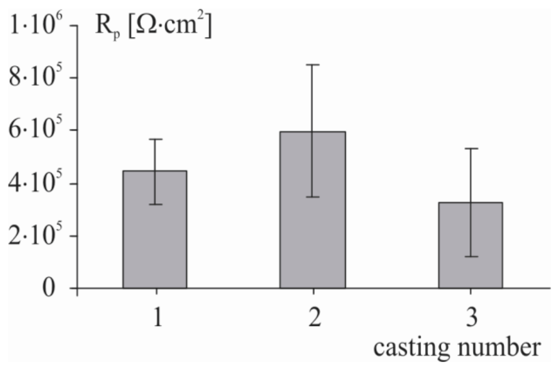

Fig. 2. Dependence of polarization resistance R_p versus casting number

Average values of polarization resistance R_p are in the range from $3.25{\cdot}10^5$ $\Omega{\cdot}cm^2$ to $5.97{\cdot}10^5$ $\Omega{\cdot}cm^2$. There is no unequivocal relation between R_p values and alloy casting number. Taking into account high values of standard deviation of all results it can not be unequivocally stated, that casting number has an effect on polarization resistance R_p. These high values of standard deviation are connected with complex computational procedure. As corrosion rate of alloy is proportional to reciprocal of resistance R_p so it is difficult to correlate this quantity with casting number as well.

3.3. Potentiodynamic characteristic in wide range of anodic polarization

Potentiodynamic characteristics were measured from start potential E_{cor} - 0.2 V to potential at which current density achieved a value of 0.001 $A \cdot cm^{-2}$ or 0.005 $A \cdot cm^{-2}$, then polarization was reversed and returned to start potential. The scan rate was 0.001 $V \cdot s^{-1}$. Typical potentiodynamic characteristics of investigated samples are presented in Fig. 3.

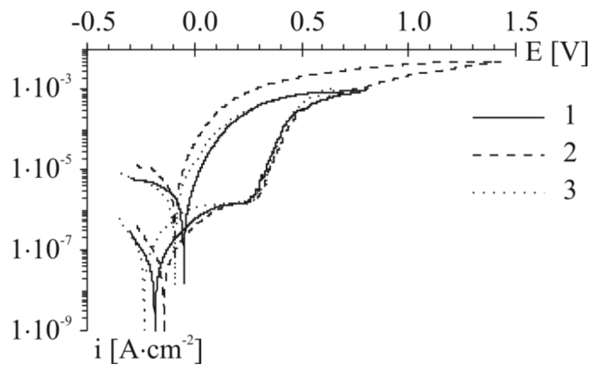

Fig. 3. Potentiodynamic characteristics of investigated samples

From the potentiodynamic characteristics values of several potentials describing corrosion processes were determined: pit initiation potential $E_{prepits}$, breakdown potential E_b and repassivation potential E_{rep}. Obtained values of these potentials are shown in Table 2.

Table 2.
Characteristic corrosion potentials

Casting number	$E_{prepits}$ [V]	E_b [V]	E_{rep} [V]
1	0.225 ± 0.035	0.288 ± 0.021	-0.069 ± 0.037
2	0.265 ± 0.030	0.308 ± 0.030	-0.096 ± 0.006
3	0.275 ± 0.029	0.321 ± 0.029	-0.068 ± 0.021

Analyzing $E_{prepits}$ and E_b values it can be stated that pitting corrosion resistance of investigated alloy increases with increasing casting number. This result do not confirm conclusions drawn on the basis of described earlier results of measurements at free corrosion potential E_{cor}.

Optical microscopic observation of samples' surfaces after corrosion processes has shown that only near the gasket of electrolytic cell deep corrosion pits were formed.

4. Conclusions

On the basis of free corrosion potential measurements it may be stated that value of this potential does not monotonically change with casting number. Additionally, the assessment of these relations is difficult due to relatively large dispersion of E_{cor} values. For analogous FeCrNi alloy in artificial saliva solution Schiff et al. [8] have obtained E_{cor} value equal 0 V. In this paper Schiff has also reported that a number of authors have investigated corrosion potential with varying findings. For example, Kedici et al. obtained E_{cor} value equal -0.140 V for the same FeCrNi alloy. They also signalize fact of high unrepeatablity of E_{cor} values in case of other alloys as well as titanium (for example reported E_{cor} values for Ti are in the range of -0.425 V to 0.050 V).

Similarly no monotonic changes of polarization resistance R_p (as well as corrosion rate) versus casting number have been observed. R_p values have a large dispersion, what is the reason for high values of standard deviation.

Whereas, measurements of corrosion properties at extreme anodic potentials better corrosion resistance of three times recasted alloy have showed. This result is qualitatively compatible with data presented by Khamis [11] which showed that breakdown potential E_b of Ni-Cr (Wirolloy) alloy increases with increasing casting number. However such comparison should be done very carefully, because chemical composition of Wirolloy and DUCINOX alloys differs in Ni and Fe content. The same authors [11] signalize that in case of other prosthetic alloys after 4th recasting the changes of corrosion resistance are negligible. Analogous conclusions Ozdemir et al. [12] have drawn for Wirolloy alloy. In contrary Ameer et al. [13] have stated worse corrosion properties of the same alloy after 3rd recasting.

Summarizing the results of corrosion measurements described above we can state that unequivocal determination of casting number effect on corrosion properties of prosthetic alloys is difficult. In our opinion investigation of large number of samples prepared in standardized conditions (recasting procedure, grinding and polishing, corrosion medium and parameters of corrosion measurements) may be a solution to this problem. Corrosion investigations should be also completed with structure and phase analyzes of such prepared samples.

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